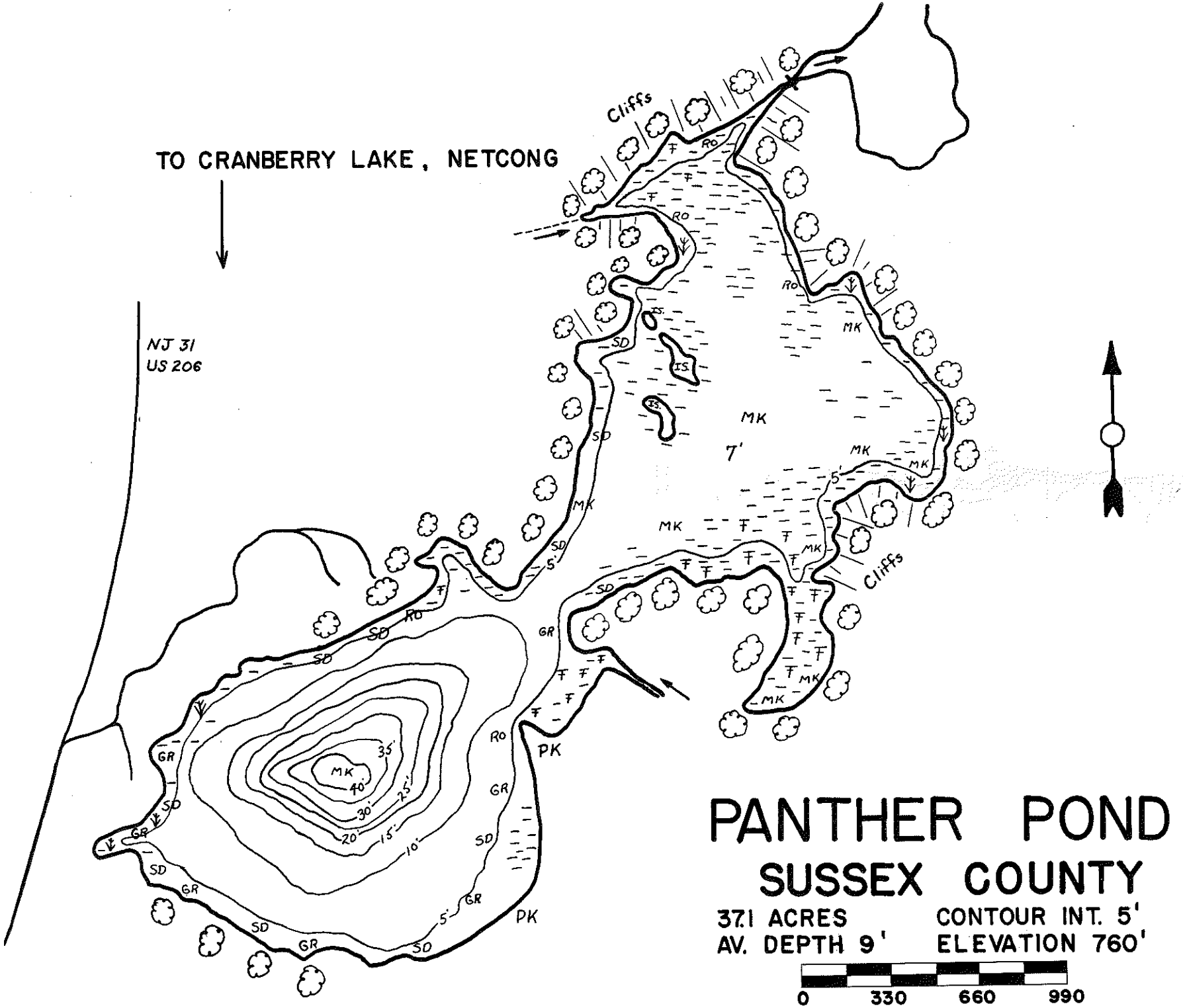
APPENDIX I: HISTORICAL WATER QUALITY DATA



PANTHER POND

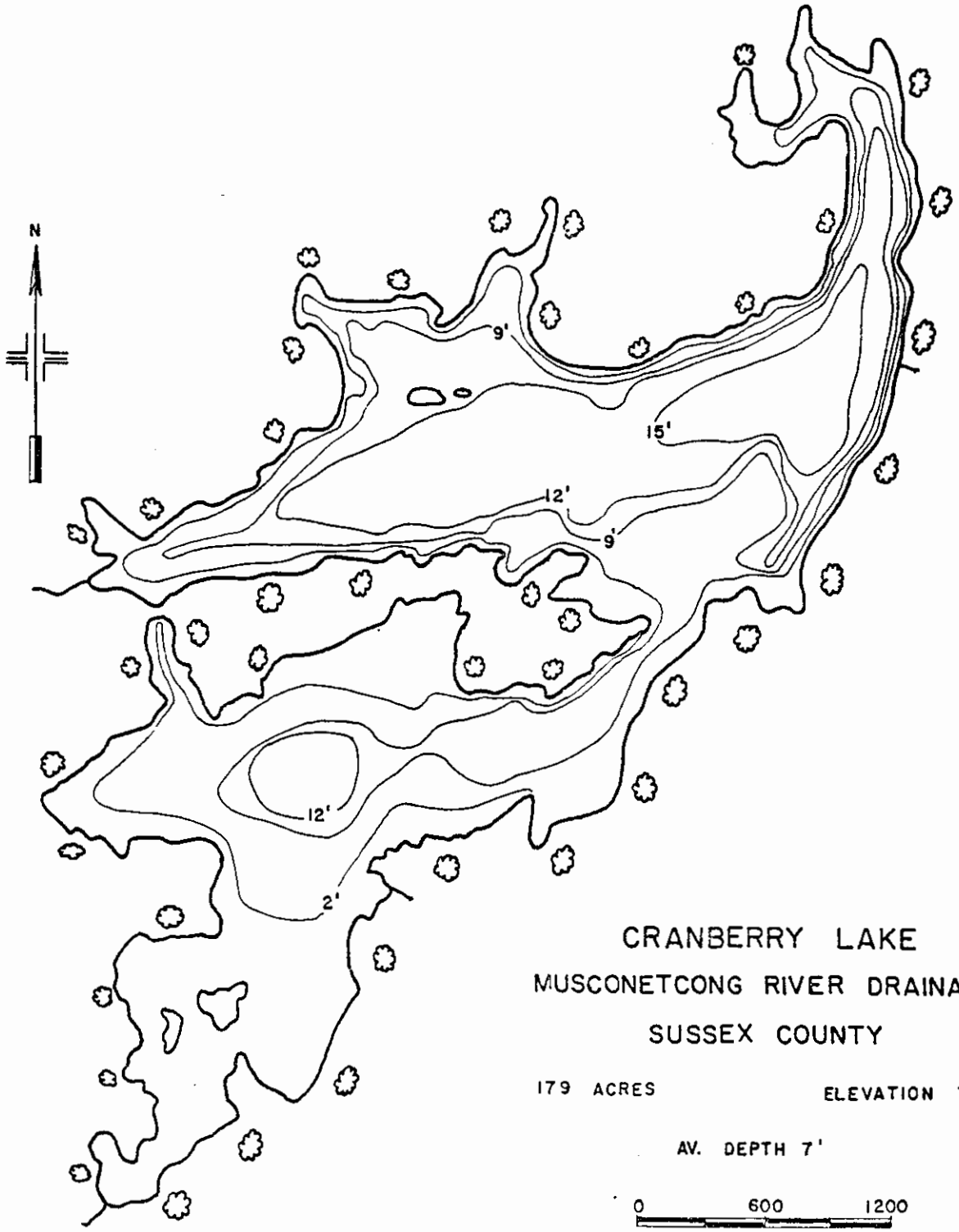
SUSSEX COUNTY

37.1 ACRES
AV. DEPTH 9'

CONTOUR INT. 5'
ELEVATION 760'

0 330 660 990

SCALE IN FEET



CRANBERRY LAKE

MUSCONETCONG RIVER DRAINAGE

SUSSEX COUNTY

179 ACRES ELEVATION 780'

AV. DEPTH 7'

0 600 1200

SCALE IN FEET

NOTE: THIS IS A COURTESY COPY OF THIS AMENDMENT ADOPTION. THE OFFICIAL VERSION WILL BE PUBLISHED IN THE JULY 20, 2020 NEW JERSEY REGISTER. SHOULD THERE BE ANY DISCREPANCIES BETWEEN THIS TEXT AND THE OFFICIAL VERSION, THE OFFICIAL VERSION WILL GOVERN

ENVIRONMENTAL PROTECTION

WATER RESOURCE MANAGEMENT

DIVISION OF WATER MONITORING AND STANDARDS

Adopted Amendment to the Atlantic County, Cape May County, Lower Delaware, Lower Raritan/Middlesex County, Mercer County, Monmouth County, Northeast, Ocean County, Sussex County, Tri-County, Upper Delaware and Upper Raritan Water Quality Management Plans to Establish 26 Total Maximum Daily Loads Addressing Mercury Impairments

Public Notice

Take notice that on 05/28/2020 , pursuant to Section 303(d) of the Federal Clean Water Act at 33 U.S.C. 1313(d), the New Jersey Water Quality Planning Act at N.J.S.A. 58:11A-7, and the Water Quality Management Planning rules at N.J.A.C. 7:15-5.4, the New Jersey Department of Environmental Protection (Department) adopted an amendment to the Atlantic County, Cape May County, Lower Delaware, Lower Raritan/Middlesex County, Mercer County, Monmouth County, Northeast, Ocean County, Sussex County, Tri-County, Upper Delaware and Upper Raritan Water Quality Management (WQM) Plans. The adopted amendment established 26 total maximum daily loads (TMDLs) that address mercury impairments in non-tidal, freshwater waterbodies where, the level of mercury in fish tissue exceeded the threshold used in fish consumption advisories, mercury is not present in the water column in excess of the numeric surface water quality criteria, and there are no known significant sources of mercury other than air deposition. The adopted TMDL document and support materials are available on the Department's website at https://www.state.nj.us/dep/wms/bears/tmdls-completed.html under "Documents". Preliminary notice of the proposed amendment was published in the New Jersey Register

on October 7, 2019 (51 N.J.R. 1542(a)) and on the Department's website at https://www.nj.gov/dep/wqmp/wmpnotices.html and https://www.state.nj.us/dep/wms/bears/tmdls-proposed-tmdls.html. The public comment period ended on November 6, 2019. No comments were received. On December 9, 2019, the Department submitted these TMDLs to the U.S. Environmental Protection Agency (USEPA) for approval in accordance with N.J.A.C. 7:15-5.4. USEPA approved the TMDLs on January 6, 2020.

Background

All states are required, pursuant to Section 305(b) of the Federal Clean Water Act (CWA), 33 U.S.C. 1315(b), to biennially prepare and submit to U.S. Environmental Protection Agency (USEPA), a report addressing the overall water quality of the State's waters, including support of designated uses (the Integrated List of Waters, or "Integrated List"). States are also required, under Section 303(d) of the Federal Clean Water Act, 33 U.S.C. 1313(d), to develop a list of waters that currently do not meet, or are not expected to meet, applicable water quality standards after the implementation of technology-based controls. This list is known as the 303(d) List of Water Quality Limited Waters or, more simply, the "303(d) List." The 303(d) List includes a priority ranking for scheduling TMDLs, as well as identifying TMDLs expected to be completed in the next two years. These two lists, along with strategies to maintain and improve water quality and other pertinent information, comprise the Integrated Water Quality Assessment Report (Integrated Report). The Integrated Report identifies where regulatory and other actions have been successful in restoring water quality, where water quality improvement is needed, where high quality waters are threatened and/or need protection, and where further study and/or research is needed to address unresolved water quality issues, such as nutrient impacts on aquatic life uses. These results provide a sound scientific foundation to inform and prioritize the State's water regulatory and management programs. USEPA compiles this water quality information from all states and tribes and, as required by the CWA, compiles it into a national assessment of water quality.

The Integrated List is divided into five sublists. Sublists 1 through 4 of the Integrated List include: waterbodies that are generally unimpaired and fully support one or more applicable designated uses (Sublists 1 and 2), waterbodies with insufficient information to assess applicable designated uses (Sublist 3), and waterbodies that are either impaired due to pollution rather than pollutants or have had a TMDL or other enforceable management measures approved by USEPA (Sublist 4). Sublist 5 constitutes the 303(d) List for waters impaired or threatened by one or more pollutants, for which a TMDL or alternative restoration measure is required.

Impaired waterbodies not supporting the fish consumption use due to mercury in fish tissue, (among other parameters) were previously identified on the *2008 303(d) List of Water Quality Limited Waters* (published November 16, 2009 at 41 N.J.R. 4321(a)), *2010 303(d) List of Water Quality Limited Waters* (published March 5, 2012 at 44 N.J.R. 598(b)), *2012 303(d) List of Water Quality Limited Waters* (published January 5, 2015 at 47 N.J.R. 231(b)) and *2014 303(d) List of Water Quality Limited Waters* (published October 16, 2017 at 49 N.J.R. 3444(a)) based on the data available when each 303(d) List was developed.

Mercury is a bioaccumulative neurotoxin. When it enters the environment and is consumed or taken up by aquatic organisms, the mercury persists in each organism and becomes magnified through the food chain. When mercury concentrations reach a certain level in fish tissues, fish consumption advisories are triggered. Fish consumption advisories (https://www.nj.gov/dep/dsr/fishadvisories/Fish_Advisories_2019.pdf) are jointly issued by the New Jersey Department of Environmental Protection and the New Jersey Department of Health. They provide advice to the general population and high-risk individuals (for example, women of childbearing age and children). Fish consumption advisories provide guidance on reducing risks such as the types and sizes of specific species of fish and the number of meals that may be eaten. They are not promulgated surface water quality standards under N.J.A.C. 7:9B but provide a scientifically sound basis for assessing whether

the fish consumption designated use is fully supported as part of Integrated List/303(d) List development. Where fish tissue mercury levels exceed the advisory thresholds in a waterbody, the waterbody is identified as impaired by mercury in fish tissue and the assessment unit containing that waterbody is placed on the 303(d) List triggering the development of a TMDL.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of the pollutant of concern, natural background, and surface water withdrawals. A TMDL quantifies the amount of a pollutant a waterbody can assimilate without violating applicable water quality standards, allocates that loading capacity to known point sources in the form of Wasteload Allocations (WLAs) and to nonpoint sources in the form of Load Allocations (LAs), and includes a margin of safety and optional consideration of reserve capacity. All TMDLs must be calculated to achieve compliance with the applicable adopted surface water quality standard for the pollutant of concern. Accordingly, the targets to be achieved by the mercury TMDL are attainment of fish tissue levels that are considered safe for unlimited consumption by the general population and for one meal per week by the high-risk population. As explained in the Statewide Mercury TMDL (see https://www.state.nj.us/dep/wms/bears/tmdls.html) adopted in 2010 at 42 N.J.R 1630(a), achieving the required fish tissue levels will ensure achievement of the most conservative Surface Water Quality Standard numeric criterion summarized in Table 1 below. Criteria for saline waters are provided for informational purposes only; this TMDL does not cover any saline waters. The fish consumption advisory levels are summarized in Tables 2 and 3 below.

Table 1: New Jersey Surface Water Quality Criteria for Mercury

	Fresh Water (FW2) Criteria			**Saline Water (SE&SC) Criteria**		
	Aquatic		Human	Aquatic		Human Health
	Acute	Chronic	Health	Acute	Chronic	

Mercury Concentration (µg/l)	1.4 (d)(s)	0.77 (d)(s)	0.050 (h)(T)	1.8 (d)(s)	0.94 (d)(s)	0.051 (h)(T)

(d): criterion expressed as a function of the water effects ratio

(s): dissolved

(h): noncarcinogenic effect-based human health criteria

(T): total

Table 2: Advisories for High-Risk Individuals

(Women of Child Bearing Age, Nursing Mothers and Children)

Fish Tissue Mercury Concentration	Advisory
Greater than 0.54 µg/g (ppm)	Do not eat
Between 0.19 and 0.54 µg/g (ppm)	One meal per month
Between 0.08 and 0.18 µg/g (ppm)	One meal per week
0.07 µg/g (ppm	Unlimited consumption

Table 3: Advisories for the General Population

Fish Tissue Mercury Concentration	Advisory
Greater than 2.81 µg/g (ppm)	Do not eat
Between 0.94 and 2.81 µg/g (ppm)	One meal per month
Between 0.35 and 0.93 µg/g (ppm)	One meal per week.
0.34 µg/g (ppm)	Unlimited consumption

The overwhelming source of mercury contamination, both in New Jersey and globally, is from air deposition. Waters across the nation, even in otherwise pristine areas, are affected because air can transport mercury across the bounds of land and water. This makes mercury contamination from air deposition uniquely suited to a regional or statewide TMDL that models the relative contribution of mercury from various air sources and identifies the levels of reduction needed to make fish safe to eat. Because of the variability of the air pollution source, adequate control of sources of mercury contamination will depend on regional, national and international efforts.

In 2007, the New England Interstate Water Pollution Control Commission (NEIWPCC) established a regional TMDL for the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont, which addressed impairments due to mercury contamination in fish tissue where the main source of mercury contamination was air deposition. The NEIWPCC TMDL relies on modeling of the air sources on the premise that reduction in air sources is linearly related to levels found in fish and identifies the need for source controls outside the jurisdiction of the affected states to attain water quality objectives. The NEIWPCC regional TMDL was approved by USEPA on December 20, 2007. Since USEPA has approved establishment of regional TMDLs for mercury impairments with air deposition as the primary source using the NEIWPCC approach, the Department determined that it was appropriate for New Jersey to develop a similar TMDL for comparable impairments in New Jersey, not only to recommend a course of action to reduce mercury contamination in New Jersey, but also to emphasize that substantial source reductions from outside New Jersey will be needed to achieve water quality objectives.

New Jersey has issued statewide fish advisories for mercury in fish tissue based on the ubiquitous nature of the air deposition sources, even in the absence of fish tissue data. However, TMDLs are required only for those specific assessment units for which fish tissue data verifying an impairment are available, thereby resulting in inclusion of the mercury-impaired waterbody/assessment unit on New Jersey's 303(d) List. As stated in the Statewide Mercury TMDL adopted in 2010:

As additional fish tissue data is obtained, it is expected that other assessment units will be identified that conform to the parameters established for this TMDL approach and would appropriately be addressed by this TMDL, had the data been available. Therefore, in addition to the impaired waters listed in Table 1, this TMDL may, in appropriate circumstances, also apply to waterbodies that are identified in the future as being impaired for mercury. For such waterbodies, this TMDL may apply if, after listing the waters for mercury impairment and taking into account all relevant comments submitted on the Impaired Waters List, the Department determines, with EPA approval of the list, that this TMDL should apply to future mercury impaired waterbodies. Under these circumstances, the assessment units will be placed on Sublist 4.

Due to time constraints when the TMDL adopted in 2010 was being developed, some assessment units were excluded from that TMDL because further investigation was needed to determine if air deposition was the major source of mercury contamination. With subsequent further investigation and new fish tissue data becoming available, as reflected in the 2010, 2012 and 2014 Integrated Lists, the Department confirmed that the additional assessment units listed in Table 4 below are impaired by mercury in fish tissue mainly due to atmospheric deposition. Under the adopted amendment, these assessment units are now subject to the allocations specified in the 2010 Statewide Mercury TMDL.

Table 4. Assessment Units from the 2008, 2010, 2012, and 2014 Integrated List Subject to Allocations Specified in the Statewide Mercury TMDL Adopted in 2010

	Watershed Management Area (WMA)	Assessment Unit ID	Waterbody Name	2008 Integrated List	2010 Integrated List	2012 Integrated List	2014 Integrated List

1	03	02030103100060	Crystal Lake/Pond Brook *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
2	11	02040105230020	Assunpink Ck (New Sharon Br to/incl Lake) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
3	11	02040105230030	New Sharon Branch (Assunpink Creek) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
4	11	02040105230040	Assunpink Ck (Trenton Rd to New Sharon Br) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
5	12	02030104090040	Shark River (above Remsen Mill gage) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
6	13	02040301080060	Toms R Lwr (Rt 166 to Oak Ridge Pkwy) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4

7	15	020403020500 80	Stephen Creek (GEHR) *	Sublist 3	Sublist 5	Sublist 4	Sublist 4
8	17	020402061800 30	Menantico Creek (above Rt 552) *	Sublist 3	Sublist 5	Sublist 4	Sublist 4
9	18	020402021600 20	Oldmans Creek (Rt 45 to Commissione rs Rd) *	Sublist 5	Sublist 5	Sublist 3	Sublist 3
10	20	020402010500 60	Ellisdale trib (Crosswicks Creek) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
11	20	020402010500 30	Crosswicks Ck (Lahaway Ck to New Egypt) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
12	20	020402010500 50	Crosswicks Ck (Ellisdale trib to Walnford) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4

13	20	02040201050040	Crosswicks Ck (Walnford to Lahaway Ck) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
14	20	02040201040070	Crosswicks Ck (New Egypt to/incl North Run) *	Sublist 5	Sublist 5	Sublist 4	Sublist 4
15	01	02040104240010	Van Campens Brook	Sublist 3	Sublist 3	Sublist 5	Sublist 5
16	01	02040105050010	Paulins Kill (Blairstown to Stillwater)	Sublist 3	Sublist 3	Sublist 5	Sublist 5
17	01	02040105050050	Paulins Kill (below Blairstown gage)	Sublist 3	Sublist 3	Sublist 5	Sublist 5
18	01	02040105070020	New Wawayanda Lake/Andover Pond trib	Sublist 3	Sublist 3	Sublist 3	Sublist 5
19	01	02040105070050	Trout Brook / Lake Tranquility	Sublist 3	Sublist 3	Sublist 3	Sublist 5

20	01	020401050900 50	Furnace Brook	Sublist 3	Sublist 3	Sublist 5	Sublist 5
21	01	020401051500 30	Musconetcon g R (Wills Bk to Lk Hopatcong)	Sublist 3	Sublist 3	Sublist 5	Sublist 5
22	10	020301051000 50	Rocky Brook (below Monmouth Co line)	Sublist 3	Sublist 3	Sublist 5	Sublist 5
23	11	020401052300 50	Assunpink Ck (Shipetaukin to Trenton Rd)	Sublist 5	Sublist 5	Sublist 5	Sublist 5
24	11	020401052400 20	Shabakunk Creek WB	Sublist 3	Sublist 3	Sublist 3	Sublist 5
25	17	020402060300 60	Salem R (39-40-14 dam-Courses Lndg)/Canal	Sublist 3	Sublist 3	Sublist 3	Sublist 5
26	17	020402061600 40	Mill Creek (lower)	N/A	Sublist 5	Sublist 5	Sublist 5

*Assessment Units submitted to USEPA on August 5, 2011 and approved on September 14, 2011 to be subject to the 2010 TMDL but not proposed as an amendment to the areawide WMQ plans at that time.

As explained earlier, air deposition is the primary source of mercury contamination for the waterbodies shown in Table 4. Accordingly, reductions of mercury levels from this source will result in reductions in levels found in fish tissue in accordance with a simple linear relationship. A portion of mercury from air deposition is from natural sources and cannot be reduced. Therefore, mercury from human sources must be the focus for achieving the reductions needed to achieve the targeted fish tissue concentrations. New Jersey is actively engaged in an initiative to aggressively reduce human sources of mercury, including air deposition, mercury containing products, and discharges to wastewater treatment facilities. Information on this initiative is set forth in the implementation plan for the adopted 2010 TMDL.

While air deposition is the primary source of mercury contamination on a statewide basis, municipal and industrial discharges to surface water are point sources that must be addressed specifically in a TMDL and assigned a wasteload allocation. It is estimated that wastewater discharges to surface water account for approximately one percent of the overall load contributed to waterbodies and are considered *de minimus* sources when compared to air deposition. Dental facilities are believed to be the largest source of mercury reaching wastewater treatment plants. Through the New Jersey Pollutant Discharge Elimination System, Requirements for Indirect Users – Dental Facilities rules, N.J.A.C. 7:14A-21.12 (see http://www.nj.gov/dep/dwq/dap.htm) adopted on October 1, 2007, dental facilities that generate amalgam waste are required to comply with best management practices and install amalgam separators. The amalgam separators allow the mercury containing amalgam to be collected and recycled, thereby reducing the amount entering the environment primarily through sludge incineration. The Department required major wastewater treatment facilities to carry out baseline monitoring of their effluent to determine mercury levels prior to implementation of the dental rules. A second round of monitoring was performed in 2011 after rule implementation to determine the impact on the mercury levels in the

discharges. There was a reported decrease of about 36 percent in wastewater mercury effluent concentrations, and a 31 percent decrease in sewage sludge mercury concentration. By calendar year 2016, the mercury concentration in sewage sludge had decreased by 48 percent since the inception of the dental BMPs (https://www.nj.gov/dep/dwq/dap.htm). The Department has been working to better control mercury emissions. A *Mercury Emission Trend Report* published in 2017 summarized the measurable reductions in mercury emissions and the declined mean wet deposition mercury concentration observed under National Mercury Deposition Network (https://www.nj.gov/dep/dsr/trends/mercury.pdf). The Department's *Air Deposition Reduction Strategy* is expected to be updated with new information and technology when it is available.

05/28/2020

Date

SIGNED

Bruce S. Friedman, Director

Division of Water Monitoring and Standards

Amendment to the Sussex County Water Quality Management Plan and Upper Delaware Water Quality Management Plan

Total Maximum Daily Loads for Pathogens to Address 11 Lakes in the Northwest Water Region

Watershed Management Area 1
(Lake Winona, Lake Hopatcong, Green Valley Beach Campground, Forest Lake, Fox Hollow Lake, Lackawanna Lake, and Furnace Lake)
Watershed Management Area 2
(Crystal Springs Lake, Deer Trail Lake, Lake Mohawk, and Sleepy Valley Lake)

Proposed: July 16, 2007
Established: September 21, 2007
Approved: September 28, 2007
Adopted: October 19, 2009

Prepared by:
New Jersey Department of Environmental Protection
and

TETRA TECH, INC.

With assistance provided by:
United States Environmental Protection Agency, Region 2

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EXECUTIVE SUMMARY

In accordance with Section 305(b) and 303(d) of the Federal Clean Water Act (CWA), the State of New Jersey, Department of Environmental Protection (Department) is required to assess the overall water quality of the State's waters and identify those waterbodies with a water quality impairment for which TMDLs may be necessary. A TMDL is developed to identify all the contributors of a pollutant of concern and the load reductions necessary to meet the Surface Water Quality Standards (SWQS) relative to that pollutant. The Department fulfills its assessment obligation under the CWA through the Integrated Water Quality Monitoring and Assessment Report, which includes the Integrated List of Waterbodies, issued biennially. On October 4, 2004 the Department adopted the *2004 Integrated List of Waterbodies* as an amendment to the Statewide Water Quality Management Plan (36 NJR 4543(a)), as part of the Department's continuing planning process pursuant to the Water Quality Planning Act at N.J.S.A. 58:11A-7 and the Water Quality Management Planning rules at N.J.A.C. 7:15-6.4(a). The *2004 Integrated List of Waterbodies* identifies eleven lakes as impaired with respect to pathogens in the Northwest Water Region.

The Department has recently adopted the *2006 Integrated Water Quality Monitoring and Assessment Report*, including the *2006 Integrated List of Waterbodies*, which identifies impairments based on HUC 14 Assessment Units rather than stream segments associated with discrete monitoring locations. This change in assessment methodology allows establishment of a stable base of assessment units for which the attainment or non-attainment status of all designated uses within each subwatershed or assessment unit will be identified. In addition, lakes are assessed and listed separately when impaired. The *2006 Integrated List of Waterbodies* identifies eleven lakes that are impaired with respect to pathogens in the Northwest Water Region. A lake is determined to be impaired if it does not fully support primary contact recreation as evidenced by beach closings in accordance with Health Department standards. The water quality trigger for beach closings is exceedance of 200 cfu/100 ml of fecal coliform (NJDOH, 2004). TMDLs are adopted for the impaired lakes listed in Table 1.

Table 1. Lakes in the Northwest Water Region impaired for pathogens for which TMDLs are adopted.

TMDL Number	WMA	Lake Assessment Unit Name	County(s)*
1	1	Lake Winona	Morris/Sussex
2	1	Lake Hopatcong	Morris/ Sussex
3	1	Green Valley Beach Campground	Sussex
4	1	Forest Lake	Sussex
5	1	Fox Hollow Lake	Sussex

TMDL Number	WMA	Lake Assessment Unit Name	County(s)*
6	1	Lackawanna Lake	Sussex
7	1	Furnace Lake	Warren
8	2	Crystal Springs Lake	Sussex
9	2	Deer Trail Lake	Sussex
10	2	Lake Mohawk	Sussex
11	2	Sleepy Valley Lake	Sussex

*The drainage area/lakeshed for each lake may encompass municipalities beyond the identified County in which the lake is located.

Nonpoint and stormwater point sources are the primary sources of fecal coliform loads to the impaired lakes. Source loads were estimated for land uses in each watershed using the Watershed Treatment Model (WTM) (WTM, 2001). The WTM model is a series of spreadsheets that quantifies the loading of pathogen indicators based on land use distribution, stream network length in the watershed, and annual rainfall. Traditional point sources, i.e., treatment facilities that have a sanitary waste component, were considered de minimus due to the use of effective disinfection practices by these facilities. TMDLs were developed based on an analysis of the existing pathogen indicator data compared to Health Department indicator criteria and the loading capacity has been allocated among the point and nonpoint sources.

This report establishes eleven TMDLs that were adopted as amendments to the appropriate area-wide water quality management plan in accordance with N.J.A.C. 7:15-3.4(g). This report was developed consistent with EPA's May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Sutfin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs. These TMDLs were approved by EPA on September 28, 2007, and will be adopted as amendments to the Sussex County and Upper Delaware Water Quality Management Plans in accordance with N.J.A.C. 7:15-3.4 (g).

1.0 INTRODUCTION

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey, Department of Environmental Protection (Department) is required biennially to prepare and submit to the EPA a report that identifies waters that do not meet or are not expected to meet water quality standards after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the Department is also

required biennially to prepare and submit to the EPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report. The Integrated Water Quality Monitoring and Assessment Report combines these two assessments and assigns waterbodies to one of five sublists on the Integrated List of Waterbodies. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and 2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants, or have had a TMDL or other enforceable management measure approved by EPA (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants, for which a TMDL may be required.

In the New Jersey 2004 *Integrated Water Quality Monitoring and Assessment Report* the water quality impairments were identified by segment name and pollutant(s) or non-attained designated use responsible for the finding that the segment was impaired. Each segment was assessed using the data from one or more discrete monitoring locations that were determined to be representative of the water quality in that segment. This impaired segment delineation method was changed in 2006.

The *New Jersey 2006 Integrated Water Quality Monitoring and Assessment Report* now identifies impairments based on designated use attainment and then lists the parameters responsible for the non-attainment of the designated use. The assessments are conducted for each of the seven categories of designated use, which include aquatic life, recreational use (primary and secondary contact), drinking water, fish consumption, shellfish harvesting (if applicable), agricultural water supply use and industrial water supply use. In addition, lakes are assessed and listed separately if impaired. In the Northwest Water Region, the *2006 Integrated List of Waterbodies* currently identifies eleven lakes as impaired for pathogens. These lakes do not fully support primary contact recreation as evidenced by beach closings and water quality data that demonstrate exceedance of the water quality criterion that triggers closings.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background, and surface water withdrawals. A TMDL quantifies the amount of a pollutant a waterbody can assimilate and still conform to applicable water quality standards and support designated uses. The TMDL or loading capacity is allocated to known point and nonpoint sources in the form of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

Recent EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. These TMDLs address the following required items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.

This report establishes eleven TMDLs for pathogens to address the impaired lakes in the Northwest Water Region. All of the impaired lakes were listed for fecal coliform and assigned a high priority on the *2004 Integrated List of Waterbodies* and a High priority ranking on the *2006 Integrated List of Waterbodies* Sublist 5. These TMDLs include management approaches to reduce pathogen contributions from various sources in order to attain applicable surface water quality standards and fully support the designated primary contact recreation use. These TMDLs affect the drainage areas of the impaired lakes due to the fact that the implementation measures must be applied to the contributing drainage areas, not just the impaired lakes. Following approval of the TMDLs by EPA, pathogens will be removed as a basis of impairment in the next Integrated List. In addition to the pathogen impairments, Lake Hopatcong was listed for mercury and unknown pollutants on the *2006 Integrated List*. These pollutants will be addressed in future TMDL efforts. A total phosphorus TMDL was approved by EPA in 2003 for Lake Hopatcong.

2.0 POLLUTANT OF CONCERN AND AREA OF INTEREST

The pollutant of concern for these TMDLs is pathogens. Standards are established in terms of indicator organisms which, when present in excess of the standard, suggest that the waterbody is not suitable for primary contact recreation because of an elevated risk of disease. New Jersey Surface Water Quality Standards (SWQS) include pathogen indicator criteria for the assessment of the recreational use (primary and secondary contact recreation) for all waterbodies. However, for lakes with bathing beaches, the New Jersey Health Department Standards N.J.A.C. 8:26-7.18 establish the basis for beach closings. These standards are more stringent than the Surface Water Quality Standards. As a result, the Health Department Standards will serve as the water quality target for these TMDLs. The Health Department Standards and SWQS are summarized as follows:

> **As stated in N.J.A.C. 8:26-7.18 Microbiological water quality standards for bathing beaches:**

The multiple-tube fermentation technique for fecal coliforms shall be conducted in accordance with the procedures set for in Method 9222D Fecal Coliform Membrane Filter Procedure or Method 9221E.2. Fecal Coliform MPN Procedure (A-1 medium) found in the 19th edition of "Standard Methods for the Examination of Water and Wastewater." American Public Health Association, incorporated herein by reference, as amended and supplemented. The estimated fecal coliform concentrations shall not exceed 200 fecal coliform per 100 milliliters.

As stated in N.J.A.C. 7:9B-1.14(d) of the New Jersey Surface Water Quality Standards Fresh Water 2 (FW2) waters:

1. Bacterial quality (Counts/100 ml)

    ii. Primary Contact Recreation:

        (2) E. Coli levels shall not exceed a geometric mean of 126/100 ml or a single sample maximum of 235/100 ml.

The lakes assessed as impaired based on water quality data and for which TMDLs have been developed are identified in Table 2 and depicted in Figures 1 and 2.

Table 2. Impaired Waterbodies as identified on the *2004 Integrated List of Waterbodies* and the *2006 Integrated List* for which Pathogen TMDLs are being adopted.

TMDL Number	WMA	Lake Assessment Unit Name	Lake Assessment Unit ID	2004 Status	2006 Status	County(s)*	Proposed Action
1	1	Lake Winona	Lake Winona-01	Sublist 5	Sublist 5	Morris/ Sussex	Adopt TMDL
2	1	Lake Hopatcong	Lake Hopatcong-01	Sublist 5	Sublist 5	Morris/ Sussex	Adopt TMDL
3	1	Green Valley Beach Campground	Green Valley Beach Campground-01	Sublist 5 (as Pequest River at Green Valley Beach Campground)	Sublist 5	Sussex	Adopt TMDL
4	1	Forest Lake	Forest Lake-01	Sublist 5	Sublist 5	Sussex	Adopt TMDL
5	1	Fox Hollow Lake	Fox Hollow Lake-01	Sublist 5	Sublist 5	Sussex	Adopt TMDL
6	1	Lackawanna Lake	Lackawanna Lake-01	Sublist 5	Sublist 5	Sussex	Adopt TMDL
7	1	Furnace Lake	Furnace Lake-01	Sublist 5	Sublist 5	Warren	Adopt TMDL
8	2	Crystal Springs Lake	Crystal Springs Pond -02	Sublist 5	Sublist 5	Sussex	Adopt TMDL
9	2	Deer Trail Lake	Deer Trail Lake-02	Sublist 5	Sublist 5	Sussex	Adopt TMDL

TMDL Number	WMA	Lake Assessment Unit Name	Lake Assessment Unit ID	2004 Status	2006 Status	County(s)*	Proposed Action
10	2	Lake Mohawk	Lake Mohawk-02	Sublist 5	Sublist 5	Sussex	Adopt TMDL
11	2	Sleepy Valley Lake	Sleepy Valley-02	Sublist 5	Sublist 5	Sussex	Adopt TMDL

*The drainage area/lakeshed for each lake may encompass municipalities beyond the identified County in which the lake is located.

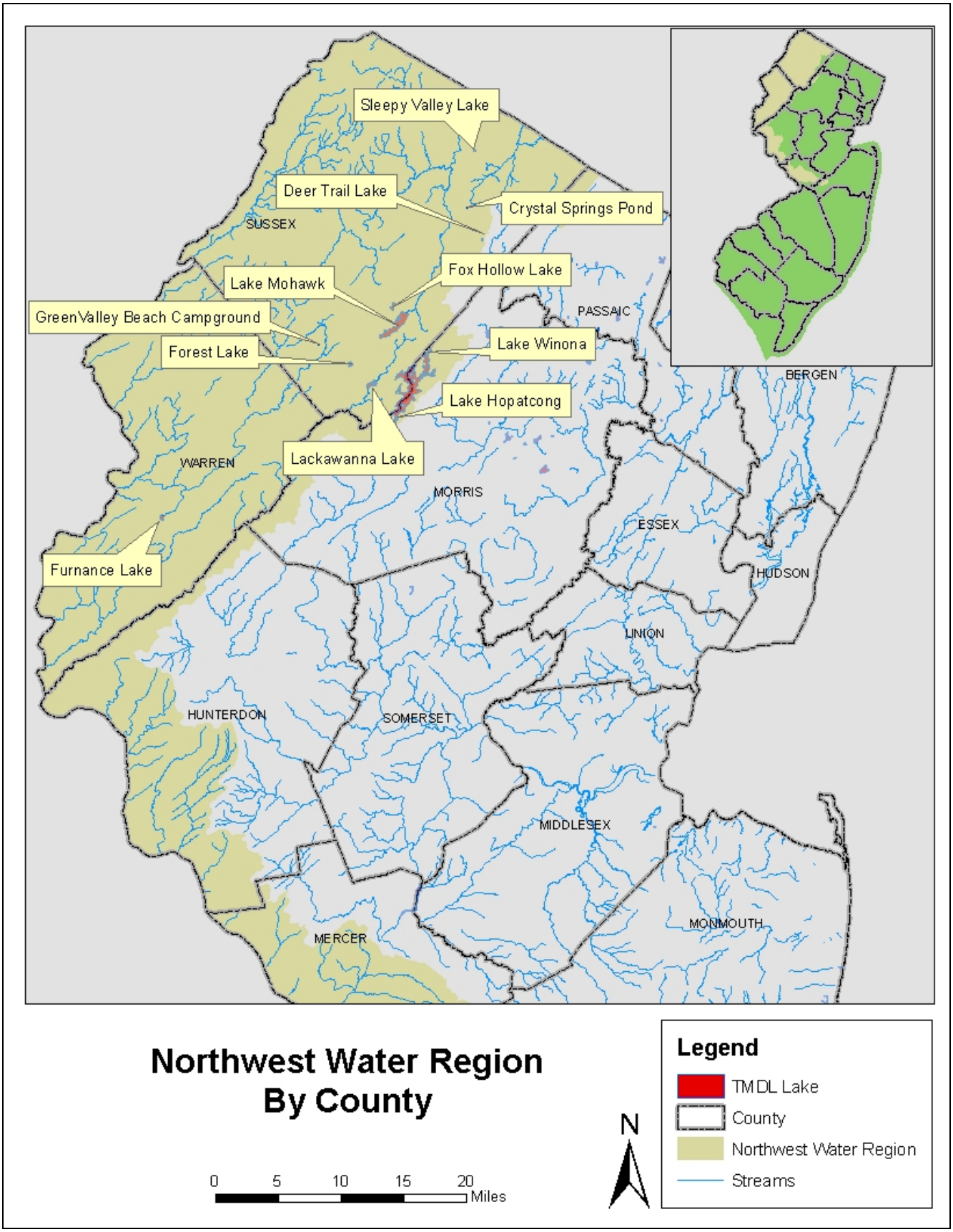

Figure 1. Pathogen impaired lakes in the Northwest Water Region by county.

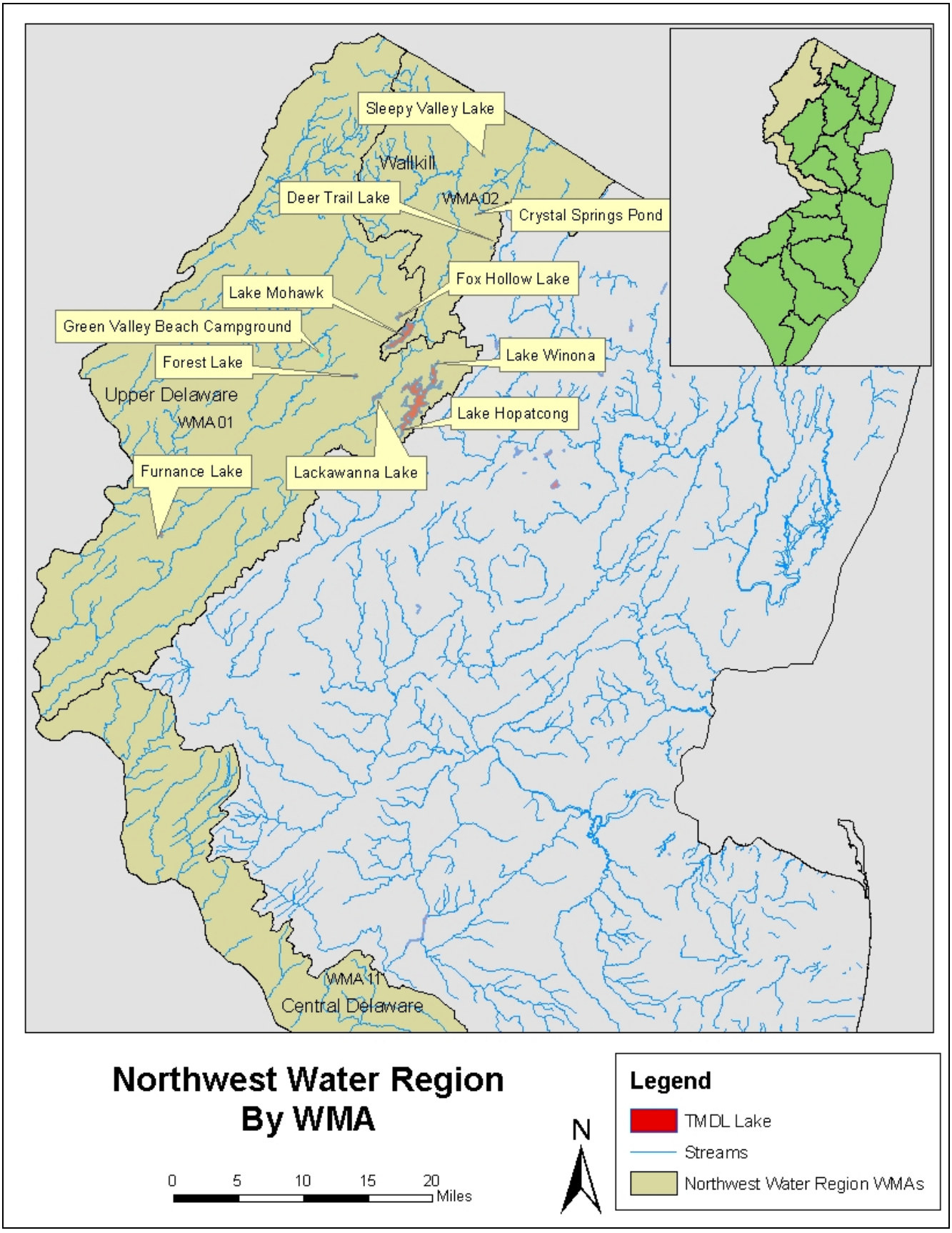

Figure 2. Pathogen impaired lakes in the Northwest Water Region by WMA.

Deer Trail Lake, Furnace Lake, Lackawanna Lake, Lake Hopatcong and Lake Winona are classified as Fresh Water 2 (FW2), Trout Maintenance (TM). All other impaired lakes addressed in this document are classified as FW2, Non-Trout (NT).

In all FW2 waters, the designated uses are (NJAC 7:9B-1.12):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

3.0 SOURCE ASSESSMENT

A source assessment was conducted to identify and characterize potential pathogen sources that may be impacting water quality in the listed waters. Both point and nonpoint sources were considered in TMDL development. Source assessment also includes the determination of the relative contribution of the primary bacteria sources to facilitate proper management responses through TMDL implementation. A variety of information was used to characterize possible pathogen sources including land use information gathered for each watershed, point source information, literature sources, and other available data.

3.2 Assessment of Point Sources

For TMDL development purposes, point sources include domestic and industrial wastewater treatment plants that discharge to surface waters, as well as surface water discharges of stormwater subject to regulation under the National Pollutant Discharge Elimination System (NPDES). This includes facilities with individual or general industrial stormwater permits, Tier A municipalities, and federal, interstate agency, state, and county facilities regulated under the New Jersey Pollutant Discharge Elimination System (NJPDES) municipal stormwater permitting program. Tier A municipalities are generally located within the more densely populated regions of the state or along the coast. These municipalities meet the population size requirements of EPA's Municipal Separate Storm Sewer System (MS4) program for regulating urban stormwater discharges. Stormwater point sources, like stormwater nonpoint sources, derive their pollutant loads from runoff from land surfaces and load reduction is accomplished through the use of best management practices (BMPs). The distinction is that stormwater point sources are regulated under the Clean Water Act (under the MS4 program). Stormwater point sources will be addressed through the management practices required through the MS4 permits.

Wastewater treatment facilities and Tier A municipalities that directly discharge to the pathogen impaired lakes in the Northwest Water Region are identified in Appendix B. Per Department NJPDES Regulation, N.J.A.C. 7:14A-12.5(a), "All wastewater that could contain pathogenic organisms such as fecal coliform and/or enterococci organisms shall be subject to continuous year round disinfection prior to discharge into surface waters." Therefore, loads from wastewater treatment facilities were considered de minimus, consistent with previous pathogen TMDLs developed by the Department. The NJPDES permit limits for these point sources will not be changed as a result of these TMDLs and will remain a 200 cfu/100 ml monthly geometric mean and a 400 cfu/100 ml weekly geometric mean.] Stormwater loads from Tier A MS4 systems are point sources that can be significant. These loads were estimated using the watershed loading methods described in the nonpoint source section, as they will be addressed through BMPs.

3.3 Assessment of Nonpoint Sources

Nonpoint sources that may affect lakes include stormwater discharges that are not subject to regulation under the Clean Water Act, including Tier B municipalities, direct stormwater runoff from land surfaces, as well as malfunctioning sewage conveyance systems, failing or inappropriately located septic systems, and direct contributions from wildlife, livestock and pets. Tier B municipalities are generally located in more rural, non-coastal regions of the state.

Watershed Treatment Model (WTM) (WTM, 2001), a steady-state spreadsheet model, was chosen to estimate nonpoint source bacteria loads for these TMDLs. WTM simulates loadings generated by watershed washoff processes. The WTM model was selected because it encompasses local rainfall data and stream length information to better tailor load estimates. In addition, it has been successfully applied in previous coastal TMDL studies, including the development of pathogen TMDLs for impaired shellfish waterbodies in New Jersey. The goal of applying WTM is to characterize all the point and nonpoint sources, as available data allows, in the existing system and to determine their relative contributions to the waterbody of interest. The loading values thus derived serve as the reference point from which reductions are made to meet TMDL targets.

The WTM model is a series of spreadsheets that quantifies the loading of pathogen indicators based on land use distribution, stream network length in the watershed, and annual rainfall. The model is designed as a planning level tool for watersheds that do not have sufficient data for complex modeling applications. Pathogen concentrations in runoff and receiving waters are highly variable due to many factors, therefore average annual land use loads derived using the WTM model are gross estimates. Although the WTM model has several tiers of data specificity, loading estimates can be calculated with simple land use data, as they were for these lake TMDLs. Land use loads are calculated on an annual basis by using a series of coefficients for runoff volume and pathogen loading derived from scientific literature. General land use categories are assigned either a coefficient that is then multiplied by an annual runoff volume to calculate an annual load (e.g., urban land uses) or an annual unit

area load that is applied as a function of land use (e.g., rural land uses). These coefficients are presented in Table 3 and discussed in the WTM user manual (Caraco, 2001). According to the WTM user manual, the urban loading coefficient was based on the median urban runoff value derived from Nationwide Urban Runoff Program (NURP) monitoring data (Pitt, 1998). Loading values for rural land uses were taken from Horner et. al., 1994. Note that barren land is not represented in the WTM model, therefore it was assumed that the forest loading value was reasonable for this land use type.

Table 3. Default WTM land use categories and loading variables.

WTM Land Use	Corresponding New Jersey Land Uses	Average % Impervious Cover	Fecal Coliform Conc. (MPN/100 ml) or Annual Load (billion/acre)
Low Density Residential	Low Density Residential, Rural Residential, Recreational Land, Athletic Fields	19	20,000
Medium Density Residential	Medium Density Residential, Mixed Residential, Mixed Urban or Built-Up, Other Urban or Built-Up, Military Reservations, No Longer Military	35	20,000
High Density Residential	High Density Residential	56	20,000
Commercial	Commercial Services	71	20,000
Roadway	Transportation/Communication/Utilities	39	20,000
Industrial	Industrial, Industrial/Commercial	78	20,000
Forest	Forest/Wetland	0	Load: 12 billion/acre
Rural	Agriculture	0	Load: 39 billion/acre
Barren (replaced "Vacant Lots" category in WTM)	Barren	2	Load: 12 billion/acre (estimated)

The watershed for each TMDL waterbody was delineated using the Hydrologic Unit Coverage (HUC-14 digit) developed by NJDEP, digital elevation model (DEM) data, the National Hydrography Dataset (NHD) stream coverage for New Jersey, and ArcHydro, a watershed delineation tool available as an extension for the ArcGIS geospatial mapping software suite. Land use data for each watershed was obtained from the 2002 land use coverage developed for New Jersey's WMAs. Land use categories were consolidated into broader groups for use in estimating land-based loads using the WTM model and for presenting the loading results. The percent impervious information for each land use category was derived from the percent impervious information in the Department's GIS land use coverage, averaged across similar land uses. The bacterial loads for urban areas in each watershed were calculated based on the default fecal coliform concentration literature value for urban land uses, the average percent impervious cover, and the annual runoff volume calculated by the WTM model. Agricultural, forest, and barren land use loads were calculated based on the specific loading rate for each category. The literature loading rate for forested land was applied to wetland areas to estimate a wetland land use load. Waterways were not included in loading calculations based on WTM model assumptions.

Direct contributions from illicit discharges, livestock, pets, and wildlife (e.g. seagulls, geese, and other waterfowl in particular) were not estimated based on the lack of site-specific information needed to represent these sources. Population estimates, bacteria production rates, and other information would be needed to estimate these sources. Bacteria may also be present in the sediment in some areas, as a result of contamination from stormwater, failing septic systems, malfunctioning sewer systems, agricultural runoff, and other sources. For these TMDLs, the loads contributed by wildlife, sediment, and the other sources were assumed to be included in the land use loading coefficients.

The drainage area and land use distribution of the impaired watersheds are presented in Table 4. Maps of the watershed land use distributions are presented in Appendix C.

Table 4. Land use area distributions for impaired watersheds in the Northwest Water Region.

WMA	Lake Assessment Unit ID	Agriculture		Barren Land		Forest		Urban		Water		Wetland		Total Area
		km²	%	km²	%	km²	%	km²	%	km²	%	km²	%	km²
1	Forest Lake-01	0.00	0.0	0.00	0.0	0.37	34.8	0.50	47.4	0.19	17.9	0.00	0.0	1.05
1	Fox Hollow Lake-01	0.05	1.3	0.02	0.5	1.27	35.0	1.28	35.1	0.40	10.9	0.63	17.3	3.64
1	Furnace Lake-01	0.89	12.7	0.07	1.0	4.09	58.1	1.04	14.7	0.24	3.4	0.71	10.1	7.04
1	Green Valley Beach Campground-01	0.05	40.8	0.00	0.0	0.01	12.3	0.04	37.4	0.01	8.6	0.00	0.9	0.12
1	Lackawanna Lake-01	0.47	1.4	0.36	1.1	22.35	65.2	5.89	17.2	1.80	5.2	3.44	10.0	34.31
1	Lake Hopatcong-01	0.01	0.0	1.00	1.5	31.90	48.5	16.81	25.6	10.91	16.6	5.11	7.8	65.73
1	Lake Winona-01	0.00	0.0	0.00	0.0	2.54	73.7	0.48	14.1	0.04	1.2	0.38	11.0	3.44
2	Crystal Springs Pond -02	0.00	0.0	0.01	3.7	0.03	9.5	0.24	83.8	0.01	3.0	0.00	0.0	0.28
2	Deer Trail Lake-02	0.00	0.0	0.00	0.0	0.60	72.5	0.17	20.4	0.04	5.1	0.02	2.0	0.83
2	Lake Mohawk-02	0.00	0.0	0.01	0.1	2.79	25.2	5.02	45.4	3.11	28.1	0.14	1.2	11.06
2	Sleepy Valley-02	0.00	0.0	0.02	0.5	1.80	54.0	0.91	27.2	0.25	7.6	0.36	10.7	3.34

4.0 WATER QUALITY ANALYSIS

Relating pathogen sources to concentrations of indicator organisms in the impaired waters is distinguished from quantifying that relationship for other pollutants given the inherent variability in population size and dependence not only on physical factors such as temperature and soil characteristics, but also on less predictable factors such as re-growth media. Since bacteria loads and concentrations can vary many orders of magnitude over short distances and over time at a single location, dynamic water quality models can be very difficult to calibrate. Options available to control nonpoint sources of bacteria typically include measures such as sewage infrastructure improvements, goose management strategies, pet waste ordinances, agricultural conservation management plans, and septic system replacement and maintenance. The effectiveness of these control measures is not easily measured relative to observed ambient concentrations. Given these considerations, detailed water quality modeling was not selected for determining the load reductions needed to attain standards and support the designated primary contact recreation use.

Fecal coliform data collected by county and township municipal health departments were used as the basis for TMDL development for the listed pathogen impaired lakes. These data were reviewed to identify potential data excursions in accordance with the Quality Assurance Project Plan (QAPP) that was developed for this study (QAPP, 2007). The percent reduction required to meet New Jersey bathing beach requirements was calculated based on comparing the maximum fecal coliform concentration recorded for each lake to the TMDL target (200 cfu/100 ml). The data available for each lake are included in Appendix D.

4.1 Seasonal Variation/Critical Conditions

The technical approach used to develop these TMDLs includes consideration of seasonal variability and critical conditions. The TMDL lakes are listed as impaired based on the designated primary contact bathing use. Water quality criteria for bathing beaches are established by the New Jersey Department of Health (NJDOH), which conducts monitoring at the municipal level in support of meeting the applicable criteria. Bathing beaches are typically in use during the late spring and summer months and data collection efforts are coordinated to coincide with this time period (May-September). TMDL loading reductions are based on the single sample maximum concentration identified in the record of observed in-lake water quality, therefore, TMDL development is based on the highest concentration observed for the time period of greatest exposure. Seasonal variability is of less importance because of the need to meet NJDOH bathing beach requirements during the summer critical condition period. TMDL loads are presented as average annual loads, which incorporate the summer critical condition period and the average load contributed during the other seasons.

4.2 Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality" (40 CFR 130.7(c)). For these TMDLs, both an implicit and explicit Margin of Safety (MOS) were incorporated. An implicit

MOS was incorporated by using conservative assumptions, including treating fecal coliform as a conservative substance (source loads were estimated without including die-off rates, soil incorporation, etc.) and using conservative methods to estimate land-based loads. In addition, a 5% explicit MOS was calculated for each lake.

5.0 TMDL CALCULATIONS

Pathogen load percent reductions were calculated by comparing the maximum fecal coliform concentration recorded for each lake to the TMDL target concentration (200 cfu/100 ml). Load capacities were the remaining loads after applying the required reductions on the current loads. In addition, 5% of the load capacity was reserved as the explicit MOS (see example below). The percent reduction specified for each lake was applied equally to pathogen sources in each watershed except in cases where load reductions could be met without reducing the loads contributed by forest, wetlands and barren lands: in such cases these loadings were not reduced in the TMDL allocation. In cases where load reductions on these land use sources were greater than or equal to 99.5%, the percent reduction specified for each lake was applied equally to all pathogen sources including forest and barren land loads.

Percent Reduction = (1 – TMDL target conc./max conc.) x 100
Load Capacity = (1 – percent reduction) * overall current load (using WTM)
MOS = 5% * Load capacity
Overall percent reduction = 1 – (Load capacity – MOS) / overall current load
Overall current load = agricultural and urban land use loads + forest, wetland and barren land loads

When $1 - \frac{Load\ Capacity - MOS - Forest, Wetland\ and\ Barren\ Land\ Load}{Agricultural\ and\ Urban\ LandUseLoad} \geq 99.5\%$,

Require the same percent reduction on Forest, Wetland and Barren land loads as on other land use loads;

Otherwise,

Zero percent reduction on Forest, Wetland and Barren lands loads

5.1 Wasteload Allocations and Load Allocations

WLAs were established for municipal stormwater discharges subject to regulation under the CWA. LAs were established for all stormwater sources that are not subject to regulation under the CWA and for all other nonpoint sources. Stormwater point sources that received a WLA were distinguished from stormwater sources receiving a LA on the basis of land use type and municipal tier designation (Tier A/Tier B).

This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured

within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system" (Wayland, November 2002, p.1). Therefore, allocations are established according to source categories as shown in Table 5. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial, and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES.

Table 5. Assignment of WLAs and LAs for stormwater point sources and nonpoint sources.

Land Use Source Category	Municipal Tier	TMDL Allocation Type
High density residential	A	WLA
Medium density residential (incl. mixed residential, mixed urban, other urban, military reservations, and no longer military)	A	WLA
Low density residential (incl. rural residential, recreational land, and athletic fields)	A	WLA
Commercial	A	WLA
Industrial	A	WLA
Roadways	A	WLA
High density residential	B	LA
Medium density residential (incl. mixed residential, mixed urban, other urban, military reservations, and no longer military)	B	LA
Low density residential (incl. rural residential, recreational land, and athletic fields)	B	LA
Commercial	B	LA
Industrial	B	LA
Roadways	B	LA
Agricultural	N/A	LA
Forest/Wetland	N/A	LA
Barren land	N/A	LA

A summary of the WLAs, LAs, and MOS is provided for each lake in Table 6 and source loads and allocations are presented in Table 7. As described above, when the loads contributed by forest/wetland/barren lands were not reduced in the TMDL allocation table, the load reduction for urban lands and agricultural lands was increased proportionally to meet the overall percent reduction required for each lake. Note that the overall percent reduction shown in Tables 6 and 7 takes into account the 5% explicit MOS if not based on the previously established stream Fecal Coliform TMDL.

In cases where impaired lakeshed is hydrologically connected to a streamshed addresssed in an established Fecal Coliform TMDL or to another impaired lakeshed, different approaches were utilized to calculate the load reduction for each "nested" watershed.

Lakeshed connected with the Fecal Coliform TMDL established streamshed

If the entire lakeshed is located within the impaired streamshed, the more stringent overall percent reduction between the lake and the stream is applied to the lakeshed. When the streamshed is part of the lakeshed, the rivershed is treated as an upper stream "lake" shed. The same approach, as described below for the nested lakesheds, was used to determine the adjusted load reduction for different areas.

Lakeshed connected with another impaired lakeshed

The following methodology was used to determine the adjusted percent reduction for the nested lake watersheds:

1. Existing pathogen loads calculated for each lake watershed (using WTM) were reduced based on the overall percent reduction that was calculated from the observed lake water quality data. The reduced load was termed the target load.
2. The target load for the upstream watershed was subtracted from the target load of the downstream watershed, giving a target load for the downstream (local) watershed area. The existing load for the downstream (local) watershed was calculated similarly.
3. If the target load for the downstream (local) watershed area was less than or equal to zero, the downstream lake's higher percent reduction needed to be applied to the upper stream lakeshed. This means that the entire drainage area of the downstream lake is ruled by the downstream lake's reduction percentage.
4. If the target load of the downstream (local) watershed area was higher than zero, the percent difference between the existing and target loads for the downstream (local) watershed was calculated. This adjusted percent reduction superseded the original downstream lake percent reduction and was used as the required percent reduction for the downstream (local) watershed area while the upstream lakeshed stayed with the original overall percent reduction. The adjusted percent reduction would be higher than the original overall percent reduction for the downstream lake when the upstream lake required a less percent reduction than the downstream lake and less than the original value if the upstream lake required a higher percent reduction than the downstream lake.

Table 6. TMDL calculations for pathogen impaired lakes in the Northwest Water Region.

WMA	Lake Assessment Unit ID	WLA (10^6 colonies/yr)	LA (10^6 colonies/yr)	MOS (10^6 colonies/ yr)	TMDL (10^6 colonies/ yr)	Overall % Reduction	% MOS	Reduction from associated Stream TMDL
1	Forest Lake-01	5.13E+02	1.72E+01	2.79E+01	5.58E+02	98.42%	5.00%	
1	Fox Hollow Lake-01[c]	1.48E+03	1.23E+02	8.46E+01	1.69E+03	98.00%	N/A	98%
1	Furnace Lake-01[c]	0.00E+00	5.47E+03	2.88E+02	5.76E+03	93.00%	N/A	93%
1	Green Valley Beach Campground-01	7.85E-02	2.28E+02	1.20E+01	2.40E+02	90.50%	5.00%	
1	Lackawanna Lake-01	2.23E+04	5.77E+03	1.48E+03	2.95E+04	92.96%	5.00%	
1	Lake Hopatcong-01[b]	4.37E+04	3.35E+03	2.48E+03	4.96E+04	96.79%[b]	5.00%	
1	Lake Winona-01[a]	8.92E+02	1.64E+02	5.56E+01	1.11E+03	98.10%	5.00%	
2	Crystal Springs Pond -02	0.00E+00	5.02E+03	2.64E+02	5.28E+03	75.32%	5.00%	
2	Deer Trail Lake-02	0.00E+00	3.08E+03	1.62E+02	3.24E+03	74.25%	5.00%	
2	Lake Mohawk-02[d]	5.25E+03	1.50E+02	2.84E+02	5.68E+03	98.27%	5.00%	90%
2	Sleepy Valley-02[c]	0.00E+00	3.30E+03	1.74E+02	3.48E+03	95.00%	N/A	95%

a. within the watershed of Lake Hopatcong and stays with its own reduction

b. Reduction on the local Lake Hopatcong watershed is less than the original overall percent reduction (96.83%) after taking into account Lake Winona's higher reduction.

c. lake shed located within a stream watershed and goes with the stream's reduction

- Fox Hollow Lake is nested with the watershed of Paulins Kill at Balesville, on which a reduction of 98% was required (NJDEP, 2003).
- Furnace Lake is nested with the watershed of Pequest River at Pequest, on which a reduction of 93% was required (NJDEP, 2003).
- Sleepy Valley is nested with the watershed of Wallkill River near Unionville, on which a reduction of 95% was required (NJDEP, 2003).

d. lake shed located within a stream watershed and stays with its own reduction

- Lake Mohawk is nested with the watershed of Wallkill River at Sparta, on which a reduction of 90% was required (NJDEP, 2003).

Table 7. Northwest Water Region land-based load allocations.

WMA	Lake Assessment Unit ID	Overall % Reduction	Agriculture			Barren Land			Forest/Wetland			Urban Total (WLA)			Urban Total (LA)		
			Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)
1	Forest Lake-01	98%	0.00E+00	98%	0.00E+00	0.00E+00	98%	0.00E+00	1.09E+03	98%	1.72E+01	3.24E+04	98%	5.13E+02	0.00E+00	98%	0.00E+00
1	Fox Hollow Lake-01	98%	4.62E+02	98%	9.25E+00	5.83E+01	98%	1.17E+00	5.64E+03	98%	1.13E+02	7.42E+04	98%	1.48E+03	0.00E+00	98%	0.00E+00
1	Furnace Lake-01	93%	8.61E+03	93%	6.03E+02	2.16E+02	93%	1.51E+01	1.42E+04	93%	9.96E+02	0.00E+00	93%	0.00E+00	5.51E+04	93%	3.86E+03
1	Green Valley Beach Campground-01	91%	4.68E+02	92%	3.61E+01	0.00E+00	0%	0.00E+00	4.67E+01	0%	4.67E+01	1.02E+00	92%	7.85E-02	1.89E+03	92%	1.45E+02
1	Lackawanna Lake-01	93%	4.50E+03	93%	3.17E+02	1.07E+03	93%	7.52E+01	7.65E+04	93%	5.38E+03	3.16E+05	93%	2.23E+04	0.00E+00	93%	0.00E+00
1	Lake Hopatcong-01	97%	1.01E+02	97%	3.25E+00	2.97E+03	97%	9.56E+01	1.01E+05	97%	3.25E+03	1.36E+06	97%	4.37E+04	0.00E+00	97%	0.00E+00
1	Lake Winona-01	98%	0.00E+00	98%	0.00E+00	0.00E+00	98%	0.00E+00	8.64E+03	98%	1.64E+02	4.70E+04	98%	8.92E+02	0.00E+00	98%	0.00E+00
2	Crystal Springs Pond -02	75%	0.00E+00	76%	0.00E+00	3.11E+01	0%	3.11E+01	7.87E+01	0%	7.87E+01	0.00E+00	76%	0.00E+00	2.02E+04	76%	4.91E+03
2	Deer Trail Lake-02	74%	0.00E+00	88%	0.00E+00	0.00E+00	0%	0.00E+00	1.84E+03	0%	1.84E+03	0.00E+00	88%	0.00E+00	1.01E+04	88%	1.24E+03
2	Lake Mohawk-02	98%	0.00E+00	98%	0.00E+00	2.67E+01	98%	4.61E-01	8.67E+03	98%	1.50E+02	3.04E+05	98%	5.25E+03	0.00E+00	98%	0.00E+00

WMA	Lake Assessment Unit ID	Overall % Reduction	Agriculture			Barren Land			Forest/Wetland			Urban Total (WLA)			Urban Total (LA)		
			Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)
2	Sleepy Valley-02	95%	1.33E+01	95%	6.63E-01	4.65E+01	95%	2.32E+00	6.41E+03	95%	3.21E+02	0.00E+00	95%	0.00E+00	5.96E+04	95%	2.98E+03

5.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included for the lakes addressed in these TMDLs. Wastewater treatment facilities will continue to be required to achieve disinfection. Nonpoint source reduction strategies applied to land uses will be equally effective with respect to existing and future use of the land.

6.0 FOLLOW - UP MONITORING

Monitoring requirements for the listed lakes are established under NJDOH regulations for state bathing beaches. NJDOH regulations include sampling requirements before and during seasonal operation. Before bathing beaches are opened each year, NJDOH requires a pre-operational assessment, which includes

- A review of historical sampling and epidemiological data
- A field investigation of the bathing and surrounding areas to identify sources of potential contamination
- A sampling of waters in the bathing area and in areas of suspected sources of contamination

During the bathing season, NJDOH requires that bathing beach water be sampled one week prior to opening and at one-week intervals once in use. Samples are collected during periods of maximum user load and from depths used for bathing. In cases where water samples were found to meet the NJDOH water quality criterion for three consecutive months in the prior year, operators can apply for biweekly sampling responsibilities (NJDOH, 2004).

7.0 IMPLEMENTATION

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, citing criteria, operating methods, or other alternatives" (USEPA, 1993).

Development of effective management measures depends on accurate source assessment. Coliform bacteria are contributed to the environment from a number of categories of sources including human, domestic or captive animals, agricultural practices, and wildlife. Coliform bacteria from these sources can reach waterbodies directly, through overland runoff, or through sewage or stormwater conveyance facilities. Each potential source will respond to one or more management strategies designed to eliminate or reduce that source of coliform bacteria. Each management strategy has one or more entities that can take lead responsibility to effect the strategy. Various funding sources are available to assist in accomplishing the management strategies. The Department will address the sources of impairment by matching strategies with sources, selecting responsible entities and aligning available resources to effect implementation.

For example, the stormwater discharged to the impaired waterbodies through "municipal separate storm sewer systems" (MS4s) are regulated under the Department's Municipal Stormwater Regulation Program. Under these rules and associated general permits, many municipalities (and various county, State, and other agencies) are required to implement various control measures that should substantially reduce bacteria loadings, including measures to eliminate "illicit connections" of domestic sewage and other waste to the MS4s. Measures that are currently in effect include ordinances to manage pet waste, prohibit feeding of unconfined wildlife on public property, clean catch basins, perform good housekeeping at maintenance yards, and provide related public education and employee training. These measures are required in accordance with the Department's Municipal Stormwater Regulation program. The Department has provided State funds as well as a portion of its Clean Water Act 319(h) pass through grant funds to assist municipalities in meeting these requirements.

Sewage conveyance facilities are potential sources of fecal coliform in that equipment failure or operational problems may result in the release of untreated sewage. These sources, once identified, can be eliminated through appropriate corrective measures that can be affected through the Department's enforcement authority. Inadequate on-site sewage disposal can also be a source of fecal coliform. Systems that were improperly designed, located or maintained may result in surfacing of effluent; illicit remedies such as connections to storm sewers or streams add human waste directly to waterbodies. Once these problems have been identified through local health departments, sanitary surveys, or other means, alternatives to address the problems can be evaluated and the best solution implemented. The New Jersey Environmental Infrastructure Financing Program, which includes New Jersey's State Revolving Fund, provides low interest loans to assist in correction of water quality problems related to stormwater and wastewater management.

Geese are migratory birds that are protected by the Migratory Bird Treaty Act of 1918 and other Federal and State Laws. Resident Canada geese do not migrate, but are nevertheless protected by this and other legislation. The United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS)-Wildlife Services program reports that the 1999 estimated population of non-migratory geese in New Jersey was 83,000. Geese may produce up to 1½ pounds of fecal matter a day and when the congregate in large numbers they can represent a locally significant source of coliform bacteria. This may warrant taking steps to reduce populations in areas with excessive populations.

Because geese are free to move about and commonly graze and rest on large grassy areas associated with schools, parks, golf courses, corporate lawns, and cemeteries, measures to reduce populations, where necessary, are best developed and conducted at the community level through a community-based goose damage management program. USDA's Wildlife Services program recommends that a community prepare a written Canada Goose Damage Management Plan that may include the following actions:

- Initiate a fact-finding and communication plan
- Enact and enforce a "no feeding" ordinance (already required per MS4 permits)
- Conduct goose damage control activities such as habitat modification

- Review and update land use policies
- Reduce or eliminate goose reproduction (permit required)
- Hunt geese to reinforce nonlethal actions (permit required)

Procedures such as handling nests and eggs, capturing and relocating birds, and the hunting of birds require a depredation permit from either the USDA APHIS Wildlife Services or U.S. Fish and Wildlife Services. Procedures requiring permits should be a last resort after a community has exhausted the other listed measures. The Department's draft guide *Management of Canada Geese in Suburban Areas, March 2001,* which may be found at www.state.nj.us/dep/watershedmgt under publications, provides extensive guidance on how to modify habitat to serve as a deterrent to geese as well as other prevention techniques such as education through signage and ordinances.

In coastal areas, other waterfowl are naturally present in significant numbers and vary seasonally with migratory patterns. Other wildlife contributions may include deer populations, which have been identified as a potential fecal coliform source in the impaired watersheds. The forested and low-density residential areas that provide deer habitat can be found in close proximity to the impaired watersheds. Deer have been evaluated in fecal coliform TMDLs by other States (e.g. Alabama and South Carolina) and could be a fecal coliform source in New Jersey. Management measures to reduce coliform bacteria contributed by wildlife are not generally practicable, but could respond to measures such as improved riparian buffers.

Agricultural activities are another example of potential sources of coliform bacteria. Possible contributors are direct contributions from livestock permitted to traverse streams and stream corridors, manure management from feeding operations, or use of manure as a soil fertilizer/amendment. Implementation of conservation management plans and best management practices are the best means of controlling agricultural sources of coliform bacteria. Several programs are available to assist farmers in the development and implementation of conservation management plans and best management practices. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

- **The Environmental Quality Incentive Program (EQIP)** is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

- **The Conservation Reserve Program (CRP)** is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter

strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP).

- **The Conservation Reserve Enhancement Program** The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, have established a $100 million dollar CREP agreement. The program matches $23 million of State money with $77 million from the Comodity Credit Corporation within USDA. Through CREP, financial incentives are offered for agricultural landowners to voluntarily implement conservation practices on agricultural lands. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). There will be a ten-year enrollment period, with CREP leases ranging between 10-15 years. The State intends to augment this program thereby making these leases permanent easements. The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

Management strategies are summarized below in Table 8.

Table 8. Implementation management strategies.

Source Category	Responses	Potential Responsible Entity	Funding options
Human Sources			
Inadequate (per design, operation, maintenance, location, density) on-site disposal systems	Sanitary surveys, septic management programs/ordinances	Municipality	CWA 604(b) for confirmation of inadequate condition; Environmental Infrastructure Financing Program for construction of selected option
Inadequate or improperly maintained stormwater facilities; illicit connections	Measures required under Municipal Stormwater permitting program including any additional measures determined in the future to be needed through TMDL process	Municipality, State and County regulated entities, stormwater utilities	CWA 319(h); Environmental Infrastructure Financing Program for construction of selected option
Malfunctioning sewage conveyance facilities	Identify through source trackdown and repair	Owner of malfunctioning facility--compliance issue	User fees
Domestic/captive animal sources			
Pets	Pet waste ordinances	Municipalities for ordinance adoption and compliance	State source and CWA 319(h) assistance to municipalities to implement municipal stormwater regulations

Source Category	Responses	Potential Responsible Entity	Funding options
Horses, livestock, zoos	Confirm through source trackdown: SCD/NRCS develop conservation management plans	Property owner	EQIP, CRP, CREP
Agricultural practices	Confirm through source trackdown; SCD/NRCS develop conservation management plans, exercise CAFO/AFO authority if applicable	Property owner	EQIP, CRP, CREP
Wildlife			
Locally excessive populations of resident Canada geese or other waterfowl	Feeding ordinances; Goose Management BMPs	Municipality for ordinance; local community groups for BMPs	State source; CWA 319(h)
Indigenous wildlife	Confirm through trackdown; riparian buffer restoration; consider revising designated uses	State	State source

7.1 Specific Projects

In addition to the more generalized strategies described previously, a number of projects have been undertaken which are expected to aid in achieving the load reductions assigned to the impaired waterbodies. Ongoing activities to develop and implement watershed restoration plans are expected to result in additional specific projects to reduce pollutant loads.

Table 9. Northwest Water Region Outreach and Restoration Projects

WMA	FY	Funding Source	Recipient	Project Title	Grant Amount
1	2005	319(h)	Lake Hopatcong Commission	Implementation of Nonpoint Source Management Measures to Reduce the Phosphorus and Sediment Loads Entering Lake Hopatcong	$910,440
1	2006	CBT	Princeton Hydro, LLC	Refined Phosphorus TMDL and Restoration Plan for Lake Hopatcong and Lake Musconetcong	$94,000
1	2007	319(h)	Sussex County Municipal Utilities Authority, Wallkill River Watershed Management Group	Watershed Restoration Plan for the Paulins Kill Headwaters to Balesville: Three Phased Approach (Fox Hollow Lake)	$464,025

8.0 REASONABLE ASSURANCE

With the implementation of source reduction measures such as reducing the number of failing septic systems, leaching sewer lines, and controlling agricultural runoff, the Department has reasonable assurance that a significant improvement in the support of primary contact recreation in the impaired lakes will be attained. The results from on-going existing monitoring programs will be evaluated to determine effectiveness of the identified measures and if additional measures are needed.

9.0 PUBLIC PARTICIPATION

The Water Quality Management Planning Rules at N.J.A.C. 7:15-7.2 require the Department to initiate a public process prior to the development of each TMDL and to allow public input to the Department on policy issues affecting the development of the TMDL. Further, the Department shall adopt each TMDL as an amendment to the appropriate area-wide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g). As part of the public participation process for the development and implementation of the subject TMDLs, the Department solicited information from stakeholder groups and from the general public directly and through a web posting beginning in October 2006. Additionally in November 2006, the list of impaired lakes was distributed to the New Jersey volunteering monitoring community, through the Watershed Watch Network. The Watershed Watch Network is a program acting as an umbrella for all of the volunteer monitoring programs within New Jersey. Interested parties had the opportunity to supply the Department with information about each via e-mail. The Department specifically solicited information regarding potential sources and/or current non point sources of pollution reduction projects within the impaired watersheds. Information received regarding potential sources of fecal contamination were assessed in the development of these TMDLs.

10.0 AMENDMENT PROCESS

Notice proposing these TMDLs appeared in the July 16, 2007 New Jersey Register and in a newspaper of general circulation in order to provide the public an opportunity to review the TMDL document and submit formal comments. In addition, a public hearing was held on August 17, 2007 at the New Jersey Department of Environmental Protection Public Hearing Room, 401 E. State St., Trenton, NJ 08608. There was an informal presentation from 1:00 p.m. to 2:00 p.m., followed by the public hearing from 2:00 p.m. until the end of testimony, whichever was earlier. One person attended the hearing and no testimony was given. Notice of the proposal and hearing was provided to affected counties, municipalities and lake associations in the watershed.

There were no comments received during the public notice period or at the public hearing. This TMDL was approved by EPA on September 28, 2007 and was adopted on October 19, 2009 as an amendment to the Sussex County and Upper Delaware Water Quality Management Plans in accordance with New Jersey's Water Quality Management Planning Rules at N.J.A.C. 7:15-3.4 (g).

APPENDIX A: REFERENCES

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APPENDIX B: NJPDES WASTEWATER TREATMENT FACILITIES, TIER A MUNICIPALITIES, TIER B MUNICIPALITIES

Northwest Water Region Wastewater Treatment Facilities

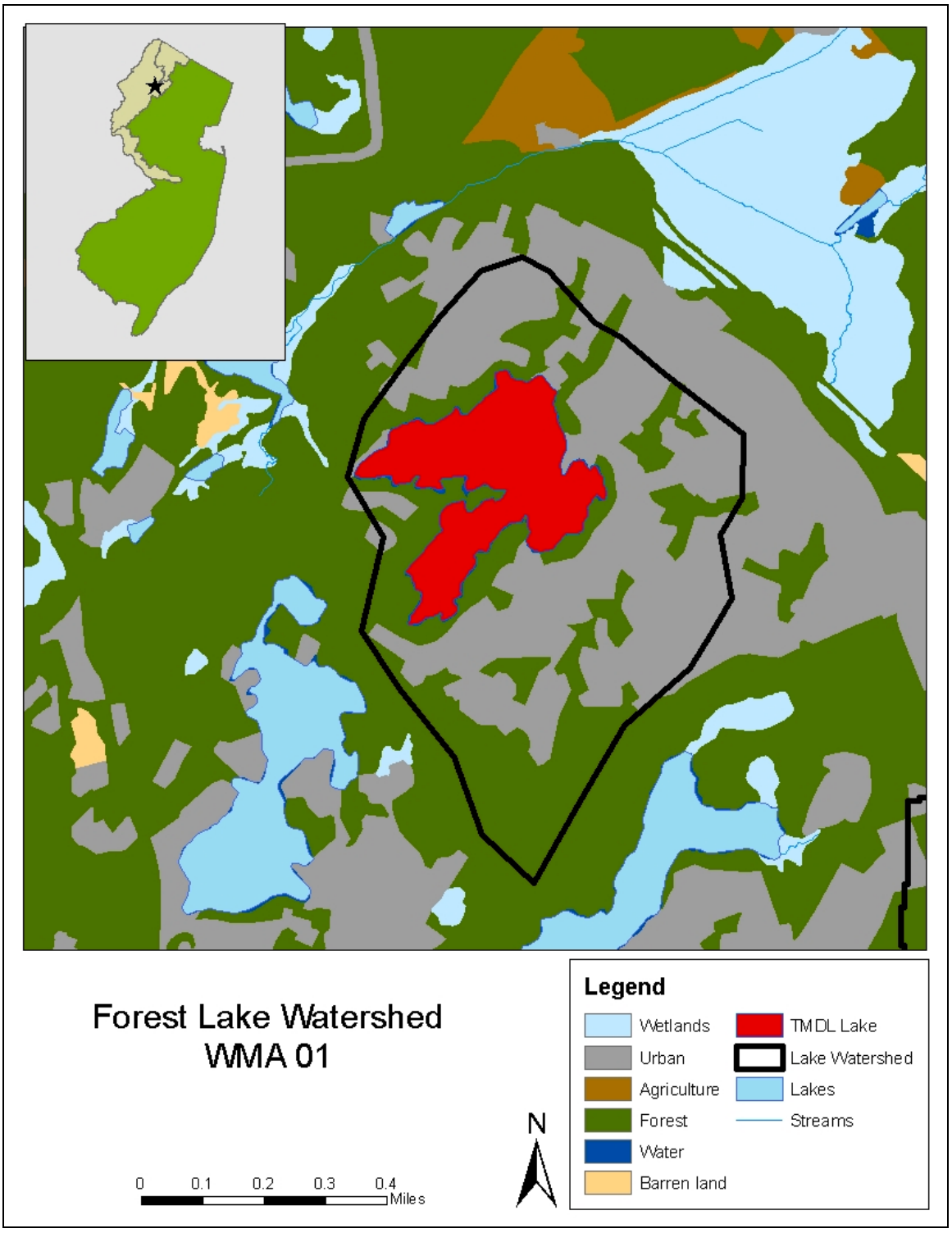
NJPDES ID	Facility Name	Pipe	FC Limit	Permit Category*	Receiving Waters/Associated Lake
NJ0021105	Jefferson Twp - Arthur Stanlick School	001A	NA	A	Lake Shawnee via unnamed trib/Lake Hopatcong
NJ0027049	Pope John XXIII High School	001A	NA	A	Fox Hollow Lake via unnamed trib

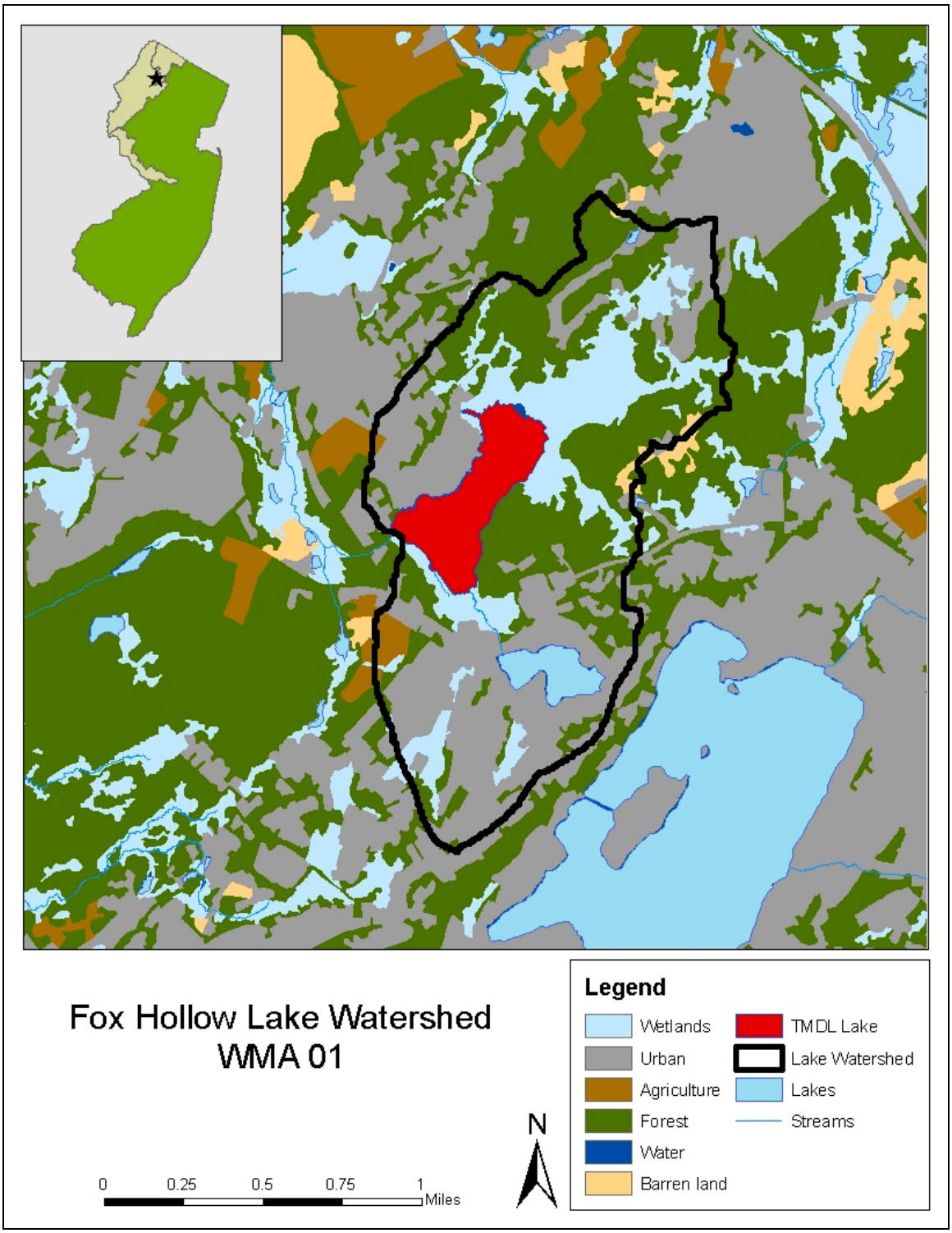
*Permit Categories: A = Sanitary Surface Water Discharge

Northwest Water Region Tier A and Tier B Municipalities

Tier	Watershed	Municipality	WMA	Permit #
A	Fox Hollow	Sparta Twp	1	NJG0148059
	Green Valley Beach Campground	Andover Twp	1	NJG0153290
	Lake Hopatcong	Sparta Twp	1	NJG0148059
		Jefferson Twp	1	NJG0151793
		Hopatcong Boro	1	NJG0147931
		Mount Arlington Boro	1	NJG0153265
		Roxbury Twp	1	NJG0152641
	Lackawanna Lake	Sparta Twp	1	NJG0148059
		Hopatcong Boro	1	NJG0147931
		Byram Twp	1	NJG0149209
	Forest Lake	Andover Twp	1	NJG0153290
		Byram Twp	1	NJG0149209
	Lake Winona	Sparta Twp	1	NJG0148059
		Jefferson Twp	1	NJG0151793
	Lake Mohawk	Sparta Twp	2	NJG0148059
		Andover Twp	2	NJG0153290
		Byram Twp	2	NJG0149209
B	Furnace Lake	White Twp	1	NJG0149683
		Oxford Twp	1	NJG0151904
		Washington Twp	1	NJG0150690
	Green Valley Beach Campground	Green Twp	1	NJG0152943
	Deer Trail Lake	Hardyston Twp	2	NJG0152269
	Crystal Springs Lake	Hardyston Twp	2	NJG0152269

APPENDIX C: LAKE WATERSHED MAPS

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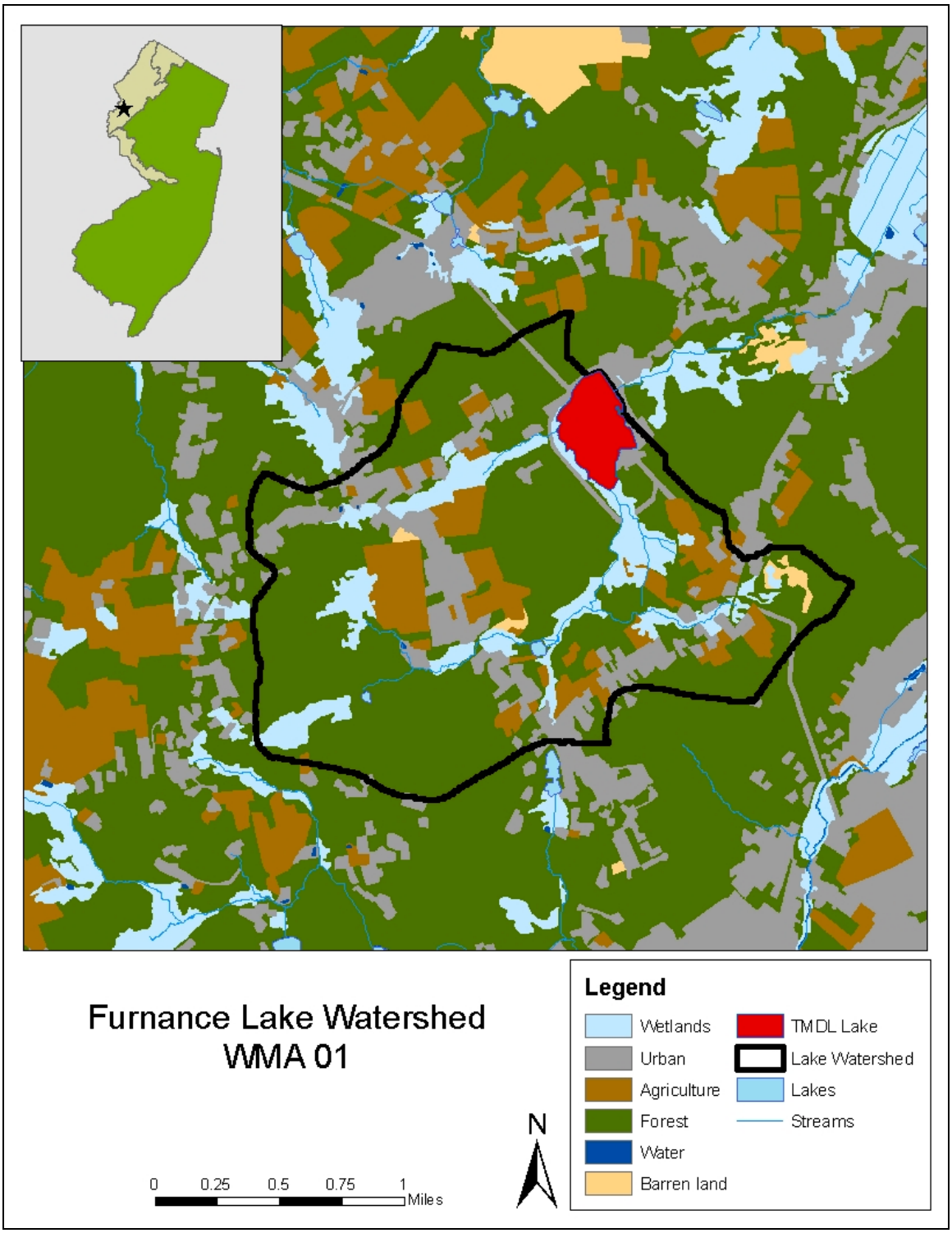
TMDL Lake
Lake Watershed
Lakes
Streams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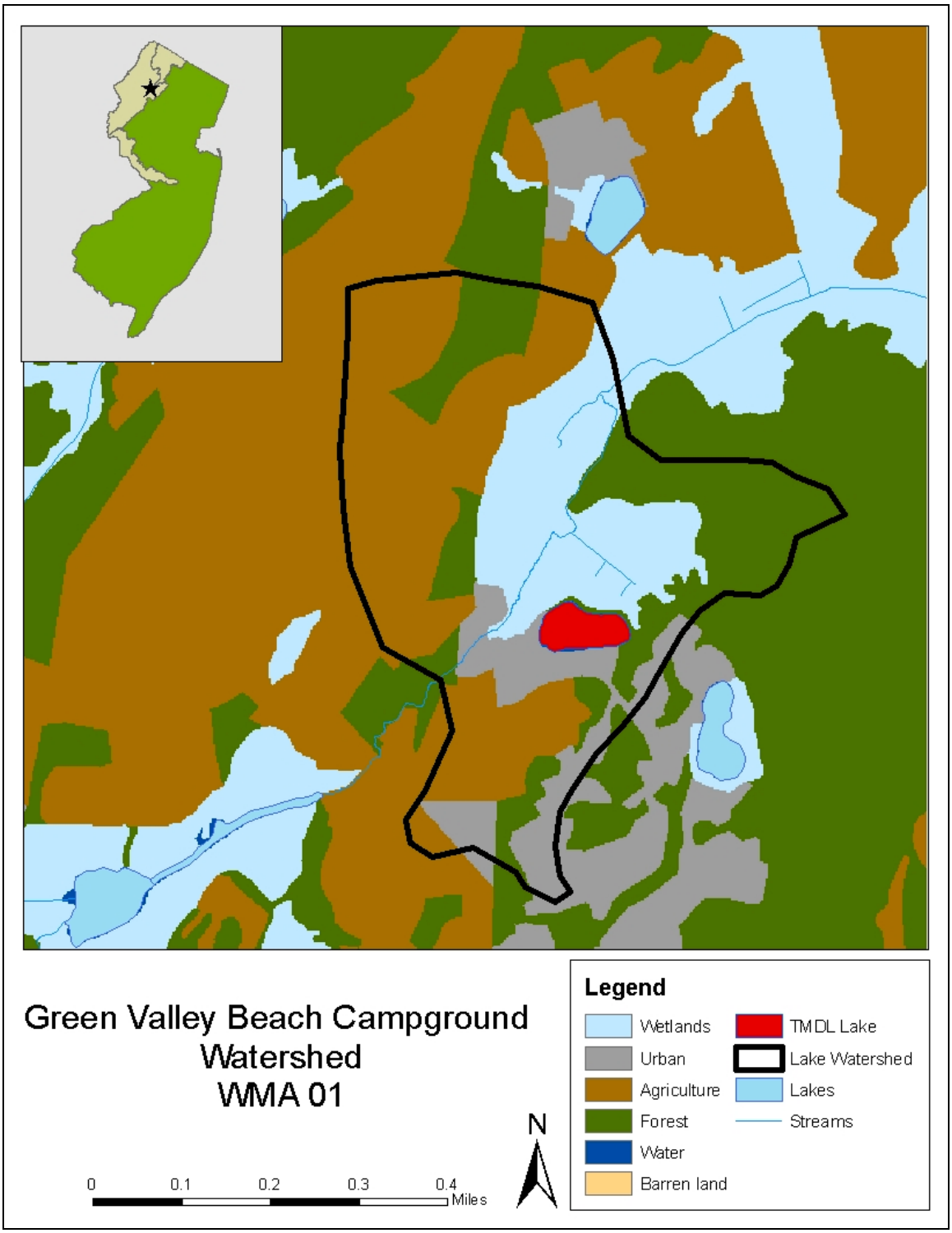
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TMDL Lake
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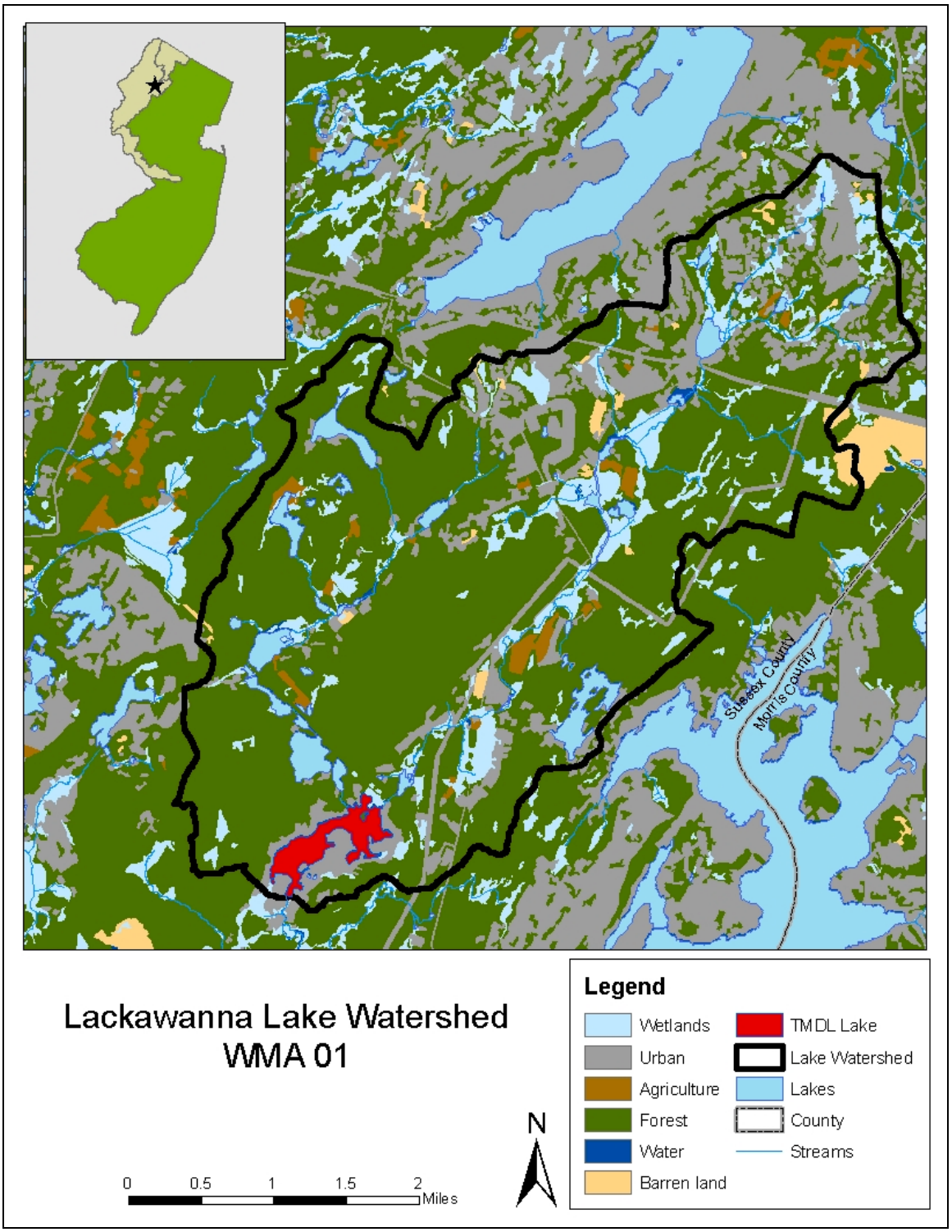
Lakes
Streams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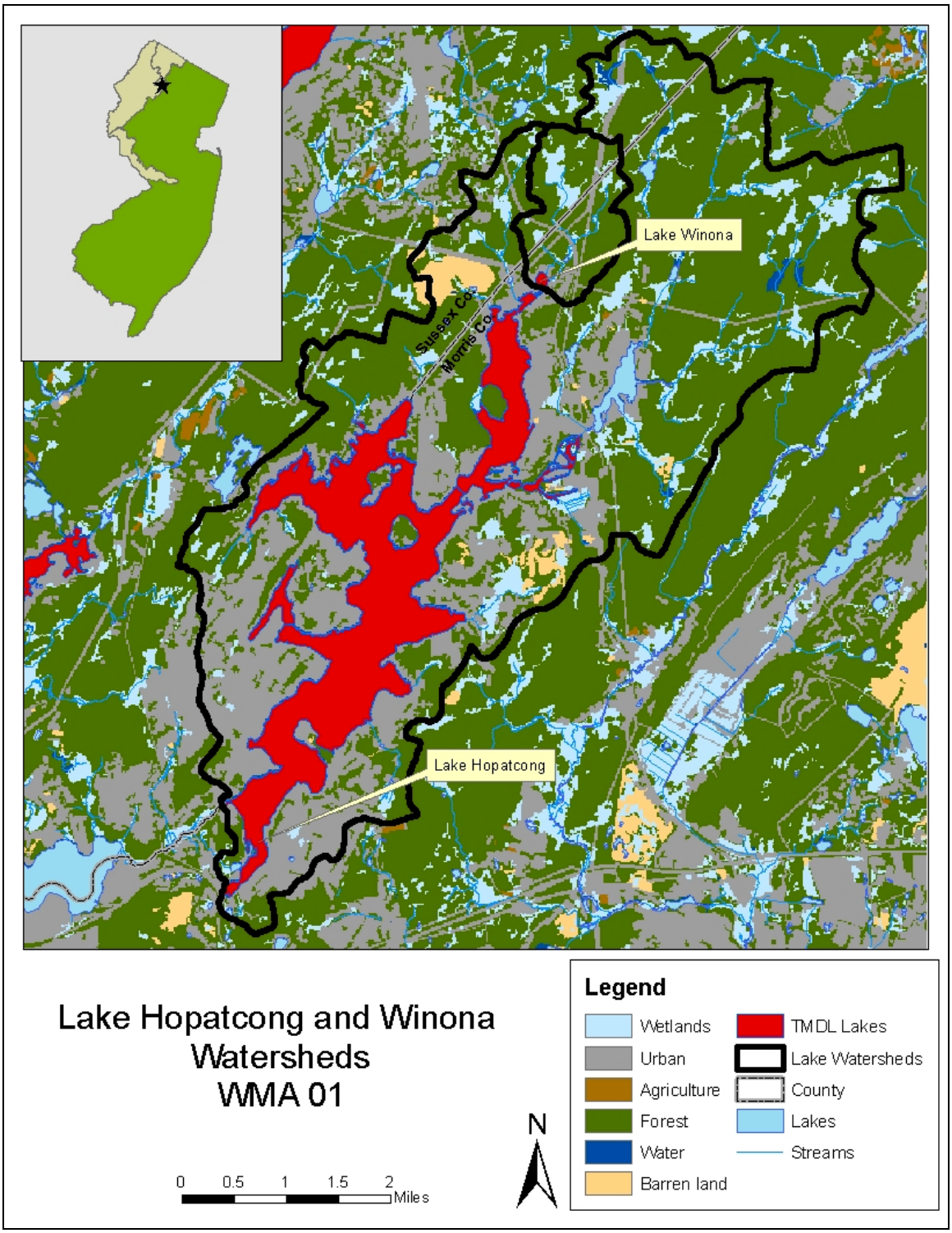
Streams


Lake Winona
Lake Hopatcong
Sussex Co.
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County
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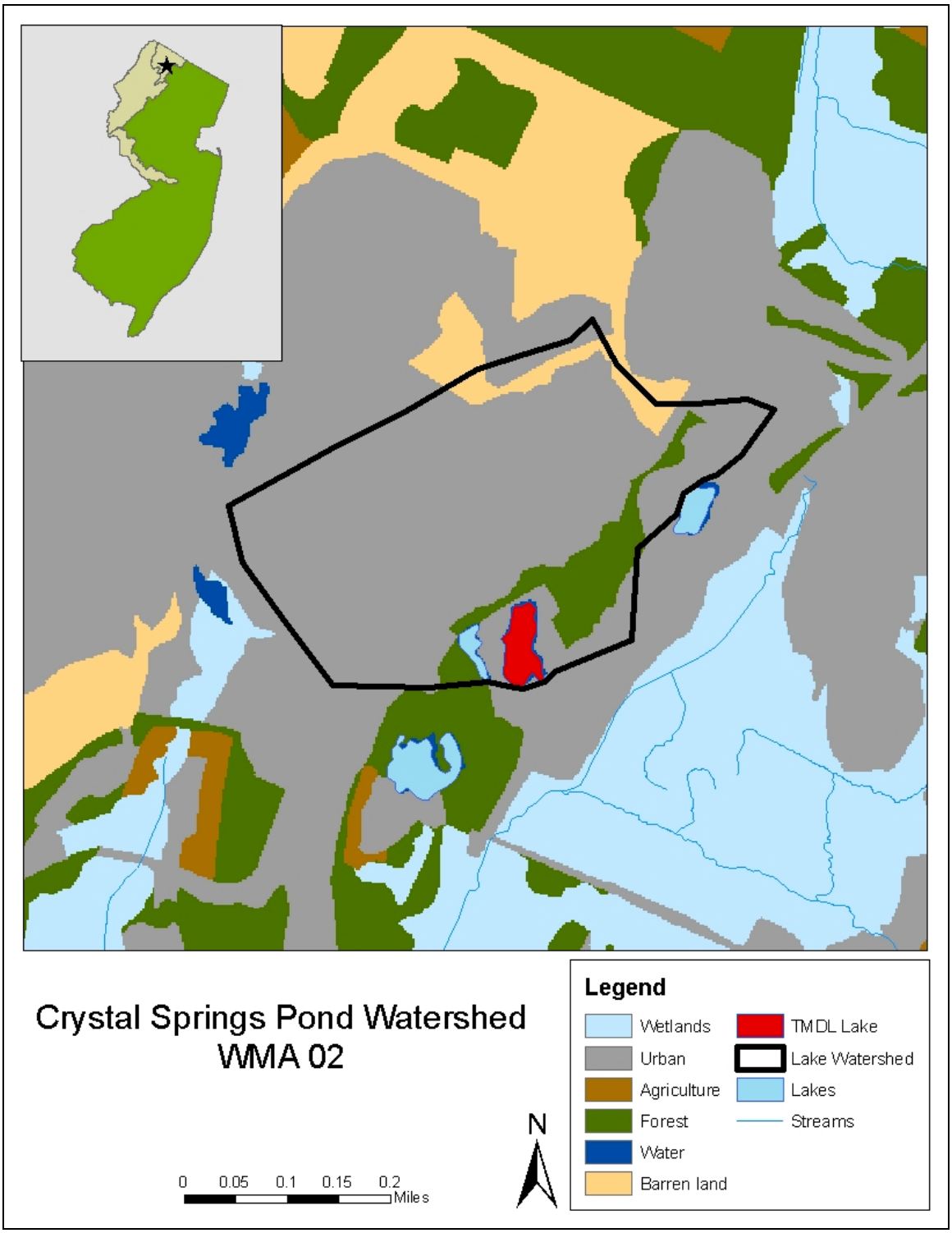
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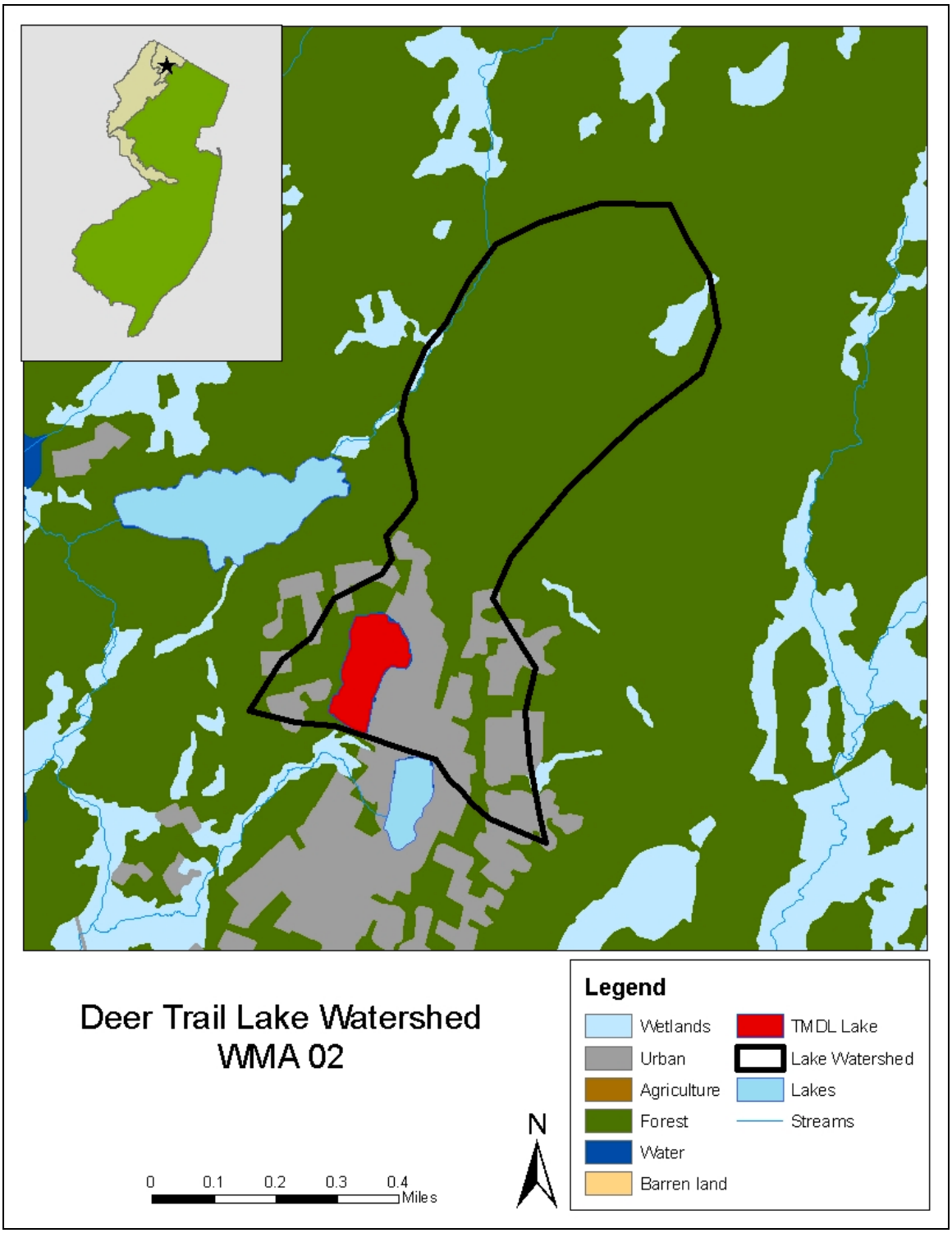
Lakes
Streams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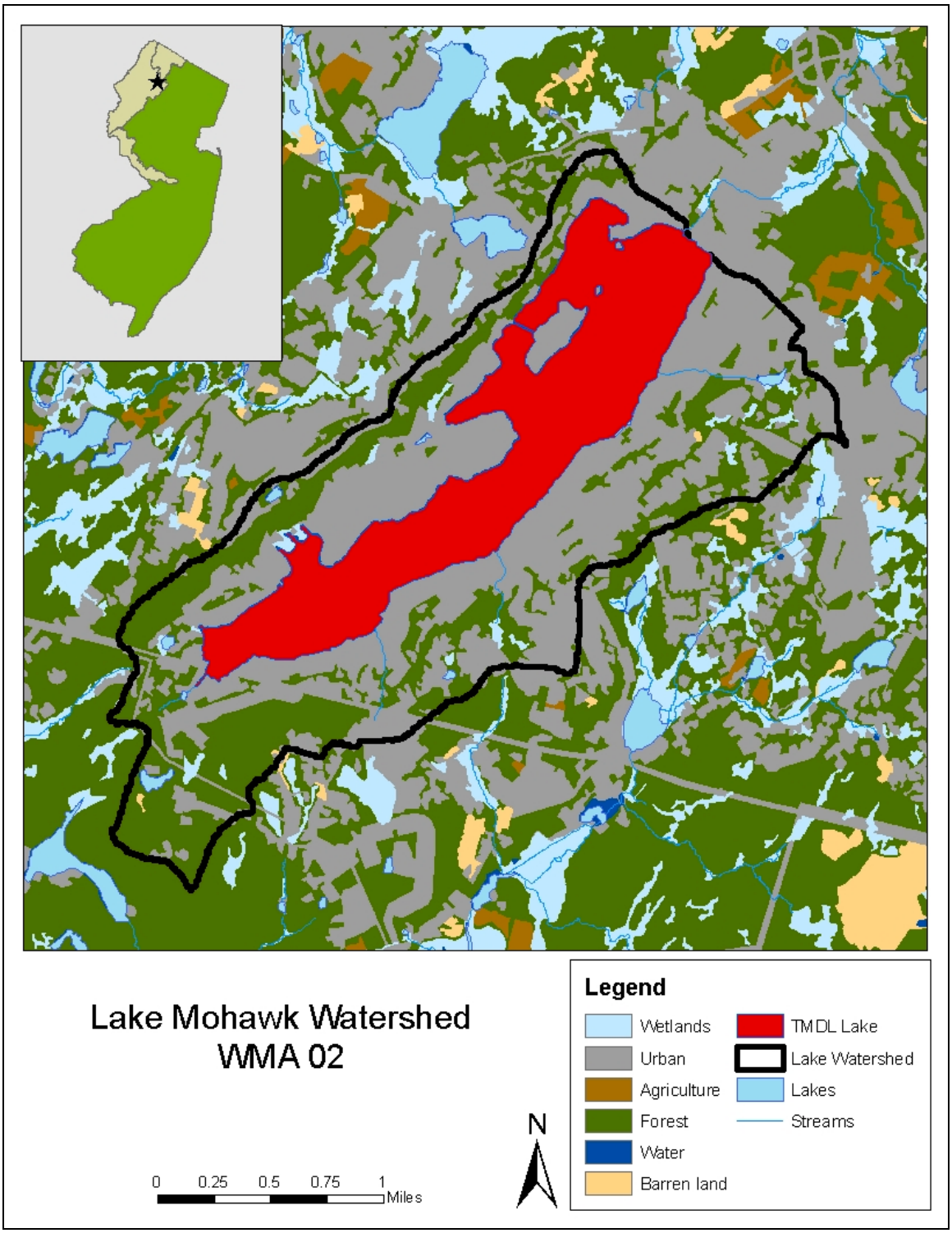
Lakes
Streams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Urban
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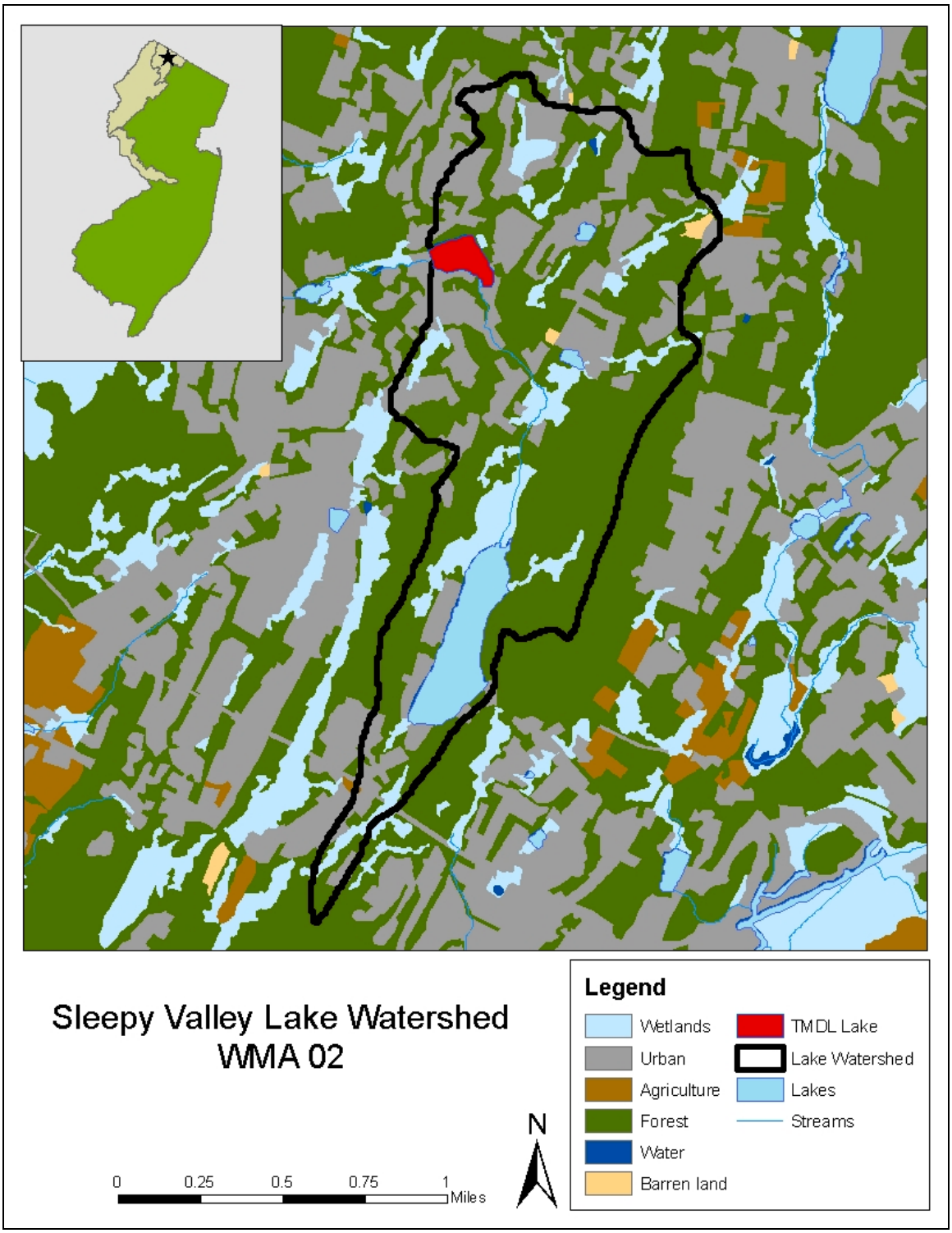
Forest
Water
Barren land
TMDL Lake
Lake Watershed
Lakes
Streams


Sleepy Valley Lake Watershed
WMA 02
0
0.25
0.5
0.75
1
Miles
N
Legend
Wetlands
Urban
Agriculture
Forest
Water
Barren land
TMDL Lake
Lake Watershed
Lakes
Streams

APPENDIX D: NORTHWEST WATER REGION WATER QUALITY DATA

* Highlighted values are greater than 200 cfu/100 ml of fecal coliform bacteria

WMA 01

Forest Lake			
Stats:			
count	333	mean+3stdev	2657
median	10	% Reduction	98%
max	12000		
stdev	834	**no data excluded**	
mean	154		
mean+3stdev	2657		

DATA			
Station	**Date**	**Value**	**Remark**
SXL190402	05/18/98	2	K
SXL190402	06/03/98	2	K
SXL190402	06/17/98	2	K
SXL190402	07/01/98	30	
SXL190402	07/13/98	50	
SXL190402	07/31/98	30	
SXL190402	08/10/98	98	
SXL190402	08/17/98	1	
SXL190402	09/01/98	20	
SXL190403	05/18/98	2	K
SXL190403	06/03/98	20	
SXL190403	06/17/98	350	
SXL190403	06/20/98	2	K, RESAMPLE
SXL190403	06/22/98	2	K, RESAMPLE
SXL190403	07/01/98	60	
SXL190403	07/13/98	2	K
SXL190403	07/13/98	2	K
SXL190403	07/31/98	30	
SXL190403	07/31/98	2	K
SXL190403	08/14/98	40	
SXL190403	09/01/98	2	K
SXL190404	05/18/98	2	K
SXL190404	06/03/98	2	K
SXL190404	06/17/98	40	
SXL190404	07/01/98	2	K
SXL190404	07/13/98	20	
SXL190404	07/31/98	2	K
SXL190404	08/14/98	2	K
SXL190404	09/01/98	30	
SXL190405	05/18/98	150	
SXL190405	06/03/98	30	
SXL190405	06/17/98	120	
SXL190405	07/01/98	70	
SXL190405	07/13/98	20	
SXL190405	07/31/98	2	K
SXL190405	08/14/98	2	K
SXL190405	09/01/98	2	K
FOREST LAKE: BOARDWALK BEACH	05/24/99	190	
SXL190402	06/11/99	20	
SXL190402	06/18/99	10	K
SXL190402	07/05/99	10	K
SXL190402	07/22/99	20	
SXL190402	08/05/99	10	
SXL190402	08/17/99	10	K
SXL190402	08/02/99	40	
FOREST LAKE: COVE BEACH	05/24/99	10	
SXL190403	06/11/99	10	K
SXL190403	06/18/99	20	
SXL190403	07/05/99	10	K
SXL190403	07/22/99	10	K
SXL190403	08/05/99	10	K
SXL190403	08/17/99	10	K
SXL190403	09/02/99	30	
FOREST LAKE: HARBOR VIEW BEACH	05/24/99	**12000**	
SXL190404	05/28/99	680	beach closed, RESAMPLE
SXL190404	06/01/99	780	beach closed, RESAMPLE
SXL190404	06/11/99	10	K, RESAMPLE
SXL190404	06/18/99	10	K
SXL190404	06/25/99	10	K
SXL190404	07/05/99	10	K
SXL190404	07/09/99	10	K
SXL190404	07/15/99	10	K
SXL190404	07/22/99	10	
SXL190404	07/26/99	10	
SXL190404	08/05/99	20	
SXL190404	08/13/99	10	K
SXL190404	08/17/99	50	
SXL190404	08/27/99	180	
SXL190404	09/02/99	10	K
FOREST LAKE: MAIN BEACH	05/24/99	130	
SXL190405	06/11/99	160	
SXL190405	06/18/99	10	K
SXL190405	07/05/99	10	K
SXL190405	07/22/99	40	
SXL190405	08/05/99	10	
SXL190405	08/17/99	20	
SXL190405	09/02/99	20	

SXL190402	05/12/00	10	K
SXL190402	06/23/00	10	
SXL190402	06/27/00	10	K
SXL190402	07/05/00	20	
SXL190402	07/11/00	10	K
SXL190402	07/18/00	10	
SXL190402	08/01/00	40	
SXL190402	08/08/00	10	
SXL190402	08/15/00	40	
SXL190402	08/29/00	10	
SXL190403	05/12/00	10	K
SXL190403	06/23/00	10	K
SXL190403	06/27/00	10	K
SXL190403	07/05/00	10	K
SXL190403	07/11/00	20	
SXL190403	07/18/00	10	K
SXL190403	08/01/00	30	
SXL190403	08/08/00	10	K
SXL190403	08/15/00	100	
SXL190403	08/29/00	10	K
SXL190404	05/12/00	70	
SXL190404	06/23/00	10	K
SXL190404	06/27/00	10	K
SXL190404	07/05/00	40	
SXL190404	07/11/00	10	K
SXL190404	07/18/00	30	
SXL190404	08/01/00	20	
SXL190404	08/08/00	30	
SXL190404	08/15/00	20	
SXL190404	08/29/00	10	K
SXL190405	05/12/00	40	
SXL190405	06/23/00	10	K
SXL190405	06/27/00	10	K
SXL190405	07/05/00	10	K
SXL190405	07/11/00	10	K
SXL190405	07/18/00	60	

SXL190405	08/01/00	20	
SXL190405	08/08/00	10	
SXL190405	08/29/00	20	
Boardwalk Beach	05/17/01	10	K
Boardwalk Beach	06/07/01	10	K
Boardwalk Beach	06/15/01	10	K
Boardwalk Beach	06/19/01	10	K
Boardwalk Beach	06/26/01	10	K
Boardwalk Beach	07/12/01	10	K
Boardwalk Beach	07/24/01	10	K
Boardwalk Beach	07/29/01	10	K
Boardwalk Beach	08/01/01	10	K
Boardwalk Beach	08/07/01	10	K
Boardwalk Beach	08/16/01	10	K
Boardwalk Beach	08/23/01	8	
Cove Beach	05/17/01	10	K
Cove Beach	06/07/01	80	
Cove Beach	06/15/01	10	
Cove Beach	06/19/01	20	
Cove Beach	06/26/01	10	
Cove Beach	07/12/01	40	
Cove Beach	07/24/01	10	K
Cove Beach	07/29/01	380	
Cove Beach	08/01/01	10	K
Cove Beach	08/07/01	10	K
Cove Beach	08/16/01	140	
Harbor View Beach	05/17/01	10	K
Harbor View Beach	06/07/01	20	
Harbor View Beach	06/15/01	70	
Harbor View Beach	06/19/01	640	Beach closed voluntarily
Harbor View Beach	06/26/01	200	Beach reopened 6/29
Harbor View Beach	07/12/01	20	

Harbor View Beach	07/24/01	10	K
Harbor View Beach	07/29/01	10	K
Harbor View Beach	08/01/01	20	
Harbor View Beach	08/07/01	70	
Harbor View Beach	08/16/01	2400	Voluntary closure
Harbor View Beach	08/21/01	10	K
Main Beach	05/17/01	10	K
Main Beach	06/07/01	10	K
Main Beach	06/15/01	190	
Main Beach	06/19/01	200	
Main Beach	06/26/01	150	
Main Beach	07/12/01	10	
Main Beach	07/24/01	10	K
Main Beach	07/29/01	10	K
Main Beach	08/01/01	10	K
Main Beach	08/07/01	30	
Main Beach	08/16/01	40	
BOARDWALK BEACH	05/16/02	20	
BOARDWALK BEACH	05/31/02	10	K
BOARDWALK BEACH	06/05/02	50	
BOARDWALK BEACH	06/10/02	10	
BOARDWALK BEACH	06/25/02	10	K
BOARDWALK BEACH	06/28/02	10	
BOARDWALK BEACH	07/02/02	10	
BOARDWALK BEACH	07/15/02	10	K
BOARDWALK BEACH	07/26/02	10	K

BOARDWALK BEACH	07/31/02	10	K
BOARDWALK BEACH	08/13/02	20	
BOARDWALK BEACH	08/15/02	10	K
BOARDWALK BEACH	08/19/02	60	
BOARDWALK BEACH	08/22/02	40	
BOARDWALK BEACH	08/26/02	30	
COVE BEACH	05/16/02	50	
COVE BEACH	05/31/02	260	
COVE BEACH	06/05/02	10	K, RESAMPLE
COVE BEACH	06/10/02	10	
COVE BEACH	06/25/02	100	
COVE BEACH	06/28/02	310	
COVE BEACH	07/02/02	10	RESAMPLE
COVE BEACH	07/15/02	30	
COVE BEACH	07/26/02	10	
COVE BEACH	07/31/02	10	K
COVE BEACH	08/13/02	310	RESAMPLE
COVE BEACH	08/15/02	4900	RESAMPLE, CLOSED
COVE BEACH	08/19/02	40	RESAMPLE
COVE BEACH	08/22/02	130	
COVE BEACH	08/26/02	300	
HARBOR VIEW BEACH	05/16/02	10	K
HARBOR VIEW BEACH	05/31/02	10	
HARBOR VIEW BEACH	06/05/02	260	
HARBOR VIEW BEACH	06/10/02	20	RESAMPLE
HARBOR VIEW BEACH	06/25/02	40	
HARBOR VIEW BEACH	06/28/02	190	
HARBOR VIEW BEACH	07/02/02	30	

HARBOR VIEW BEACH	07/11/02	370	
HARBOR VIEW BEACH	07/15/02	10	RESAMPLE
HARBOR VIEW BEACH	07/26/02	140	
HARBOR VIEW BEACH	07/31/02	10	
HARBOR VIEW BEACH	08/13/02	10	
HARBOR VIEW BEACH	08/15/02	80	
HARBOR VIEW BEACH	08/19/02	160	
HARBOR VIEW BEACH	08/22/02	160	
HARBOR VIEW BEACH	08/26/02	100	
MAIN BEACH	05/16/02	10	K
MAIN BEACH	05/31/02	10	K
MAIN BEACH	06/05/02	100	
MAIN BEACH	06/10/02	30	
MAIN BEACH	06/25/02	220	HEAVY RAINS
MAIN BEACH	07/02/02	100	
MAIN BEACH	07/11/02	10	
MAIN BEACH	07/15/02	10	K
MAIN BEACH	07/26/02	80	
MAIN BEACH	07/31/02	20	
MAIN BEACH	08/13/02	40	
MAIN BEACH	08/15/02	5100	
MAIN BEACH	08/19/02	920	RESAMPLE
MAIN BEACH	08/22/02	200	RESAMPLE
MAIN BEACH	08/26/02	200	RESAMPLE
Forest Lake:Boardwalk Beach	05/30/03	10	K
	06/09/03	10	K
	06/16/03	10	K
	06/24/03	10	K
	06/27/03	10	

	06/30/03	80	
	07/07/03	20	
	07/24/03	10	
	08/11/03	40	
	08/20/03	20	
	08/25/03	60	
Forest Lake:Cove Beach	05/30/03	10	K
	06/09/03	10	K
	06/16/03	10	K
	06/24/03	10	K
	06/27/03	10	
	06/30/03	30	
	07/07/03	10	K
	07/24/03	230	
	07/29/03	10	K
	08/05/03	10	
	08/11/03	230	
	08/20/03	30	
	08/25/03	10	K
Forest Lake:Harborview Beach	05/30/03	40	
	06/09/03	10	K
	06/16/03	10	K
	06/24/03	10	K
	06/27/03	30	
	06/30/03	30	
	07/07/03	50	
	07/24/03	90	
	07/29/03	10	K
	08/05/03	60	
	08/11/03	60	
	08/20/03	3000	
	08/25/03	30	

Forest Lake:Main Beach	05/30/03	10	K
	06/09/03	20	
	06/16/03	70	
	06/24/03	330	
	06/27/03	140	
	06/30/03	70	
	07/07/03	80	
	07/24/03	60	
	07/29/03	10	
	08/05/03	10	
	08/11/03	80	
	08/20/03	10	
	08/25/03	60	
Forest Lake: Boardwalk	05/17/04	10	
	06/02/04	10	K
	06/09/04	1100	
	06/11/04	20	
	06/16/04	80	
	06/23/04	40	
	06/29/04	10	K
	07/06/04	10	K
	07/15/04	10	K
	07/20/04	10	
	07/26/04	10	K
	08/03/04	10	K
	08/10/04	10	K
	08/18/04	10	K
	08/25/04	10	K
Forest Lake: Cove	05/17/04	10	K
	06/02/04	10	K
	06/09/04	40	
	06/11/04	590	
	06/16/04	10	K
	06/23/04	30	

	06/29/04	30	
	07/06/04	40	
	07/15/04	10	K
	07/20/04	10	K
	07/26/04	10	K
	08/03/04	10	K
	08/10/04	10	K
	08/18/04	10	K
	08/25/04	30	
Forest Lake: Harborview	05/17/04	10	K
	06/02/04	40	
	06/09/04	510	preseason testing
	06/11/04	300	preseason testing
	06/16/04	40	
	06/23/04	10	K
	06/29/04	10	
	07/06/04	10	K
	07/15/04	40	
	07/20/04	10	
	07/26/04	10	K
	08/03/04	10	
	08/10/04	10	K
	08/18/04	10	
	08/25/04	110	
Forest Lake: Main	05/17/04	10	
	06/02/04	50	
	06/09/04	4900	
	06/11/04	50	
	06/16/04	90	
	06/23/04	110	
	06/29/04	30	
	07/06/04	40	
	07/15/04	100	
	07/20/04	10	K
	07/26/04	10	K

	08/03/04	30	
	08/10/04	10	K
	08/18/04	10	
	08/25/04	10	

Fox Hollow Lake			
count	116	mean+3stdev	2755
median	20	%reduction	80%
Max	9300		
stdev	868	**1 value excluded (9300)**	
mean	152	**Excluded. Next highest value in dataset is 1000. Also, there was no remark code and resample concentration is 50 (9300 possibly a data entry error)**	
mean+3stdev	2755		

STATION	DATE	VALUE	REMARK
SXL115	5/26/1998	10	K
SXL115	6/1/1998	100	
SXL115	6/8/1998	20	
SXL115	6/15/1998	370	
SXL115	6/17/1998	70	RESAMPLE
SXL115	6/22/1998	10	K
SXL115	6/29/1998	10	K
SXL115	7/6/1998	40	
SXL115	7/13/1998	10	K
SXL115	7/20/1998	40	
SXL115	7/27/1998	310	
SXL115	7/29/1998	170	RESAMPLE
SXL115	8/3/1998	40	
SXL115	8/10/1998	10	K
SXL115	8/17/1998	560	
SXL115	8/19/1998	120	RESAMPLE
SXL115	8/24/1998	20	
SXL115	8/31/1998	100	
Fox Hollow	5/24/1999	10	
SXL115	6/1/1999	10	K
SXL115	6/7/1999	10	K
SXL115	6/14/1999	40	
SXL115	6/21/1999	150	
SXL115	6/28/1999	10	
SXL115	7/6/1999	30	

SXL115	7/12/1999	10	K
SXL115	7/19/1999	20	
SXL115	7/26/1999	**310**	
SXL115	7/28/1999	**260**	Resample
SXL115	8/2/1999	**630**	
SXL115	8/4/1999	170	Resample
SXL115	8/9/1999	40	
SXL115	8/16/1999	30	
SXL115	8/23/1999	10	K
SXL115	8/30/1999	50	
Fox Hollow Lake	5/22/2000	70	
SXL115	5/30/2000	10	
SXL115	6/5/2000	10	K
SXL115	6/12/2000	170	
SXL115	6/19/2000	60	
SXL115	6/26/2000	30	
SXL115	7/5/2000	70	
SXL115	7/10/2000	10	K
SXL115	7/17/2000	20	
SXL115	7/24/2000	10	K
SXL115	7/31/2000	170	
SXL115	8/7/2000	**9300**	
SXL115	8/9/2000	50	Resample
SXL115	8/16/2000	20	
SXL115	8/21/2000	10	
SXL115	8/28/2000	70	
Fox Hollow Lake			
	5/23/2001	170	
	6/4/2001	8	
	6/11/2001	330	
	6/14/2001	112	
	6/18/2001	2	K
	6/25/2001	4	
	7/2/2001	96	
	7/9/2001	28	
	7/16/2001	18	
	7/23/2001	30	
	7/30/2001	40	
	8/6/2001	114	
	8/13/2001	4	
	8/20/2001	30	
	8/27/2001	18	

	5/20/2002	20	
	5/29/2002	20	
	6/3/2002	10	K
	6/10/2002	1000	
	6/14/2002	50	Resample
	6/17/2002	30	
	6/24/2002	360	
	6/26/2002	10	K
	7/1/2002	20	
	7/8/2002	50	
	7/15/2002	10	
	7/22/2002	10	
	7/29/2002	10	K
	8/5/2002	50	
	8/12/2002	10	
	8/19/2002	80	
	8/26/2002	40	
FOX HOLLOW LAKE	5/21/2003	10	
	5/28/2003	40	
	6/2/2003	10	
	6/9/2003	30	
	6/16/2003	**260**	
	6/18/2003	40	Resample
	6/23/2003	20	
	6/30/2003	140	
	7/7/2003	10	
	7/14/2003	10	K
	7/21/2003	10	
	7/28/2003	10	
	8/4/2003	30	
	8/11/2003	10	
	8/18/2003	10	K
	8/25/2003	10	K
FOX HOLLOW LAKE	5/24/2004	10	K
	6/2/2004	10	K
	6/7/2004	10	K
	6/14/2004	90	
	6/17/2004	10	K
	6/18/2004	20	
	6/21/2004	10	K
	6/28/2004	10	
	7/7/2004	10	

	7/12/2004	50	
	7/21/2004	10	
	7/26/2004	10	K
	8/2/2004	10	K
	8/9/2004	10	
	8/16/2004	10	
	8/23/2004	50	
	8/30/2004	10	

Furnace Lake			
count	122	mean+3stdev	589
median	30	%reduction	76%
max	840		
stdev	162	**no data excluded**	
mean	103		
mean+3stdev	589		

STATION	DATE	VALUE	REMARKS
WC3	5/5/1998	160	
WC3	5/26/1998	90	
WC3	6/2/1998	1	
WC3	6/9/1998	10	
WC3	6/16/1998	140	
WC3	6/23/1998	40	
WC3	6/30/1998	260	
WC3	7/7/1998	40	
WC3	7/14/1998	1	
WC3	7/21/1998	1	
WC3	7/28/1998	1	
WC3	8/4/1998	10	
WC3	8/11/1998	50	
WC3	8/18/1998	30	
WC3	8/25/1998	1	
WC3	9/1/1998	10	
WC3	5/11/1999	10	
WC3	5/18/1999	10	
WC3	5/25/1999	30	
WC3	6/1/1999	10	
WC3	6/8/1999	20	
WC3	6/15/1999	90	
WC3	6/22/1999	100	
WC3	6/29/1999	380	
WC3	7/2/1999	10	
WC3	7/6/1999	30	

WC3	7/13/1999	50	
WC3	7/20/1999	190	
WC3	7/27/1999	400	
WC3	7/29/1999	10	
WC3	8/3/1999	10	
WC3	8/10/1999	50	
WC3	8/17/1999	120	
WC3	8/24/1999	20	
WC3	8/31/1999	10	
Furnace Lake Beach	5/16/2000	180	
Furnace Lake Beach	5/23/2000	60	
Furnace Lake Beach	5/30/2000	80	
Furnace Lake Beach	6/5/2000	10	
Furnace Lake Beach	6/12/2000	420	
Furnace Lake Beach	6/14/2000	180	
Furnace Lake Beach	6/19/2000	50	
Furnace Lake Beach	6/27/2000	10	
Furnace Lake Beach	7/3/2000	70	
Furnace Lake Beach	7/10/2000	40	
Furnace Lake Beach	7/20/2000	550	
Furnace Lake Beach	7/24/2000	10	
Furnace Lake Beach	7/27/2000	180	
Furnace Lake Beach	7/31/2000	580	
Furnace Lake Beach	8/3/2000	10	
Furnace Lake Beach	8/7/2000	710	
Furnace Lake Beach	8/9/2000	10	
Furnace Lake Beach	8/15/2000	20	
Furnace Lake Beach	8/21/2000	170	
Furnace Lake Beach	8/28/2000	30	67.45346506

	5/17/2001	10	
	5/24/2001	90	
	5/31/2001	10	
	6/4/2001	10	
	6/11/2001	10	
	6/18/2001	20	
	6/25/2001	10	
	7/2/2001	10	
	7/9/2001	40	
	7/16/2001	10	
	7/23/2001	100	
	7/30/2001	30	
	8/6/2001	840	
	8/8/2001	410	
	8/9/2001	470	
	8/13/2001	10	
	8/13/2001	20	
	8/20/2001	20	
	8/20/2001	130	
	8/27/2001	20	33.73
FURNACE LAKE BEACH	6/24/2002	10	
	7/1/2002	10	
	7/8/2002	10	
	7/15/2002	10	
	7/22/2002	10	
	7/29/2002	10	
	8/5/2002	30	
	7/12/2002	180	
	8/19/2002	10	
	8/26/2002	10	**14.90**
Furnace Lake Beach	5/12/2003	40	
	5/20/2003	490	
	5/22/2003	10	
	5/27/2003	10	
	6/2/2003	80	
	6/9/2003	120	
	6/16/2003	40	
	6/23/2003	180	
	6/30/2003	30	
	7/7/2003	10	
	7/14/2003	30	
	7/21/2003	30	

	7/28/2003	60	
	8/4/2003	180	
	8/11/2003	100	
	8/18/2003	70	
	8/25/2003	40	**51.10**
FURNACE LAKE BEACH	05/24/04	40	
	06/01/04	10	
	06/07/04	600	
	06/10/04	10	
	06/16/04	20	
	06/23/04	30	
	06/29/04	10	
	07/06/04	10	
	07/13/04	110	
	07/19/04	120	
	07/29/04	190	
	08/02/04	600	
	0/03/2004	120	
	08/09/04	20	
	08/17/04	20	
	08/23/04	10	
	08/30/04	230	
	08/31/04	270	
	09/01/04	210	
	09/02/04	60	55.66

Green Valley Beach CG			
count	55	mean+3stdev	1855
median	50	% Reduction	91%
max	2000		
stdev	535	**no data excluded**	
mean	249		
mean+3stdev	1855		

STATION	DATE	VALUE	REMARK
	5/20/2003	10	
	6/26/2003	60	
	8/4/2003	160	
	5/7/2002	4	
	5/21/2002	30	
	5/28/2002	40	

	6/5/2002	10	
	6/11/2002	240	
	6/18/2002	120	RESAMPLE
	6/18/2002	120	
	6/26/2002	150	
	7/3/2002	60	
	7/8/2002	30	
	7/16/2002	30	
	7/23/2002	90	
	7/30/2002	130	
	8/6/2002	50	
	8/13/2002	10	K
	8/20/2002	10	K
	8/27/2002	10	K
	5/22/2001	2000	L not being used
	7/31/2001	10	
	8/7/2001	20	
	8/21/2001	420	lake not being used
SXL190801	5/24/2000	250	
SXL190801	5/26/2000	10	K
SXL190801	6/1/2000	80	
SXL190801	6/7/2000	180	
SXL190801	6/13/2000	3	
SXL190801	6/21/2000	2000	L
SXL190801	6/26/2000	2000	L, beach closed
SXL190801	6/27/2000	1330	
SXL190801	6/29/2000	1	K, resample beach reopened
SXL190801	7/5/2000	140	
SXL190801	7/11/2000	230	
SXL190801	7/18/2000	130	
SXL190801	7/25/2000	120	
SXL190801	8/1/2000	190	
SXL190801	8/7/2000	10	K
SXL190801	8/8/2000	90	
SXL190801	8/15/2000	10	K
SXL190801	8/22/2000	10	K
SXL190801	12/13/4611	700	
SXL190801	3/3/4612	40	RESAMPLE
SXL190801	3/10/4612	140	
SXL190801	3/17/4612	20	
SXL190801	3/24/4612	NEG	
SXL190801	3/31/4612	2000	L
SXL190801	6/15/4612	10	
SXL190801	6/23/4612	NEG	
SXL190801	6/30/4612	NEG	
SXL190801	7/7/4612	NEG	
SXL190801	9/21/4612	N20	
SXL190801	10/5/4612	10	
SXL190801	10/12/4612	70	
SXL190801	10/19/4612	50	
SXL190801	7/2/1998	40	
SXL190801	8/6/1998	2	K
SXL190801	8/27/1998	20	
SXL190801	9/3/1998	10	

Lake Lackawanna			
count	91	mean+3stdev	1051
median	60	%reduction	93%
max	2700		
stdev	306	**no data excluded**	
mean	134		
mean+3stdev	1051		

STATION	**DATE**	**VALUE**	**REMARK**
SXL190408	5/30/1998	730	
SXL190408	6/4/1998	90	RESAMPLE
SXL190408	6/5/1998	40	RESAMPLE
SXL190408	6/17/1998	510	
SXL190408	6/23/1998	30	RESAMPLE
SXL190408	6/25/1998	2	K
SXL190408	6/29/1998	90	
SXL190408	7/6/1998	290	
SXL190408	7/8/1998	60	RESAMPLE
SXL190408	7/13/1998	150	
SXL190408	7/20/1998	50	
SXL190408	7/27/1998	50	
SXL190408	8/3/1998	40	
SXL190408	8/10/1998	70	
SXL190408	8/18/1998	130	
SXL190408	8/31/1998	70	
SXL190408	9/1/1998	60	
LAKE LACKAWANNA: SPEERS BEACH	6/9/1999	30	
SXL190408	6/18/1999	20	
SXL190408	6/26/1999	20	
SXL190408	7/7/1999	120	
SXL190408	7/16/1999	10	K
SXL190408	7/22/1999	30	
SXL190408	7/29/1999	60	
SXL190408	8/6/1999	10	K
SXL190408	8/12/1999	60	
SXL190408	8/23/1999	30	
SXL190408	6/7/2000	430	
SXL190408	6/9/2000	10	K
SXL190408	6/22/2000	200	
SXL190408	6/27/2000	770	
SXL190408	7/2/2000	70	
SXL190408	7/14/2000	80	
SXL190408	7/21/2000	50	
SXL190408	8/3/2000	170	
SXL190408	8/8/2000	120	
SXL190408	8/16/2000	20	
SXL190408	8/22/2000	10	K
SXL190408	8/22/2000	10	K
Speers Beach	5/24/2001	2700	not presently in use
Speers Beach	5/30/2001	40	
Speers Beach	6/7/2001	130	
Speers Beach	6/9/2001	50	
Speers Beach	6/12/2001	30	
Speers Beach	6/19/2001	200	
Speers Beach	6/22/2001	40	
Speers Beach	6/29/2001	40	
Speers Beach	7/5/2001	100	
Speers Beach	7/12/2001	220	
Speers Beach	7/16/2001	70	
Speers Beach	7/24/2001	10	
Speers Beach	7/30/2001	10	
Speers Beach	8/7/2001	260	
Speers Beach	8/16/2001	100	
Speers Beach	8/23/2001	50	
Speers Beach	8/23/2001	50	
SPEERS BEACH	5/14/2002	130	
SPEERS BEACH	6/17/2002	170	
SPEERS BEACH	6/25/2002	210	
SPEERS BEACH	7/11/2002	30	
SPEERS BEACH	7/15/2002	30	
SPEERS BEACH	7/26/2002	20	

SPEERS BEACH	7/31/2002	80	
SPEERS BEACH	8/8/2002	30	
SPEERS BEACH	8/20/2002	30	
SPEERS BEACH	8/26/2002	200	
Lake Lackawanna:Speers Beach	5/27/2003	60	
	5/29/2003	200	
	6/17/2003	80	
	6/27/2003	20	
	6/30/2003	360	
	7/2/2003	70	
	7/7/2003	210	
	7/24/2003	80	
	7/28/2003	40	
	8/5/2003	70	
	8/11/2003	30	
Lake Lackawanna: Spears Beach	5/13/2004	90	
	6/9/2004	40	
	6/16/2004	20	
	6/23/2004	480	
	6/29/2004	50	
	7/6/2004	160	
	7/15/2004	70	
	7/20/2004	10	
	7/26/2004	10	
	8/3/2004	20	
	8/3/2004	20	
	8/10/2004	20	
	8/18/2004	40	
	8/25/2004	140	

Lake Hopatcong			
Stats with state Park			
count	825	mean+3stdev	1170
Median	20	%reduction	97%
max	6000		
stdev	357	**no data excluded**	
mean	98		
mean+3stdev	1170		

STATION	**DATE**	**VALUE**	**REMARK**
SXL191201	06/03/98	2	
SXL191201	06/17/98	5	

SXL191201	07/01/98	12	
SXL191201	07/15/98	1	
SXL191201	07/29/98	3	
SXL191201	08/05/98	1	K
SXL191201	08/19/98	1	
SXL191202	07/01/98	106	
SXL191202	07/15/98	22	
SXL191202	07/29/98	2	
SXL191202	08/12/98	18	
SXL191202	08/26/98	64	
SXL191202	09/09/98	41	
SXL191203	07/08/98	4	
SXL191203	07/22/98	29	
SXL191203	08/05/98	90	
SXL191203	08/19/98	28	
SXL191204	06/03/98	1	
SXL191204	06/17/98	15	
SXL191204	07/01/98	3	
SXL191204	07/15/98	1	K
SXL191204	07/29/98	2	
SXL191204	08/12/98	8	
SXL191204	08/26/98	3	
SXL191205	06/24/98	15	
SXL191205	07/08/98	4	
SXL191205	07/22/98	14	
SXL191205	08/05/98	26	
SXL191207	06/09/98	40	
SXL191207	07/02/98	10	K
SXL191207	07/06/98	30	
SXL191207	07/23/98	100	
SXL191207	08/20/98	10	K
SXL191208	06/09/98	50	
SXL191208	06/25/98	30	
SXL191208	07/02/98	200	
SXL191208	07/06/98	10	K
SXL191208	07/23/98	10	K
SXL191208	08/20/98	10	K
SXL191209	06/09/98	50	
SXL191209	07/02/98	9	
SXL191209	07/06/98	10	K
SXL191209	07/23/98	50	
SXL191209	08/20/98	10	K
SXL191210	07/03/98	20	
SXL191211	07/08/98	500	
SXL191211	07/10/98	168	RESAMPLE

SXL191211	07/22/98	179	
SXL191211	08/26/98	550	
SXL191211	08/28/98	65	RESAMPLE
SXL191212	07/08/98	16	
SXL191212	07/22/98	50	
SXL191212	08/05/98	22	
SXL191212	08/19/98	27	
SXL191213	07/08/98	6	
SXL191213	07/22/98	18	
SXL191213	08/05/98	15	
SXL191213	08/19/98	15	
SXL191213	09/02/98	12	
SXL191214	07/21/98	20	
SXL191214	08/21/98	20	
SXL191215	06/17/98	750	
SXL191215	06/19/98	7	RESAMPLE
SXL191215	07/01/98	875	
SXL191215	07/06/98	122	RESAMPLE
SXL191215	07/15/98	7	
SXL191215	07/22/98	106	
SXL191215	08/05/98	111	
SXL191216	06/24/98	99	
SXL191216	07/08/98	2	K
SXL191216	07/22/98	75	
SXL191216	08/05/98	13	
SXL191216	08/19/98	14	
SXL191217	06/24/98	1900	
SXL191217	06/26/98	2500	RESAMPLE
SPERRY SPRINGS	05/26/99	7	
SXL191201	06/09/99	16	
SXL191201	06/23/99	2	
SXL191201	07/07/99	2	
SXL191201	08/18/99	4	
SHADY LAWN BEACH CLUB	06/09/99	331	
SXL191202	06/10/99	2	RESAMPLE
SXL191202	06/23/99	100	
SXL191202	07/07/99	146	
SXL191202	07/21/99	248	
SXL191202	07/22/99	50	RESAMPLE
SXL191202	08/18/99	98	
SXL191202	09/01/99	44	
BECK LANE PROPERTIES	05/26/99	9	
SXL191204	06/09/99	5	

SXL191204	06/23/99	1	
SXL191204	07/07/99	1	K
SXL191204	08/18/99	2	
SXL191204	09/01/99	18	
ELBA POINT HOMEOWNERS	06/23/99	1	K
SXL191205	07/07/99	10	
SXL191205	08/04/99	17	
WILDWOOD SHORES POA	06/28/99	50	
SXL191207	07/13/99	20	
SXL191207	08/11/99	10	K
SXL191207	08/26/99	220	
WILDWOOD SHORES POA	06/28/99	80	
SXL191208	07/13/99	10	K
SXL191208	08/11/99	10	
SXL191208	08/26/99	340	
WILDWOOD SHORES POA	06/28/99	30	
SXL191209	07/13/99	10	K
SXL191209	08/11/99	10	K
SXL191209	08/26/99	350	
HOPATCONG GARDENS COMM. CLUB	07/01/99	10	
SXL191210	07/09/99	30	
SXL191210	07/18/99	10	
SXL191210	07/24/99	10	K
SXL191210	07/30/99	1800	
SXL191210	08/12/99	10	
SXL191210	08/29/99	30	
CRESCENT COVE	06/24/99	76	
SXL191211	07/07/99	212	
SXL191211	07/09/99	1	RESAMPLE K
SXL191211	07/22/99	1	K
SXL191211	08/04/99	1	K
SXL191211	08/18/99	102	
RANDAL BEACH CLUB	07/07/99	18	
SXL191213	07/21/99	18	
SXL191213	08/04/99	5	
SXL191213	08/18/99	1	K
SXL191213	09/01/99	54	
DOX INC	07/01/99	10	
SXL191214	08/19/99	120	
INGRAM COVE	06/09/99	130	

COMMUNITY			
SXL191215	06/16/99	1	K
SXL191215	06/30/99	394	
SXL191215	07/14/99	36	RESAMPLE
SXL191215	07/28/99	68	
HOMESTEAD BEACH	06/23/99	21	
SXL191216	07/07/99	12	
SXL191216	07/22/99	18	
SXL191216	08/04/99	36	
SXL191216	08/18/99	114	
SHAWNEE DOCK ASSOCIATION	08/12/99	10	K
SXL191218	08/19/99	10	
SXL191218	08/29/99	50	
BYRAM BAY COMMUNITY CLUB	06/10/99	64	
SXL191219	07/08/99	200	L
SXL191219	07/12/99	28	RESAMPLE
SXL191219	07/29/99	20	
COLONY CLUB	06/30/99	24	
SXL191220	07/14/99	1	K
SXL191220	07/28/99	1	K
SXL191220	08/11/99	1	K
SXL191220	08/25/99	6	
SXL191220	09/08/99	6	
SPERRY SPRINGS	05/24/00	10	K
SXL191201	06/07/00	60	
SXL191201	06/21/00	70	
SXL191201	07/05/00	10	K
SXL191201	07/19/00	10	
SXL191201	08/02/00	120	
SXL191201	08/16/00	90	
SHADY LAWN BEACH CLUB	06/05/00	30	
SXL191202	06/19/00	10	K
SXL191202	07/05/00	20	
SXL191202	07/17/00	520	
SXL191202	08/07/00	40	
SXL191202	08/21/00	30	
SXL191202	08/28/00	1600	TNTC
SXL191202	08/30/00	10	K
BECK LANE PROPERTIES	05/24/00	20	
SXL191204	06/07/00	20	
SXL191204	06/21/00	20	
SXL191204	07/05/00	10	K

SXL191204	07/19/00	10	K
SXL191204	08/02/00	1200	
SXL191204	08/07/00	370	
SXL191204	08/16/00	450	
SXL191204	08/28/00	10	K
ELBA POINT HOMEOWNERS	06/05/00	2	
SXL191205	06/20/00	8	
SXL191205	07/03/00	16	
SXL191205	07/19/00	2	K
SXL191205	08/01/00	48	
SXL191205	08/15/00	152	
SXL191205	08/29/00	12	
WILDWOOD SHORES POA Pebble	07/14/00	10	
SXL191207	07/30/00	40	
SXL191207	08/01/00	10	K
SXL191207	08/09/00	20	
SXL191207	08/17/00	10	
SXL191207	08/25/00	10	K
SXL191207	08/30/00	10	K
WILDWOOD SHORES POA lines	07/14/00	10	K
SXL191208	08/09/00	50	
SXL191208	08/17/00	20	
SXL191208	08/25/00	10	
SXL191208	08/30/00	10	
WILDWOOD SHORES POA Bass Rock	07/14/00	10	K
SXL191209	08/09/00	10	K
SXL191209	08/17/00	10	K
SXL191209	08/25/00	10	
SXL191209	08/30/00	10	K
HOPATCONG GARDENS COMM. CLUB	06/04/00	30	
SXL191210	06/21/00	20	
SXL191210	07/01/00	20	
SXL191210	07/21/00	70	
SXL191210	08/17/00	60	
CRESCENT COVE	06/29/00	288	
SXL191211	07/05/00	28	
SXL191211	07/19/00	24	
SXL191211	08/03/00	164	
SXL191211	08/21/00	44	
RANDAL BEACH CLUB	06/28/00	10	

SXL191213	07/12/00	20	
SXL191213	07/26/00	10	K
SXL191213	08/09/00	10	K
SXL191213	08/21/00	40	
DOX INC	07/02/00	150	
SXL191214	07/21/00	10	K
SXL191214	08/17/00	10	
SXL191214	08/22/00	10	K
INGRAM COVE COMMUNITY	05/25/00	144	
SXL191215	06/05/00	114	
SXL191215	06/20/00	20	
SXL191215	07/03/00	14	
SXL191215	07/19/00	28	
SXL191215	08/01/00	364	
SXL191215	08/03/00	280	
SXL191215	08/08/00	44	
SXL191215	08/15/00	184	
SXL191215	08/29/00	192	
HOMESTEAD BEACH	06/09/00	32	
SXL191216	06/21/00	20	
SXL191216	07/05/00	88	
SXL191216	07/19/00	64	
SXL191216	08/02/00	40	
SXL191216	08/21/00	112	
SHAWNEE DOCK ASSOCIATION	07/02/00	10	K
SXL191218	07/08/00	20	
SXL191218	07/21/00	50	
SXL191218	07/30/00	10	K
SXL191218	08/17/00	20	
SXL191218	08/22/00	100	
BYRAM BAY COMMUNITY CLUB	05/24/00	22	
SXL191219	06/22/00	76	
SXL191219	08/03/00	20	
SXL191219	08/17/00	40	
COLONY CLUB	07/19/00	10	
SXL191220	08/02/00	70	
SXL191220	08/16/00	500	followed flood conditions
SXL191220	08/28/00	160	
	06/05/01	10	K
	06/09/01	10	K

	06/19/01	70	
	06/25/01	80	
	07/12/01	50	
	07/16/01	20	
	07/30/01	20	
	08/06/01	10	K
	06/11/01	10	
	06/25/01	120	
	07/09/01	50	
	07/23/01	40	
	08/06/01	50	
	08/20/01	110	
	05/30/01	30	
	06/13/01	10	K
	06/27/01	20	
	07/10/01	200	
	07/25/01	10	K
	08/08/01	200	
	08/22/01	10	
	06/15/01	148	
	06/21/01	2	
	07/03/01	92	
	07/19/01	22	
	08/02/01	4	
	08/13/01	68	
Pebble Beach Ave	05/29/01	40	
Pebble Beach Ave	06/10/01	10	
Pebble Beach Ave	06/27/01	10	
Pebble Beach Ave	07/12/01	10	
Pebble Beach Ave	07/17/01	30	
Pebble Beach Ave	07/25/01	10	K
Pebble Beach Ave	08/03/01	10	K
Lines Ave	05/29/01	10	K
Lines Ave	06/10/01	210	
Lines Ave	07/12/01	20	
Lines Ave	07/17/01	10	K
Lines Ave	07/25/01	20	
Lines Ave	08/03/01	10	K
Lines Ave	08/16/01	40	

Bass Rock Road	05/29/01	30	
Bass Rock Road	06/10/01	20	
Bass Rock Road	06/27/01	10	K
Bass Rock Road	07/12/01	10	K
Bass Rock Road	07/17/01	10	
Bass Rock Road	07/25/01	10	
Bass Rock Road	08/03/01	10	K
Bass Rock Road	08/16/01	40	
	05/29/01	20	
	05/24/01	3	
	07/02/01	30	
	07/18/01	10	
	08/01/01	10	
	08/15/01	210	
	08/29/01	50	
	05/29/01	70	
	06/05/01	80	
	06/09/01	30	
	06/19/01	10	
	07/05/01	10	K
	07/30/01	10	K
	08/23/01	10	
	06/05/01	20	
	06/09/01	10	K
	06/19/01	110	
	06/25/01	150	
	07/05/01	70	
	07/12/01	40	
	07/16/01	10	K
	07/30/01	60	
	08/06/01	420	
	08/23/01	250	
	06/26/01	28	
	07/12/01	72	
	07/24/01	12	
	08/08/01	54	
	08/22/01	40	
	05/29/01	40	
	06/05/01	10	
	06/09/01	10	K
	06/19/01	40	
	06/25/01	60	
	07/05/01	20	
	07/12/01	20	
	07/16/01	10	K

	08/07/01	10	K
	08/23/01	10	K
	06/21/01	2	
	07/10/01	7	
	07/31/01	13	
	08/21/01	6	
	06/20/01	10	
	07/02/01	600	
	07/09/01	30	
	07/18/01	10	K
	08/01/01	20	
	08/15/01	530	
	08/29/01	810	
MAXIM DRIVE	05/28/02	10	K
MAXIM DRIVE	05/31/02	60	
MAXIM DRIVE	06/06/02	930	
MAXIM DRIVE	06/09/02	10	
MAXIM DRIVE	06/17/02	40	
MAXIM DRIVE	06/25/02	60	
MAXIM DRIVE	07/05/02	50	
MAXIM DRIVE	07/08/02	40	
MAXIM DRIVE	07/15/02	10	K
MAXIM DRIVE	08/12/02	10	K
MAXIM DRIVE	08/20/02	20	
W. SHORE DRIVE	06/26/02	50	
W. SHORE DRIVE	07/01/02	10	K
W. SHORE DRIVE	07/10/02	TNTC	
W. SHORE DRIVE	07/12/02	50	
W. SHORE DRIVE	07/24/02	70	
W. SHORE DRIVE	08/07/02	60	
W. SHORE DRIVE	08/21/02	17	
108 MAXIM DRIVE	06/03/02	20	
108 MAXIM DRIVE	06/17/02	70	
108 MAXIM DRIVE	07/01/02	10	K
108 MAXIM DRIVE	07/15/02	10	K
108 MAXIM DRIVE	07/29/02	4	

108 MAXIM DRIVE	08/12/02	10	K
ITHANELL ROAD	05/31/02	150	
ITHANELL ROAD	06/09/02	20	
ITHANELL ROAD	06/17/02	10	K
ITHANELL ROAD	06/25/02	20	
ITHANELL ROAD	07/05/02	5600	
ITHANELL ROAD	07/08/02	100	
ITHANELL ROAD	07/15/02	10	
ITHANELL ROAD	08/26/02	140	
19 PEBBLE BCH RD	06/08/02	30	
19 PEBBLE BCH RD	06/17/02	10	
19 PEBBLE BCH RD	07/05/02	40	
19 PEBBLE BCH RD	07/09/02	30	
19 PEBBLE BCH RD	07/16/02	10	
19 PEBBLE BCH RD	07/24/02	10	K
19 PEBBLE BCH RD	07/31/02	10	
19 PEBBLE BCH RD	08/07/02	10	K
19 PEBBLE BCH RD	08/15/02	60	
19 PEBBLE BCH RD	08/20/02	240	
19 PEBBLE BCH RD	08/27/02	10	K
31 LINES AVENUE	06/08/02	10	K
31 LINES AVENUE	06/17/02	30	
31 LINES AVENUE	07/05/02	70	
31 LINES AVENUE	07/09/02	310	
31 LINES AVENUE	07/12/02	50	
31 LINES	07/24/02	10	K

AVENUE			
31 LINES AVENUE	07/31/02	10	
31 LINES AVENUE	08/15/02	30	
31 LINES AVENUE	08/20/02	180	
31 LINES AVENUE	08/27/02	20	
3 BASS LAKE ROAD	06/08/02	80	
3 BASS LAKE ROAD	06/17/02	20	
3 BASS LAKE ROAD	06/26/02	60	
3 BASS LAKE ROAD	07/05/02	10	K
3 BASS LAKE ROAD	07/09/02	20	
3 BASS LAKE ROAD	07/16/02	10	K
3 BASS LAKE ROAD	07/24/02	10	K
3 BASS LAKE ROAD	07/31/02	80	
3 BASS LAKE ROAD	08/15/02	20	
3 BASS LAKE ROAD	08/20/02	100	
3 BASS LAKE ROAD	08/27/02	10	K
	06/14/02	240	
	06/18/02	122	
	06/24/02	139	
	07/01/02	330	
	07/03/02	460	
	07/08/02	105	
	07/15/02	91	
	07/24/02	200	
	07/29/02	100	
	08/01/02	34	
	08/01/02	1	K
	08/12/02	210	
	08/19/02	60	
	08/26/02	200	
	08/29/02	600	L
	07/05/02	20	
	07/08/02	10	K
	07/26/02	10	K

	07/31/02	40	
	08/12/02	10	K
	08/26/02	50	
COVE ROAD	05/31/02	10	
COVE ROAD	06/06/02	980	
COVE ROAD	06/09/02	10	
COVE ROAD	06/25/02	40	
COVE ROAD	07/05/02	160	
COVE ROAD	07/08/02	160	
COVE ROAD	07/31/02	40	
COVE ROAD	08/12/02	10	
COVE ROAD	08/20/02	240	
COVE ROAD	08/26/02	140	
MARINERS ROAD	06/11/02	18	
MARINERS ROAD	06/21/02	86	
MARINERS ROAD	07/10/02	150	
MARINERS ROAD	07/23/02	62	
MARINERS ROAD	08/08/02	24	
MARINERS ROAD	08/21/02	68	
18 CHINCOPEE AVE	06/04/02	10	
18 CHINCOPEE AVE	06/17/02	10	K
18 CHINCOPEE AVE			INACTIVE
	05/22/02	4	
	06/07/02	122	
	06/27/02	12	
	07/12/02	22	
	07/30/02	5	
	08/09/02	17	
	08/28/02	18	
Sperry Springs-Maxim Drive	05/29/03	10	K
	06/03/03	10	
	06/09/03	30	
	06/24/03	40	
	06/30/03	40	
	07/07/03	10	K
	07/14/03	40	
	07/21/03	30	
	07/28/03	10	K

	08/05/03	10	K
	08/11/03	10	K
	08/18/03	10	K
	08/25/03	10	
Shady Lawn Beach Club	07/02/03	10	K
	07/16/03	70	
	07/30/03	20	
	08/13/03	380	
	08/18/03	160	
	08/27/03	20	
Beck Lane Properties	05/28/03	10	
	06/11/03	110	
	06/25/03	10	
	07/08/03	10	K
	07/23/03	70	K
	08/06/03	30	
	08/20/03	12	
Elba Point Homeowners	05/14/03	10	
	05/30/03	10	K
	06/03/03	10	
	06/09/03	10	K
	06/24/03	20	
	06/30/03	10	K
	07/07/03	6000	L
	07/09/03	10	K
	07/14/03	20	
	07/21/03	20	
	07/28/03	10	
	08/05/03	310	
	08/08/03	110	
	08/11/03	130	
	08/18/03	20	
	08/25/03	10	K
Wildwood Shores POA Pebble Beach Rd	05/30/03	10	K
	06/03/03	70	
	06/09/03	10	
	06/27/03	10	K
	07/21/03	150	
	08/13/03	10	K
Wildwood	05/30/03	10	

Shores POA Lines Ave			
	06/03/03	50	
	09/06/03	10	K
	06/27/03	10	
	07/21/03	50	
	08/13/03	10	K
Wildwood Shores POA Bass Lake Rd	05/30/03	20	
	06/03/03	40	
	06/09/03	10	
	06/27/03	10	K
	07/21/03	40	
	08/13/03	30	
Crescent Cove	06/03/03	180	
	06/27/03	190	
	07/01/03	260	
	07/03/03	600	K
	07/07/03	10	L
	07/15/03	500	
	07/17/03	20	
	07/22/03	10	
	07/28/03	70	
	08/04/03	110	
	08/12/03	60	K
	08/18/03	20	
	08/25/03	20	
DOX Inc.	07/07/03	10	K
	07/14/03	20	
	07/21/03	10	K
	07/28/03	10	
	08/05/03	10	
	08/11/03	10	K
	08/18/03	20	
	08/25/03	20	
Ingram Cove Community	05/29/03	210	
	06/03/03	10	K
	06/09/03	20	
	06/24/03	10	K
	06/30/03	40	
	07/07/03	30	
	07/14/03	100	
	07/21/03	70	
	07/28/03	90	

	08/05/03	450	
	08/11/03	300	
	08/18/03	20	
	08/25/03	140	
Homestead Beach	06/23/03	20	
	07/08/03	82	
	07/25/03	144	
	08/13/03	94	
	08/25/03	20	
Byram Bay Community	06/06/03	34	
	07/03/03	36	
	07/18/03	32	
	08/06/03	52	
	08/20/03	53	
	08/29/03	13	
Sperry Springs	06/16/04	2100	
	06/18/04	10	
	06/23/04	10	
	06/29/04	280	
	07/01/04	10	K
	07/06/04	10	K
	07/15/04	90	
	07/20/04	30	
	07/26/04	50	
	08/03/04	10	K
	08/10/04	40	
	08/18/04	10	
	08/25/04	40	
Shady Lawn	06/02/04	20	
	06/16/04	10	K
	06/30/04	20	
	07/14/04	100	K
	07/28/04	20	
	08/11/04	20	
	08/25/04	40	
Beck Lane	05/17/04	10	
	06/02/04	20	
	06/16/04	10	K
	06/30/04	10	
	07/14/04	10	
	07/28/04	10	K
	08/11/04	10	K
	08/25/04	20	

Elba Point	05/17/04	10	
	06/02/04	20	
	06/22/04	20	
	06/30/04	20	
	07/14/04	10	K
	07/28/04	10	
	08/11/04	40	
	08/25/04	10	
Wildwood Shores Pebble Beach	06/01/04	10	
	06/10/04	10	K
	06/14/04	10	K
	06/22/04	10	
	07/07/04	10	K
	07/20/04	10	K
	08/02/04	10	K
	08/19/04	10	
	08/30/04	10	K
Wildwood Shores Lines Ave	06/01/04	10	K
	06/10/04	30	
	06/14/04	10	
	06/22/04	20	
	07/07/04	20	
	07/20/04	50	
	08/02/04	90	
	08/19/04	30	
	08/30/04	10	K
Wildwood Shores Bass Rock Lane	06/10/04	10	K
	06/14/04	10	
	06/22/04	10	
	07/07/04	10	K
	07/20/04	10	K
	08/02/04	10	K
	08/19/04	10	
	08/30/04	10	K
Crescent Cove	07/15/04	600	L
	07/07/04	70	
	07/15/04	600	L
	07/20/04	200	
	07/29/04	110	
	08/02/04	20	

	08/09/04	100	
	08/17/04	40	
	08/24/04	130	
Dox Inc.	07/06/04	10	K
	07/20/04	40	
	08/03/04	10	K
	08/18/04	10	
Ingram Cove Community	06/16/04	20	
	06/23/04	380	
	06/29/04	100	
	07/06/04	1	K
	07/15/04	40	
	07/20/04	130	
	07/23/04	130	
	07/26/04	430	
	08/10/04	40	
	08/25/04	120	
Homestead Beach	06/21/04	14	
	07/06/04	311	
	07/08/04	66	
	07/19/04	156	
	08/03/04	38	
	08/16/04	18	
Byram Beach Community Club	05/26/04	36	
	06/09/04	48	
	07/08/04	7	
	07/23/07	18	
	08/11/04	23	
	08/26/04	26	
Beach Center	05/18/98	16	
	05/26/98	10	
	06/01/98	60	
	06/08/98	6	
	06/15/98	2	
	06/22/98	1	
	06/29/98	12	
	07/06/98	1	K
	07/13/98	29	
	07/20/98	4	
	07/27/98	1	K
	08/03/98	46	
	08/10/98	24	

	08/17/98	6	
	08/24/98	4	
	08/31/98	23	
Beach Center	05/22/00	10	
Beach Center	05/30/00	1	
Beach Center	06/05/00	1	
Beach Center	06/12/00	110	
Beach Center	06/19/00	4	
Beach Center	06/26/00	52	
Beach Center	07/05/00	18	
Beach Center	07/10/00	52	
Beach Center	07/17/00	5	
Beach Center	07/24/00	110	
Beach Center	07/31/00	11	
Beach Center	08/07/00	1	
Beach Center	08/16/00	69	
Beach Center	08/21/00	1700	
Beach Center	08/23/00	52	
Beach Center	08/28/00	7	
	05/21/01	1	k
	05/29/01	6	
	06/04/01	3	
	06/11/01	7	
	06/18/01	5	
	06/25/01	2	
	07/02/01	22	
North	05/21/02	3	
North	05/31/02	9	
North	06/04/02	280	
North	06/06/02	1100	
North	06/07/02	390	
North	06/10/02	11	
North	06/18/02	14	
North	06/24/02	158	
North	07/02/02	100	
North	07/05/02	36	
North	07/08/02	101	
North	07/19/02	2380	
North	07/26/02	10	k
North	08/02/02	290	
North	08/05/02	10	
North	08/09/02	60	
North	08/16/02	80	
North	08/23/02	20	
North	08/30/02	110	

South	07/05/02	1	k
South	07/19/02	320	
South	07/26/02	10	k
South	08/02/02	360	
South	08/05/02	20	
South	08/09/02	40	
South	08/16/02	10	
South	08/23/02	70	
South	08/30/02	40	
North	05/23/03	10	
North	05/27/03	10	
North	06/02/03	10	
North	06/09/03	10	
North	06/16/03	10	
North	06/23/03	10	
North	07/01/03	70	
North	07/07/03	10	
North	07/15/03	20	
North	07/22/03	50	
North	07/28/03	20	
North	08/04/03	100	
North	08/18/03	20	
North	08/25/03	60	
South	05/23/03	10	
South	05/27/03	10	
South	06/02/03	10	
South	06/09/03	10	
South	06/16/03	10	
South	06/23/03	80	
South	07/01/03	200	
South	07/07/03	50	
South	07/15/03	10	
South	07/22/03	80	
South	07/28/03	10	
South	08/04/03	10	
South	08/18/03	10	
South	08/25/03	10	
North	05/18/04	10	
	05/24/04	20	
	06/03/04	10	k
	06/10/04	30	
	06/14/04	20	
	06/22/04	100	
	06/29/04	200	
	07/07/04	50	

	07/13/04	600	L
	07/14/04	50	
	07/20/04	180	
	07/26/04	10	k
	08/02/04	50	
	08/09/04	10	k
	08/17/04	20	
	08/23/04	30	
	08/30/04	10	
South	05/18/04	30	
	05/24/04	20	
	06/03/04	10	k
	06/10/04	10	
	06/14/04	30	
	06/22/04	30	
	06/29/04	150	
	07/07/04	90	
	07/13/04	70	
	07/20/04	330	
	07/23/04	30	
	07/26/04	10	k
	08/02/04	30	
	08/09/04	20	
	08/17/04	80	
	08/23/04	40	
	08/30/04	60	
North	08/29/05	70	
	08/22/05	10	k
	08/15/05	90	
	08/08/05	210	
	08/10/05	80	resample
	08/01/05	110	
	07/25/05	80	
	07/18/05	70	
	07/11/05	20	
	07/05/05	70	
	06/30/05	70	
	06/23/05	60	
	06/13/05	10	
	04/09/08	10	
	06/06/05	40	
	06/01/05	10	k
	05/26/05	10	k
	05/24/05	80	
	05/16/05	10	k

South	08/29/05	70	
	08/22/05	80	
	08/15/05	110	
	08/08/05	290	
	08/10/05	160	resample
	08/01/05	60	
	07/25/05	110	
	07/18/05	160	
	07/11/05	40	
	07/05/05	30	
	06/30/05	70	
	06/23/05	20	
	06/13/05	10	
	06/06/05	10	k
	06/01/05	10	k
	05/26/05	10	k
	05/24/05	530	
	05/16/05	10	

Lake Winona			
count	48	mean+3stdev	6920
median	75	% Reduction	98%
max	10000		
Stdev	2046	**no data excluded**	
mean	781		
mean+3stdev	6920		

Station	**Date**	**Value**	**Remarks**
Lake Winona Civic Association	06/22/99	10	
	06/29/99	14	
	07/08/99	3	
	07/15/99	44	
	07/19/99	4	
	07/26/99	26	
	08/04/99	1	
	08/09/99	1	K
	08/16/99	106	
	08/23/99	408	
	09/03/99	4	
	06/25/02	100	
	07/05/02	10	
	07/09/02	360	
	07/11/02	10	k
	07/15/02	90	
	07/26/02	20	
	07/31/02	130	
	08/13/02	10	k
	08/20/02	240	
	08/22/02	90	
	08/26/02	60	
Lake Winona Civic Association	05/30/03	550	
	06/03/03	100	
	06/09/03	90	
	06/15/03	90	
	06/24/03	40	
	06/30/03	10	k
	07/07/03	10	
	07/14/03	30	
	07/21/03	50	
	07/28/03	20	
	08/05/03	350	
	08/18/03	30	
	08/25/03	10	k
Lake Winona Civic Association	06/16/04	450	
	06/17/04	60	
	06/25/04	240	
	06/29/04	6700	
	07/01/04	10000	
	07/15/04	550	
	07/20/04	440	
	07/22/04	1100	
	07/26/04	50	
	08/03/04	6000	
	08/10/04	6000	
	08/18/04	300	
	08/25/04	2500	

WMA 02

Crystal Springs			
count	9	mean+3stdev	988
Median	250	%reduction	74%
Max	770		
stdev	254	**no data excluded**	
mean	227		
mean+3stdev	988		

STATION	**DATE**	**VALUE**	**REMARK**
SXHR136	07/27/00	**770**	
SXHR136	08/03/00	**360**	
SXHR136	08/14/00	**250**	
SXHR136	08/16/00	**300**	Resample
SXHR136	08/24/00	**320**	
SXHR136	08/29/00	10	
SXLHR136	06/08/99	10	K
SXLHR136	06/30/99	10	K
SXLHR136	08/04/99	10	K

Deer Trail Lake			
count	16	mean+3stdev	653
Median	7	%reduction	73%
Max	738		
stdev	190	**no data excluded**	
mean	84		
mean+3stdev	653		

STATION	**DATE**	**VALUE**	**REMARK**
SXL191112	07/07/98	1	
SXL191112	07/13/98	2	
SXL191112	07/28/98	5	
SXL191112	08/04/98	7	
SXL191112	08/11/98	9	
SXL191112	09/02/98	1	
	07/02/01	180	
	07/10/01	6	
	07/17/01	12	
	07/24/01	26	
	07/31/01	258	
	08/03/01	738	
	08/07/01	2	K
	08/15/01	82	
	08/22/01	2	K
	08/27/01	6	

Lake Mohawk			

count	1134	mean+3stdev	1516
median	20	% Reduction	98%
max	11000		
Stdev	476	**no data excluded**	
mean	89		
mean+3stdev	1516		

STATION	DATE	VALUE	REMARK
SXL102	05/18/98	10	K
SXL102	05/26/98	10	K
SXL102	06/01/98	210	
SXL102	06/03/98	10	K, RESAMPLE
SXL102	06/08/98	10	K
SXL102	06/15/98	50	
SXL102	06/22/98	10	K
SXL102	06/29/98	10	K
SXL102	07/06/98	10	K
SXL102	07/13/98	1200	
SXL102	07/16/98	30	RESAMPLE
SXL102	07/20/98	50	
SXL102	07/27/98	60	
SXL102	08/03/98	10	K
SXL102	08/10/98	280	
SXL102	08/12/98	90	RESAMPLE
SXL102	08/17/98	10	K
SXL102	08/24/98	100	
SXL102	08/31/98	220	
SXL102	09/02/98	60	
SXL103	05/18/98	30	
SXL103	05/26/98	10	K
SXL103	06/01/98	50	
SXL103	06/08/98	10	K
SXL103	06/15/98	10	K
SXL103	06/22/98	30	
SXL103	06/29/98	10	K
SXL103	07/06/98	10	K
SXL103	07/13/98	10	K
SXL103	07/20/98	10	K
SXL103	07/27/98	10	K
SXL103	08/03/98	10	K
SXL103	08/10/98	10	K
SXL103	08/17/98	10	K
SXL103	08/24/98	10	K
SXL103	08/31/98	10	K
SXL104	05/18/98	20	
SXL104	05/26/98	10	K
SXL104	06/01/98	100	
SXL104	06/08/98	10	K
SXL104	06/15/98	50	
SXL104	06/22/98	10	K
SXL104	06/29/98	10	K
SXL104	07/06/98	10	K
SXL104	07/13/98	30	
SXL104	07/20/98	40	
SXL104	07/27/98	20	
SXL104	08/03/98	10	K
SXL104	08/10/98	10	K
SXL104	08/17/98	10	K
SXL104	08/24/98	10	K
SXL104	08/31/98	10	K
SXL105	05/18/98	20	
SXL105	05/26/98	10	K
SXL105	06/01/98	650	
SXL105	06/03/98	40	RESAMPLE
SXL105	06/08/98	10	K
SXL105	06/15/98	20	
SXL105	06/22/98	20	
SXL105	06/29/98	10	K
SXL105	07/06/98	40	
SXL105	07/13/98	10	K
SXL105	07/20/98	10	K
SXL105	07/27/98	120	
SXL105	08/03/98	30	
SXL105	08/10/98	10	K
SXL105	08/17/98	10	K
SXL105	08/24/98	20	
SXL105	08/31/98	10	K
SXL106	05/18/98	360	
SXL106	05/20/98	40	RESAMPLE
SXL106	05/26/98	410	
SXL106	05/28/98	10	K
SXL106	06/01/98	290	
SXL106	06/03/98	50	RESAMPLE
SXL106	06/08/98	10	K
SXL106	06/15/98	50	
SXL106	06/22/98	10	K
SXL106	06/29/98	40	
SXL106	07/06/98	10	K
SXL106	07/13/98	10	K
SXL106	07/20/98	50	
SXL106	07/27/98	50	
SXL106	08/03/98	10	K
SXL106	08/10/98	20	
SXL106	08/17/98	30	
SXL106	08/24/98	70	
SXL106	08/31/98	60	
SXL108	05/18/98	130	
SXL108	05/26/98	130	
SXL108	06/01/98	90	
SXL108	06/03/98	70	
SXL108	06/08/98	210	
SXL108	06/15/98	20	RESAMPLE
SXL108	06/17/98	200	
SXL108	06/22/98	10	K
SXL108	06/29/98	10	K
SXL108	07/06/98	10	K
SXL108	07/13/98	30	
SXL108	07/20/98	10	K
SXL108	07/27/98	10	K
SXL108	08/03/98	10	K
SXL108	08/10/98	40	
SXL108	08/17/98	660	
SXL108	08/19/98	220	RESAMPLE
SXL108	08/24/98	70	
SXL108	08/31/98	10	K
SXL109	05/18/98	10	K
SXL109	05/26/98	10	K
SXL109	06/01/98	90	
SXL109	06/08/98	50	
SXL109	06/15/98	120	
SXL109	06/22/98	20	
SXL109	06/29/98	40	
SXL109	07/06/98	10	K
SXL109	07/13/98	10	K
SXL109	07/20/98	10	K
SXL109	07/27/98	20	
SXL109	08/03/98	10	K
SXL109	08/10/98	20	
SXL109	08/17/98	20	
SXL109	08/24/98	110	
SXL109	08/31/98	10	K
SXL111	05/18/98	20	
SXL111	05/26/98	10	K
SXL111	06/01/98	80	
SXL111	06/08/98	20	
SXL111	06/15/98	1200	
SXL111	06/17/98	120	RESAMPLE
SXL111	06/22/98	20	
SXL111	06/29/98	70	
SXL111	07/06/98	40	

SXL111	07/13/98	80	
SXL111	07/27/98	50	
SXL111	08/03/98	10	K
SXL111	08/10/98	10	K
SXL111	08/17/98	270	
SXL111	08/19/98	10	K, RESAMPLE
SXL111	08/24/98	160	
SXL111	08/31/98	60	
SXL112	05/18/98	10	K
SXL112	05/26/98	10	K
SXL112	06/01/98	160	
SXL112	06/08/98	10	K
SXL112	06/15/98	10	K
SXL112	06/22/98	10	K
SXL112	06/29/98	10	K
SXL112	07/06/98	30	
SXL112	07/13/98	60	
SXL112	07/20/98	20	
SXL112	07/27/98	10	K
SXL112	08/03/98	10	K
SXL112	08/10/98	10	K
SXL112	08/17/98	10	K
SXL112	08/24/98	10	K
SXL112	08/31/98	30	
SXL113	05/18/98	10	K
SXL113	05/26/98	10	K
SXL113	06/01/98	80	
SXL113	06/08/98	10	K
SXL113	06/15/98	50	
SXL113	06/22/98	10	K
SXL113	06/29/98	10	K
SXL113	07/06/98	10	K
SXL113	07/13/98	10	K
SXL113	07/20/98	20	
SXL113	07/27/98	50	
SXL113	08/03/98	30	
SXL113	08/10/98	10	K
SXL113	08/17/98	10	K
SXL113	08/24/98	10	K
SXL113	08/31/98	10	K
1	05/24/99	10	K
SXL101	06/01/99	**210**	
SXL101	06/03/99	12	Resample
SXL101	06/04/99	1	Resample
SXL101	06/07/99	20	
SXL101	06/14/99	10	K
SXL101	06/23/99	150	

SXL101	06/28/99	130	
SXL101	07/06/99	160	
SXL101	07/12/99	10	
SXL101	07/19/99	**280**	
SXL101	07/21/99	10	Resample
SXL101	07/26/99	40	
SXL101	08/02/99	10	K
SXL101	08/09/99	10	K
SXL101	08/16/99	50	
SXL101	08/23/99	90	
SXL101	08/30/99	40	
2	05/24/99	**380**	
SXL102	05/26/99	**240**	Resample
SXL102	05/27/99	84	Resample
SXL102	06/01/99	120	
SXL102	06/07/99	50	
SXL102	06/14/99	10	
SXL102	06/21/99	90	
SXL102	06/28/99	50	
SXL102	07/06/99	**270**	
SXL102	07/08/99	47	Resample
SXL102	07/09/99	4	Resample
SXL102	07/12/99	10	K
SXL102	07/19/99	40	
SXL102	07/26/99	**590**	
SXL102	07/28/99	120	Resample
SXL102	08/02/99	20	
SXL102	08/09/99	20	
SXL102	08/16/99	10	K
SXL102	08/23/99	100	
SXL102	08/30/99	30	
3	05/24/99	**4600**	
SXL103	05/26/99	70	Resample
SXL103	06/01/99	10	K
SXL103	06/07/99	10	K
SXL103	06/14/99	10	K
SXL103	06/21/99	10	K
SXL103	06/28/99	10	
SXL103	07/06/99	10	K
SXL103	07/12/99	50	
SXL103	07/19/99	10	K
SXL103	07/26/99	20	
SXL103	08/02/99	10	K
SXL103	08/09/99	50	
SXL103	08/16/99	10	
SXL103	08/23/99	10	K
SXL103	08/30/99	10	K

4	05/24/99	90	
SXL104	06/01/99	10	K
SXL104	06/07/99	20	
SXL104	06/14/99	30	
SXL104	06/21/99	30	
SXL104	06/28/99	90	
SXL104	07/06/99	**530**	
SXL104	07/08/99	29	Resample
SXL104	07/09/99	12	Resample
SXL104	07/12/99	10	
SXL104	07/19/99	20	
SXL104	07/26/99	60	
SXL104	08/02/99	10	K
SXL104	08/09/99	110	
SXL104	08/16/99	20	
SXL104	08/23/99	10	K
SXL104	08/30/99	30	
5	05/24/99	**310**	
SXL105	05/26/99	50	Resample
SXL105	06/01/99	30	
SXL105	06/07/99	10	
SXL105	06/14/99	30	
SXL105	06/21/99	40	
SXL105	06/28/99	60	
SXL105	07/06/99	40	
SXL105	07/12/99	10	
SXL105	07/19/99	80	
SXL105	07/26/99	70	
SXL105	08/02/99	10	K
SXL105	08/09/99	20	
SXL105	08/16/99	**450**	
SXL105	08/18/99	30	Resample
SXL105	08/23/99	40	
SXL105	08/30/99	10	
6	05/24/99	**11,000**	
SXL106	05/26/99	**510**	Resample
SXL106	05/26/99	104	Resample
SXL106	05/27/99	**1100**	Resample
SXL106	06/01/99	60	
SXL106	06/07/99	80	
SXL106	06/14/99	30	
SXL106	06/21/99	20	
SXL106	06/28/99	**450**	
SXL106	06/30/99	80	Resample
SXL106	07/06/99	**290**	
SXL106	07/08/99	163	Resample
SXL106	07/09/99	39	Resample

SXL106	07/12/99	10	
SXL106	07/19/99	30	
SXL106	07/26/99	10	K
SXL106	08/02/99	10	
SXL106	08/09/99	10	K
SXL106	08/16/99	60	
SXL106	08/23/99	10	K
SXL106	08/30/99	20	
Happy Valley	05/24/99	90	
SXL108	06/01/99	110	
SXL108	06/07/99	40	
SXL108	06/14/99	20	
SXL108	06/21/99	160	
SXL108	06/28/99	**480**	
SXL108	06/30/99	80	Resample
SXL108	07/06/99	40	
SXL108	07/12/99	**270**	
SXL108	07/19/99	50	
SXL108	07/26/99	20	
SXL108	08/02/99	10	K
SXL108	08/09/99	50	
SXL108	08/16/99	**210**	
SXL108	08/18/99	**490**	Resample
SXL108	08/23/99	40	
Tamarack	05/24/99	50	
SXL111	06/01/99	10	
SXL111	06/07/99	10	K
SXL111	06/14/99	80	
SXL111	06/21/99	90	
SXL111	06/28/99	**400**	
SXL111	06/30/99	50	Resample
SXL111	07/06/99	**330**	
SXL111	07/08/99	14	
SXL111	07/09/99	21	
SXL111	07/12/99	90	
SXL111	07/19/99	**2300**	
SXL111	07/21/99	140	Resample
SXL111	07/26/99	140	
SXL111	08/02/99	10	K
SXL111	08/09/99	10	
SXL111	08/16/99	160	
SXL111	08/23/99	10	K
SXL111	08/30/99	20	
Alpine	05/24/99	110	
SXL112	06/01/99	10	K
SXL112	06/07/99	10	
SXL112	06/14/99	10	

SXL112	06/23/99	10	K
SXL112	06/28/99	160	
SXL112	07/06/99	10	K
SXL112	07/12/99	10	K
SXL112	07/19/99	10	K
SXL112	07/26/99	10	K
SXL112	08/02/99	10	K
SXL112	08/09/99	10	
SXL112	08/16/99	50	
SXL112	08/23/99	10	K
SXL112	08/30/99	80	
Upper	05/24/99	**410**	
SXL113	05/26/99	10	Resample
SXL113	06/01/99	50	
SXL113	06/07/99	20	
SXlL13	06/14/99	20	
SXL113	06/23/99	10	K
SXL113	06/28/99	**400**	
SXL113	06/30/99	10	Resample
SXL113	07/07/99	60	
SXL113	07/12/99	**390**	
SXL113	07/14/99	10	K
SXL113	07/19/99	**580**	
SXL113	07/21/99	180	Resample
SXL113	07/26/99	90	
SXL113	08/02/99	20	
SXL113	08/09/99	10	
SXL113	08/16/99	40	
SXL113	08/23/99	10	K
SXL113	08/30/99	10	K
Lake Mohawk Beach 1	06/26/00	40	
SXL101	07/05/00	110	
SXL101	07/10/00	30	
SXL101	08/07/00	20	
SXL101	08/16/00	50	
SXL101	08/28/00	10	K
Lake Mohawk Beach 2	05/22/00	10	K
SXL102	05/30/00	10	K
SXL102	06/05/00	10	K
SXL102	06/12/00	10	
SXL102	06/19/00	10	
SXL102	06/26/00	10	K
SXL102	07/05/00	10	K
SXL102	07/10/00	60	
SXL102	07/17/00	10	K

SXL102	07/24/00	20	
SXL102	07/31/00	10	
SXL102	08/07/00	10	K
SXL102	08/16/00	60	
SXL102	08/21/00	10	
SXL102	08/28/00	20	
Lake Mohawk Beach 3	05/22/00	10	K
SXL103	05/30/00	10	K
SXL103	06/05/00	10	
SXL103	06/12/00	10	
SXL103	06/19/00	20	
SXL103	06/26/00	10	K
SXL103	07/05/00	10	K
SXL103	07/10/00	170	
SXL103	07/17/00	10	K
SXL103	07/24/00	70	
SXL103	07/31/00	10	K
SXL103	08/07/00	20	
SXL103	08/16/00	10	
SXL103	08/21/00	10	K
SXL103	08/28/00	10	K
Lake Mohawk Beach 4	05/22/00	10	K
SXL104	05/30/00	40	
SXL104	06/05/00	10	
SXL104	06/12/00	40	
SXL104	06/19/00	60	
SXL104	06/26/00	10	K
SXL104	07/05/00	10	
SXL104	07/10/00	40	
SXL104	07/12/00	10	K
SXL104	07/17/00	10	K
SXL104	07/24/00	20	
SXL104	07/31/00	10	K
SXL104	08/07/00	20	
SXL104	08/16/00	40	
SXL104	08/21/00	10	K
SXL104	08/28/00	20	
Lake Mohawk Beach 5	05/22/00	10	K
SXL105	05/30/00	10	K
SXL105	06/05/00	**7800**	
SXL105	06/07/00	10	Resample
SXL105	06/12/00	100	
SXL105	06/19/00	40	
SXL105	06/26/00	10	

SXL105	07/05/00	60	
SXL105	07/10/00	30	
SXL105	07/17/00	150	
SXL105	07/24/00	10	K
SXL105	07/31/00	80	
SXL105	08/07/00	40	
SXL105	08/16/00	20	
SXL105	08/21/00	10	
SXL105	08/28/00	100	
Lake Mohawk Beach 6	05/22/00	50	
SXL106	05/30/00	40	
SXL106	06/05/00	**440**	
SXL106	06/07/00	60	Resample
SXL106	06/12/00	30	
SXL106	06/19/00	10	
SXL106	06/26/00	40	
SXL106	07/05/00	10	
SXL106	07/10/00	50	
SXL106	07/17/00	40	
SXL106	07/24/00	60	
SXL106	07/31/00	30	
SXL106	08/07/00	60	
SXL106	08/16/00	10	K
SXL106	08/21/00	20	
SXL106	08/28/00	10	K
Lake Mohawk Happy Valley Beach	05/22/00	10	
SXL108	05/30/00	10	K
SXL108	06/05/00	10	
SXL108	06/12/00	30	
SXL108	06/19/00	20	
SXL108	06/26/00	50	
SXL108	07/05/00	20	
SXL108	07/10/00	20	
SXL108	07/17/00	10	
SXL108	07/24/00	20	
SXL108	07/31/00	30	
SXL108	08/07/00	20	
SXL108	08/16/00	30	
SXL108	08/21/00	10	K
SXL108	08/28/00	10	K
Lake Mohawk Tamarack Beach	05/22/00	**220**	
SXL111	05/30/00	**70**	

SXL111	06/05/00	**230**	
SXL111	06/07/00	50	Resample
SXL111	06/12/00	90	
SXL111	06/19/00	90	
SXL111	06/26/00	10	K
SXL111	07/05/00	40	
SXL111	07/10/00	30	
SXL111	07/17/00	30	
SXL111	07/24/00	10	K
SXL111	07/31/00	70	
SXL111	08/07/00	10	K
SXL111	08/16/00	40	
SXL111	08/21/00	40	
SXL111	08/28/00	60	
Lake Mohawk Alpine Beach	05/22/00	10	K
SXL112	05/30/00	10	K
SXL112	06/05/00	10	K
SXL112	06/12/00	**290**	
SXL112	06/14/00	20	Resample
SXL112	06/19/00	30	
SXL112	06/26/00	10	
SXL112	07/05/00	10	
SXL112	07/10/00	20	
SXL112	07/17/00	10	K
SXL112	07/24/00	10	K
SXL112	07/31/00	10	
SXL112	08/07/00	10	
SXL112	08/16/00	10	K
SXL112	08/21/00	10	
SXL112	08/28/00	30	
Upper Lake Mohawk	05/22/00	70	
SXL113	05/30/00	20	
SXL113	06/05/00	50	
SXL113	06/12/00	**700**	
SXL113	06/14/00	40	Resample
SXL113	06/19/00	140	
SXL113	06/26/00	10	
SXL113	07/05/00	30	
SXL113	07/10/00	30	
SXL113	07/17/00	50	
SXL113	07/24/00	10	
SXL113	07/31/00	30	
SXL113	08/07/00	40	
SXL113	08/16/00	10	K
SXL113	08/21/00	10	

SXL113	08/28/00	10	K
Beach 1	05/23/01	16	
Beach 1	06/04/01	12	
Beach 1	06/11/01	160	
Beach 1	06/18/01	90	
Beach 1	06/25/01	62	
Beach 1	07/02/01	14	
Beach 1	07/09/01	172	
Beach 1	07/16/01	30	
Beach 1	07/30/01	2	
Beach 1	08/06/01	28	
Beach 1	08/13/01	104	
Beach 1	08/20/01	796	
Beach 1	08/22/01	12	
Beach 1	08/27/01	52	
Beach 2	05/23/01	118	
Beach 2	06/04/01	104	
Beach 2	06/11/01	10	
Beach 2	06/18/01	138	
Beach 2	06/25/01	164	
Beach 2	07/02/01	56	
Beach 2	07/09/01	40	
Beach 2	07/16/01	54	
Beach 2	07/23/01	12	
Beach 2	07/30/01	16	
Beach 2	08/06/01	6	
Beach 2	08/13/01	196	
Beach 2	08/20/01	18	
Beach 2	08/27/01	6	
Beach 3	05/23/01	2	
Beach 3	06/04/01	2	
Beach 3	06/11/01	200	
Beach 3	06/18/01	92	
Beach 3	06/25/01	168	
Beach 3	07/02/01	16	
Beach 3	07/09/01	4	
Beach 3	07/16/01	20	
Beach 3	07/23/01	2	k
Beach 3	08/06/01	2	
Beach 3	08/13/01	6	
Beach 3	08/20/01	2	
Beach 3	08/27/01	2	
Beach 4	05/23/01	40	
Beach 4	06/04/01	40	
Beach 4	06/11/01	200	
Beach 4	06/18/01	136	
Beach 4	06/25/01	96	

Beach 4	07/02/01	62	
Beach 4	07/09/01	26	
Beach 4	07/16/01	2	K
Beach 4	07/23/01	2	K
Beach 4	07/30/01	18	
Beach 4	08/06/01	4	
Beach 4	08/13/01	26	
Beach 4	08/20/01	44	
Beach 4	08/27/01	6	
Beach 5	05/23/01	12	
Beach 5	06/04/01	30	
Beach 5	06/11/01	350	
Beach 5	06/14/01	164	
Beach 5	06/18/01	180	
Beach 5	06/25/01	44	
Beach 5	07/02/01	54	
Beach 5	07/09/01	186	
Beach 5	07/16/01	82	
Beach 5	07/23/01	12	
Beach 5	07/30/01	40	
Beach 5	08/06/01	164	
Beach 5	08/13/01	238	
Beach 5	08/20/01	8	
Beach 5	08/27/01	8	
Beach 6	05/23/01	84	
Beach 6	06/04/01	14	
Beach 6	06/11/01	6	
Beach 6	06/18/01	150	
Beach 6	06/25/01	298	
Beach 6	06/27/01	164	
Beach 6	07/02/01	70	
Beach 6	07/09/01	36	
Beach 6	07/16/01	36	
Beach 6	07/23/01	8	
Beach 6	08/06/01	68	
Beach 6	08/13/01	38	
Beach 6	08/20/01	54	
Beach 6	08/27/01	60	
Alpine	05/23/01	72	
Alpine	06/04/01	6	
Alpine	06/11/01	6	
Alpine	06/18/01	24	
Alpine	06/25/01	34	
Alpine	07/02/01	82	
Alpine	07/09/01	6	
Alpine	07/16/01	2	
Alpine	07/23/01	6	

Alpine	07/30/01	22	
Alpine	08/06/01	32	
Alpine	08/13/01	16	
Alpine	08/20/01	44	
Alpine	08/27/01	122	
Manitou	06/25/01	118	
Manitou	07/09/01	30	
Manitou	07/16/01	36	
Manitou	07/23/01	122	
Manitou	07/30/01	18	
Manitou	08/06/01	104	
Manitou	08/13/01	212	
Manitou	08/15/01	90	
Manitou	08/20/01	350	
Manitou	08/22/01	2	K
Manitou	08/27/01	262	
Manitou	08/30/01	30	
Upper	05/23/01	20	
Upper	06/04/01	52	
Upper	06/11/01	856	
Upper	06/14/01	188	
Upper	06/18/01	230	
Upper	06/20/01	176	
Upper	06/25/01	114	
Upper	07/02/01	98	
Upper	07/09/01	32	
Upper	07/16/01	68	
Upper	07/16/01	172	
Upper	07/23/01	2	K
Upper	07/30/01	2	
Upper	08/06/01	38	
Upper	08/13/01	4	
Upper	08/20/01	30	
Upper	08/27/01	10	
BEACH 1	05/20/02	2	
BEACH 1	05/29/02	50	
BEACH 1	06/03/02	10	
BEACH 1	06/10/02	10	K
BEACH 1	06/17/02	50	
BEACH 1	06/24/02	20	
BEACH 1	07/01/02	30	
BEACH 1	07/08/02	20	
BEACH 1	07/15/02	10	
BEACH 1	07/22/02	10	
BEACH 1	07/29/02	40	
BEACH 1	08/05/02	80	
BEACH 1	08/12/02	20	

BEACH 1	08/19/02	40	
BEACH 1	08/26/02	10	K
BEACH 2	05/20/02	70	
BEACH 2	05/29/02	720	
BEACH 2	05/31/02	91	Resample
BEACH 2	06/03/02	10	
BEACH 2	06/10/02	10	K
BEACH 2	06/17/02	10	
BEACH 2	06/24/02	10	K
BEACH 2	07/01/02	20	
BEACH 2	07/08/02	10	
BEACH 2	07/15/02	10	K
BEACH 2	07/22/02	160	
BEACH 2	07/29/02	40	
BEACH 2	08/05/02	70	
BEACH 2	08/12/02	10	K
BEACH 2	08/19/02	40	
BEACH 2	08/26/02	10	
BEACH 3	05/20/02	10	K
BEACH 3	05/29/02	10	K
BEACH 3	06/03/02	10	K
BEACH 3	06/10/02	10	K
BEACH 3	06/17/02	10	
BEACH 3	06/24/02	30	
BEACH 3	07/01/02	20	
BEACH 3	07/08/02	10	K
BEACH 3	07/15/02	10	K
BEACH 3	07/22/02	30	
BEACH 3	07/29/02	10	K
BEACH 3	08/05/02	10	
BEACH 3	08/12/02	10	K
BEACH 3	08/26/02	40	
BEACH 4	05/20/02	10	K
BEACH 4	05/29/02	200	
BEACH 4	05/31/02	11	Resample
BEACH 4	06/03/02	10	
BEACH 4	06/10/02	10	
BEACH 4	06/17/02	10	
BEACH 4	06/24/02	120	
BEACH 4	07/01/02	20	
BEACH 4	07/08/02	10	K
BEACH 4	07/15/02	30	
BEACH 4	07/22/02	110	
BEACH 4	07/29/02	60	
BEACH 4	08/05/02	10	K
BEACH 4	08/12/02	10	K
BEACH 4	08/19/02	20	

BEACH 4	08/26/02	10	K
BEACH 5	05/20/02	20	
BEACH 5	05/29/02	40	
BEACH 5	06/03/02	10	
BEACH 5	06/10/02	10	K
BEACH 5	06/17/02	10	
BEACH 5	06/24/02	70	
BEACH 5	07/01/02	200	
BEACH 5	07/08/02	180	
BEACH 5	07/15/02	60	
BEACH 5	07/22/02	40	
BEACH 5	07/29/02	40	
BEACH 5	08/05/02	10	
BEACH 5	08/12/02	10	K
BEACH 5	08/19/02	30	
BEACH 5	08/26/02	10	K
BEACH 6	05/20/02	100	
BEACH 6	05/29/02	20	
BEACH 6	06/03/02	20	
BEACH 6	06/10/02	10	
BEACH 6	06/17/02	10	K
BEACH 6	06/24/02	20	
BEACH 6	07/01/02	30	
BEACH 6	07/08/02	20	
BEACH 6	07/15/02	10	K
BEACH 6	07/22/02	50	
BEACH 6	07/29/02	30	
BEACH 6	08/05/02	10	
BEACH 6	08/12/02	30	
BEACH 6	08/19/02	40	
BEACH 6	08/26/02	20	
HAPPY VALLEY	05/20/02	20	
HAPPY VALLEY	05/29/02	130	
HAPPY VALLEY	06/03/02	10	
HAPPY VALLEY	06/10/02	10	K
HAPPY VALLEY	06/17/02	10	
HAPPY VALLEY	06/24/02	10	
HAPPY VALLEY	07/01/02	10	K
HAPPY VALLEY	07/08/02	40	
HAPPY	07/15/02	490	

VALLEY			
HAPPY VALLEY	07/17/02	330	Resample
HAPPY VALLEY	07/18/02	46	Resample
HAPPY VALLEY	07/19/02	163	Resample
HAPPY VALLEY	08/05/02	10	
HAPPY VALLEY	08/12/02	40	
HAPPY VALLEY	08/19/02	10	K
HAPPY VALLEY	08/26/02	30	
MANITOU	05/20/02	40	
MANITOU	05/29/02	10	
MANITOU	06/03/02	10	
MANITOU	06/10/02	30	
MANITOU	06/17/02	10	
MANITOU	06/24/02	180	
MANITOU	07/01/02	60	
MANITOU	07/08/02	40	
MANITOU	07/15/02	130	
MANITOU	07/22/02	90	
MANITOU	07/29/02	200	
MANITOU	08/05/02	10	K
MANITOU	08/12/02	20	
MANITOU	08/19/02	20	
MANITOU	08/26/02	50	
TAMARACK	05/22/02	10	K
TAMARACK	05/29/02	40	
TAMARACK	06/03/02	10	K
TAMARACK	06/10/02	20	
TAMARACK	06/17/02	10	K
TAMARACK	06/24/02	740	
TAMARACK	06/26/02	41	Resample
TAMARACK	07/01/02	40	
TAMARACK	07/08/02	10	
TAMARACK	07/15/02	40	
TAMARACK	07/22/02	40	
TAMARACK	07/29/02	80	
TAMARACK	08/05/02	50	
TAMARACK	08/12/02	30	
TAMARACK	08/19/02	10	
TAMARACK	08/26/02	10	K
ALPINE	05/20/02	20	
ALPINE	05/29/02	10	

ALPINE	06/03/02	20	
ALPINE	06/10/02	10	
ALPINE	06/17/02	10	
ALPINE	06/24/02	40	
ALPINE	07/01/02	10	
ALPINE	07/08/02	10	
ALPINE	07/15/02	30	
ALPINE	07/22/02	10	
ALPINE	07/29/02	10	
ALPINE	08/05/02	10	K
ALPINE	08/12/02	10	K
ALPINE	08/19/02	10	K
ALPINE	08/26/02	20	
	05/20/02	10	
	05/29/02	20	
	06/03/02	20	
	06/10/02	20	
	06/17/02	20	
	06/24/02	10	K
	07/01/02	150	
	07/08/02	20	
	07/15/02	900	
	07/17/02	40	Resample
	07/19/02	18	Resample
	07/22/02	10	
	07/29/02	40	
	08/05/02	10	
	08/12/02	20	
	08/19/02	10	
	08/26/02	10	
LAKE MOHAWK - BEACH 1	05/19/03	10	
	05/28/03	30	
	06/02/03	30	
	06/09/03	10	K
	06/16/03	10	K
	06/23/03	10	
	06/30/03	110	
	07/07/03	10	
	07/14/03	10	
	07/21/03	20	
	07/28/03	10	
	08/04/03	10	
	08/11/03	20	
	08/18/03	10	K
	08/25/03	10	K

LAKE MOHAWK BEACH 2	05/21/03	30	
	05/28/03	240	
	06/02/03	10	Resample
	06/09/03	10	
	06/16/03	20	
	06/23/03	10	K
	06/30/03	40	
	07/07/03	10	
	07/14/03	20	
	07/21/03	110	
	07/28/03	10	K
	08/04/03	20	
	08/11/03	40	
	08/25/03	10	K
LAKE MOHAWK BEACH 3	05/21/03	10	K
	05/28/03	10	
	06/02/03	10	
	06/09/03	10	K
	06/16/03	10	
	06/23/03	20	
	06/30/03	10	K
	07/07/03	10	
	07/14/03	40	
	07/21/03	40	
	07/28/03	10	K
	08/04/03	100	
	08/11/03	10	K
	08/18/03	70	
	08/25/03	10	K
LAKE MOHAWK BEACH 4	05/21/03	230	
	05/28/03	10	K, Resample
	06/02/03	10	K
	06/09/03	20	
	06/16/03	50	
	06/23/03	10	K
	06/30/03	10	K
	07/07/03	10	K
	07/14/03	10	K
	07/21/03	40	
	07/28/03	20	
	08/04/03	80	
	08/11/03	20	

	08/18/03	10	K
	08/25/03	20	
LAKE MOHAWK BEACH 5	05/21/03	40	
	05/28/03	20	
	06/02/03	30	
	06/09/03	10	
	06/16/03	80	
	06/23/03	20	
	06/30/03	60	
	07/07/03	10	
	07/14/03	50	
	07/21/03	140	
	07/28/03	70	
	08/04/03	100	
	08/11/03	20	
	08/18/03	10	
	08/25/03	50	
LAKE MOHAWK BEACH 6	05/21/03	870	
	05/28/03	90	Resample
	06/02/03	40	
	06/09/03	50	
	06/16/03	40	
	06/23/03	60	
	06/30/03	10	K
	07/07/03	10	
	07/14/03	50	
	07/21/03	20	
	07/28/03	10	K
	08/04/03	140	
	08/11/03	40	
	08/18/03	40	
	08/25/03	10	K
LAKE MOHAWK HAPPY VALLEY	05/19/03	10	K
	05/28/03	10	K
	06/02/03	40	
	06/09/03	20	
	06/16/03	210	
	06/18/03	10	K, Resample
	06/23/03	30	
	06/30/03	30	
	07/07/03	10	K

	07/14/03	40	
	07/21/03	10	
	07/28/03	40	
	08/04/03	40	
	08/11/03	80	
	08/18/03	200	
	08/20/03	10	
	08/25/03	10	
LAKE MOHAWK MANITOU	05/19/03	10	K
	05/28/03	1100	
	06/02/03	40	Resample
	06/09/03	10	
	06/16/03	30	
	06/23/03	10	
	06/30/03	130	
	07/07/03	60	
	07/14/03	20	
	07/21/03	50	
	07/28/03	10	
	08/04/03	340	
	08/06/03	20	Resample
	08/06/03	230	Resample
	08/08/03	10	Resample
	08/11/03	60	
	08/18/03	10	
	08/25/03	190	
LAKE MOHAWK TAMARACK	05/19/03	10	K
	05/28/03	10	
	06/02/03	10	
	06/09/03	40	
	06/16/03	100	
	06/23/03	40	
	06/30/03	20	
	07/07/03	20	
	07/14/03	280	
	07/16/03	110	Resample
	07/21/03	90	
	07/28/03	40	
	08/04/03	260	
	08/06/03	360	Resample
	08/06/03	20	Resample
	08/08/03	10	K, Resample
	08/11/03		

	08/18/03	10	
	08/25/03	10	K
LAKE MOHAWK ALPINE	05/21/03	60	
	05/28/03	10	K
	06/02/03	40	
	06/09/03	10	
	06/16/03	30	
	06/23/03	40	
	06/30/03	10	K
	07/07/03	10	
	07/14/03	80	
	07/21/03	30	
	07/28/03	70	
	08/04/03	140	
	08/11/03	180	
	08/18/03	10	K
	08/25/03	20	
LAKE MOHAWK UPPER LAKE	05/21/03	10	
	05/28/03	30	
	06/02/03	50	
	06/09/03	110	
	06/16/03	20	
	06/23/03	50	
	06/30/03	10	K
	07/07/03	10	
	07/14/03	10	K
	07/21/03	20	
	07/28/03	10	K
	08/04/03	70	
	08/11/03	100	
	08/18/03	10	K
	08/25/03	10	K
LAKE MOHAWK BEACH 1	05/24/04	**220**	
	06/02/04	10	Resample
	06/07/04	10	K
	06/14/04	10	
	06/21/04	10	K
	06/28/04	10	K
	07/07/04	10	
	07/15/04	**300**	
	07/21/04	10	K, Resample
	07/26/04	20	

	08/02/04	10	
	08/09/04	150	
	08/16/04	**340**	
	08/18/04	**340**	Resample
	08/23/04	**560**	Resample
	08/25/04	20	Resample
	08/30/04	10	K, Resample
LAKE MOHAWK BEACH 2	05/24/04	10	K
	06/02/04	40	
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	10	
	06/28/04	20	
	07/07/04	10	K
	07/15/04	10	
	07/21/04	10	K
	07/26/04	20	
	08/02/04	30	
	08/09/04	10	
	08/16/04	20	
	08/23/04	40	
	08/30/04	10	K
LAKE MOHAWK BEACH 3	05/24/04	10	K
	06/02/04	10	K
	06/07/04	10	
	06/14/04	10	K
	06/21/04	10	
	06/28/04	20	
	07/07/04	10	K
	07/12/04	10	K
	07/21/04	10	K
	07/26/04	20	
	08/02/04	10	
	08/09/04	10	
	08/16/04	30	
	08/23/04	10	
	08/30/04	10	K
LAKE MOHAWK BEACH 4	05/24/04	40	
	06/02/04	30	
	06/07/04	10	
	06/14/04	30	
	06/21/04	10	

	06/28/04	10	K
	07/07/04	20	
	07/12/04	20	
	07/21/04	10	K
	07/26/04	10	
	08/02/04	10	
	08/09/04	10	
	08/16/04	10	K
	08/23/04	10	K
	08/30/04	10	K
LAKE MOHAWK BEACH 5	05/24/04	180	
	06/02/04	20	
	06/07/04	70	
	06/14/04	10	
	06/21/04	10	K
	06/28/04	10	K
	07/07/04	10	K
	07/12/04	20	
	07/21/04	10	
	07/26/04	60	
	08/02/04	20	
	08/09/04	10	K
	08/16/04	10	K
	08/23/04	30	
	08/30/04	**380**	
	09/02/04	10	K,Resample
LAKE MOHAWK BEACH 6	05/24/04	40	
	06/02/04	10	K
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	10	K
	06/28/04	100	
	07/07/04	80	
	07/12/04	20	
	07/21/04	10	K
	07/26/04	30	
	08/02/04	20	
	08/09/04	10	K
	08/16/04	20	
	08/23/04	50	
	08/30/04	10	K
LAKE MOHAWK HAPPY	05/24/04	**490**	

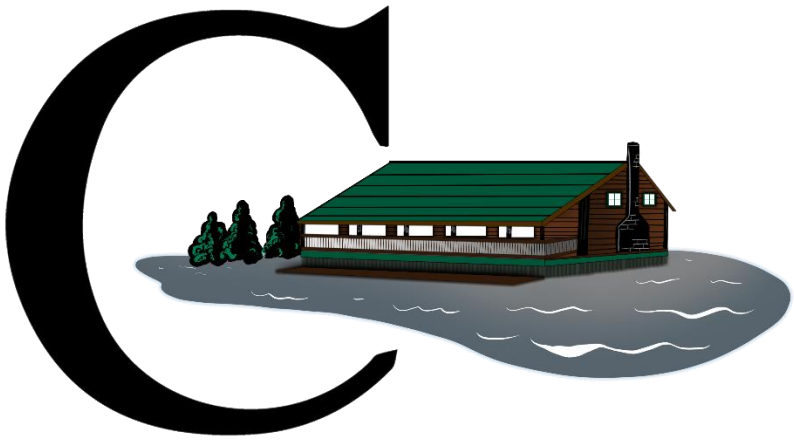
VALLEY			
	06/02/04	70	Resample
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	20	
	06/28/04	**220**	
	06/30/04	10	K, Resample
	07/07/04	10	K
	07/15/04	10	K
	07/21/04	10	k
	07/26/04	20	
	08/02/04	10	
	08/09/04	**200**	
	08/16/04	10	K
	08/23/04	40	
	08/30/04	**90**	
LAKE MOHAWK MANITOU	05/24/04	160	
	06/02/04	10	
	06/07/04	20	
	06/14/04	30	
	06/21/04	10	K
	06/28/04	190	
	07/07/04	80	
	07/15/04	10	K
	07/21/04	10	K
	07/26/04	60	
	08/02/04	20	
	08/09/04	10	
	08/16/04	40	
	08/23/04	100	
	08/30/04	10	K
LAKE MOHAWK TAMARACK	05/24/04	130	
	06/02/04	10	K
	06/07/04	50	
	06/14/04	90	
	06/21/04	180	
	06/28/04	70	
	07/07/04	10	K
	07/15/04	**6000**	L
	07/20/04	14	Resample
	07/21/04	10	K, Resample
	07/26/04	10	K,
	08/02/04	30	

	08/09/04	10	
	08/16/04	50	
	08/23/04	20	
	08/30/04	10	K
LAKE MOHAWK ALPINE	05/24/04	10	
	06/02/04	10	K
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	10	K
	06/28/04	10	K
	07/07/04	10	K
	07/15/04	10	K
	07/21/04	10	K
	07/26/04	20	
	08/02/04	10	
	08/09/04	10	
	08/16/04	10	K
	08/23/04	40	
	08/30/04	10	K
LAKE MOHAWK UPPER LAKE	05/24/04	20	
	06/02/04	10	K
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	20	
	06/28/04	10	
	07/07/04	10	K
	07/12/04	20	
	07/21/04	50	
	07/26/04	20	
	08/02/04	10	K
	08/09/04	10	K
	08/16/04	30	
	08/23/04	160	
	08/30/04	30	

Sleepy Valley			
count	67	mean+3stdev	1568
median	20	%reduction	91%
Max	2300		
stdev	460	**no data excluded**	
mean	189		
mean+3stdev	1568		

STATION	DATE	VALUE	REMARK
SXL192218	05/28/98	10	K
SXL192218	06/10/98	10	K
SXL192218	06/25/98	10	K
SXL192218	07/10/98	60	
SXL192218	07/22/98	10	K
SXL192218	08/15/98	10	K
SXL192218	08/21/98	10	K
SXL192218	09/02/98	20	
SXL192218	05/24/99	2300	
SXL192218	05/28/99	770	
SXL192218	06/04/99	90	
SXL192218	06/16/99	320	
SXL192218	06/30/99	10	K
SXL192218	07/16/99	30	
SXL192218	07/30/99	10	K
SXL192218	08/11/99	10	K
SXL192218	08/18/99	10	K
SXL192218	08/25/99	10	K
SXL192218	05/22/00	20	BEACH OPENED JULY 1
SXL192218	06/09/00	230	
SXL192218	06/22/00	190	
SXL192218	07/05/00	40	
SXL192218	07/18/00	130	
SXL192218	08/02/00	10	
SXL192218	08/16/00	10	K
SXL192218	08/30/00	10	
	05/30/01	110	
	06/13/01	40	
	06/27/01	140	
	07/11/01	2200	
	07/14/01	520	RESAMPLE
	07/14/01	190	NORTH BRACKET
	07/14/01	400	SOUTH BRACKET
	07/18/01	160	
	07/20/01	50	RESAMPLE
	07/20/01	20	NORTH BRACKET
	07/20/01	90	SOUTH BRACKET
	08/01/01	10	K

	08/15/01	10	K
	08/23/01	10	
	05/24/02	10	
	06/05/02	10	K
	06/19/02	10	
	06/26/02	500	
	06/28/02	180	RESAMPLE
	07/12/02	1	K
	07/26/02	70	
	08/07/02	10	
	08/20/02	80	
Tall Timbers POA	05/19/03	10	K
	06/04/03	250	
	06/10/03	10	RESAMPLE
	06/24/03	20	
	07/09/03	10	K
	07/23/03	420	BEACH CLOSED
	07/31/03	20	RESAMPLE
	08/06/03	560	BEACH CLOSED
	08/13/03	30	RESAMPLE
	08/19/03	10	
Tall Timbers	05/27/04	2000	
	06/08/04	40	
	06/23/04	10	K
	07/07/04	10	K
	07/21/04	10	
	08/03/04	10	
	08/18/04	10	K
	08/23/04	60	



Cranberry Lake

Lake Management Program

This program was developed and is maintained and managed by the Cranberry Lake Community Club on behalf of and for the full benefit of all members of the Cranberry Lake Community

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Overview

The Cranberry Lake Community Club is committed to ensuring our lake is properly managed and maintain by providing the necessary funds and resources to oversee the daily operational needs of the lake. We are a member of COLA in coordination with other lakes and are the liaison with State and Town (Byram) governments. These strong relationships have allowed us to pursue grants from the State and local (Byram) governments for things such as weed harvesting and receive permits to control the geese population.

Our Lake Management Program consists of but not limited to the following:

- On-going Aquatic Vegetation Control**,** Water testing and Shoreline Management
- Provide public information & awareness
    - bulletins and write ups on feeding wildlife
    - recommended use of fertilizer
- Educational programs that our vendor conducted regularly for our members
- Boating Safety Courses where we invite outside community members
- Coordination with state on the health and condition of the Dam
- Coordination with state on shoreline earth embankment. We have a court assisted document that the State should abide by regarding the make-up and appearance of the earthen “dam”
- Posting of State approved lake regulations
    - speed
    - direction
    - closeness to shore
- Working with Byram on Storm drain run off into the lake
- Providing access to the lake to obtain water for Fire Department use
- Swimming Safety
- Lake Security

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Aquatic Vegetation Control

The CLCC Executive Board appoints members to participate in a Lake Management Committee who are held responsible for reviewing qualified contractors/consultants who would partner with this committee to manage our overall aquatic vegetation concerns (lake weeds, water quality, shoreline etc..). It is in turn the responsibility of this committee to present and recommend their suggestions on which contractor/consultants would best fit the needs of the lake. This review takes place every 3 years upon renewal of the agreement.

It is also the responsibility of this committee to maintain a weekly review of the quality of our in-flight program which includes supervising the activities of our chosen contractors/consultants as well as any other activities necessary to maintain the quality of the lake for recreational uses.

To summarize our current agreement; under the supervision of a CLCC Lake Management multi-member committee we outsource our Aquatic Vegetation Control (AVC) to ***Aquatic Technologies, Inc***. Our AVC program, therefore, consists of a multi-year agreement with Aquatic Technologies that our CLCC Lake Management Committee would have reviewed and approved. In addition to our vegetation control; we execute a scheduled drawdown of the lake every third year.

Note: Approval of the drawdowns are memorialized in the minutes of the Board of Governors.

Aquatic Technologies, Inc.
P.O. Box 769
Branchville, NJ 07826
Tel: 973-773-9567 – Fax: 973-948-7118

www.aquatechnj.com

Lake Management Consultants
Experts in Aquatic Vegetation Control

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Cranberry Lake winter drawdown

Aquatic Technologies, Inc. recommends a winter lake level drawdown for Cranberry Lake. Lake level drawdowns are conducted at many of our north eastern client's lakes for a variety of reasons. The purposes may include protection of the shoreline from the erosion effects of high water, control of aquatic weeds, reducing the adverse effects of winter ice on the shoreline and shorefront structures and for providing water storage capacity to mitigate flooding.

Protection of the Shoreline

Shoreline erosion is a natural continuous process. The force of water and soil saturation gradually washes land area into the lake. High water conditions in combination with heavy winds cause erosion of the shoreline above the normal water line. Drawdowns lower the water level so that the erosive forces of waves are acting below the normal shoreline. Drawdowns also provide vertical space so that if water levels rise as a result of high runoff, they come up to normal levels rather than above normal levels, as would be the case if the waterbody were kept full.

Aquatic Weed Control

Cranberry Lake may benefit with reduction of nuisance aquatic vegetation from results of a winter drawdown. This would allow us to reduce the number of herbicides used in the Spring. Eurasian Milfoil is a significant issue in Cranberry Lake and is a species that can be affected by winter drawdown. With the ever-changing weather patterns in the north east over the past decade, it is difficult to predict how much of a winter "freeze" we get, but chances are it may occur. The effectiveness of drawdowns is dependent upon a deep frost and dewatering of the sediments. These conditions may not occur with heavy snow or mild rainy winters.

Reducing Ice Damage

Lake ice can reach a thickness of two feet or more. The force of massive ice is exerted in three ways. Under the warming spring sun, as the lake ice expands, it can exert 2,000 or more pounds of force per square inch on anything in its path including docks, walls, and the natural shoreline. Ice berms are evident around the shorelines of many lakes. Should lake levels fluctuate when the ice is frozen onto an object, that object will be moved accordingly up or down. As the near shore areas thaw in the spring, the ice sheet is driven by the wind onto the shore. Drawdowns are effective at transferring the location at which these forces are exerted away from the natural shoreline and structures built there.

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ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

Lake Drawdown for Aquatic Plant Control

Lake level drawdown and the subsequent exposure of sediments to prolonged freezing and/or drying is an inexpensive means of aquatic weed control. Drawdowns serve to stress plants and could physically remove them from their habitat. Low water levels will expose the plants to desiccation and could ultimately affect plant vascular structure, thereby rendering the plant incapable of nutrient transport and function. This can temporarily reduce plant density for an undetermined period of time. While being an economical means of plant control, lake drawdown is also rather unpredictable, and may cause some species to actually increase in abundance, or not affect some target species at all. Further, draining the water from an aquatic system can be detrimental to nontarget organisms.

Factors Necessary to Increase Potential for Drawdown Success

Several factors are necessary to increase the potential for drawdown success. The amount and degree of the drawdown are probably the foremost important factors to consider. Most importantly, the capability to draw down the lake to a level suitable to maximize the exposed littoral zone is necessary.

Typical fall/winter drawdowns are usually conducted in New Hampshire from October through early spring. The length of winter drawdown is based on ice and snow cover, water uses, and expected water renewal rates. It is imperative that the water level be brought down slowly, in order to allow for aquatic fauna to adapt to the changing water levels. It is also important that the lake be brought back to normal full-lake levels before the summer season begins for a variety of reasons, including ecological, recreational, aesthetic, and for keeping terrestrial species from encroaching on the lake bed. Water level fluctuations should always be coordinated through the DES Dam Bureau in consultation with the DES Biology Section

Fall/winter drawdowns can be beneficial in that some desiccation takes place as the waterbody is dewatering, but thorough freezing of the plants and the lake sediments is the key. Freezing of the plants damages the structure and integrity of the vegetative material. Freezing of the lake sediments will impact rooting systems and rhizomes, both by freeze damage, scouring, and subsequent uplifting of the rooting systems. Scouring action of ice moving over the exposed lakebed will force tubers and rooting systems

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from the substrate. When the water level is again raised, these anchoring plant structures will often float downstream and discharge through the lake basin, or they can be hand-removed as they float around.

Adverse Impacts of Drawdown

Though drawdowns may be a relatively low-cost technique to reduce the abundance of some littoral zone aquatic macrophytes, there may be several unanticipated problems associated with drawdowns. Algal or cyanobacteria blooms may follow a drawdown. Cyanobacteria blooms may be toxic, while an increase of green filamentous algae may decrease aesthetic values of the waterbody. Planktonic blooms of cyanobacteria typically turn the water a bluish or greenish color, while filamentous algae blooms form large green billowing masses in the shallows. Other algae may also bloom causing taste and or odor problems. Algal blooms are caused by nutrient release from decaying plants. Large amounts of aquatic plants and organisms that succumb to the drawdown begin to decay shortly after drawdown but nutrient release to the waterbody may not occur until full-pond level is achieved. Nutrients released from decayed material will quickly be utilized by algae and cyanobacteria, leading to increased cell production. Waterbodies, particularly shallow system, tend to maintain a balance between macrophyte and algal growth. Once plant populations diminish, the degree of nutrient competition in the waterbody favors increased algal populations due to their ability to quickly uptake available nutrients. Shallow lakes have shown shifts from clear, plant dominated conditions to turbid, algal dominated systems following a drawdown. Aquatic food web changes may result in shifts in plant and animal structure due to drawdown.

Impacts to organisms lower in the food web (plants, algae and insects) will have negative impacts on those organisms higher in the aquatic food web (fish, animals and waterfowl). Oxygen concentrations throughout the water column may be impacted by the drawdown. As bacteria further decompose the accumulated detritus, they create an oxygen demand to the water. During summer stratification, hypolimnetic oxygen levels and even mid-thermocline oxygen levels may be dramatically reduced, resulting in large-scale fish kills.

The difficulty of achieving complete sediment dewatering in target areas of the waterbody is also a potential problem. Physical constraints due to dam construction, underground springs, weather conditions and inflowing water may limit the degree of drawdown, lessening the expected range of impacts to the littoral zone.

Changes in the bottom sediment may also occur as a result of drawdown. Softer sediments may become compacted or frozen segments that are now lighter than water could loosen and float around in large masses or as floating islands in the waterbody, only to settle once again in a new location. Several notable drawdowns resulted in the formation of floating islands that settled at the public access, blocking all ingress and egress. These are extremely difficult to move or remove, and a Wetlands Permit would be necessary for any removal activities. Impacts and even mortality to aquatic animal species is a big risk during drawdown. The impacts may result from leaving animals

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stranded 'in the dry' as a result of drawdown, or could involve more complex impacts that result from modifications in the food chain or various stressors associated with the drawdown. Many organisms that make their home in the aquatic environment, including fish, frogs, salamanders, turtles, aquatic insect larvae, mussels, and others can all feel the impacts of drawdown. Agile and faster moving organisms (like fish) may be able to move upstream or downstream to other unimpacted habitats; still, these fish may be confined to smaller, shallower areas where they become easy prey to consumers or suffer from oxygen deprivation. The Fish and Game Department, in cooperation with DES, has documented changes in the fishery over time in one lake that was the focus of a study on drawdowns. Slower moving, more sedentary organisms have a greater risk to negative impacts. Freshwater mussels, snails, insects, and crayfish may not be able to find suitable habitat, and may succumb to the drawdown. In a long-term study of deep drawdown on one lake in New Hampshire, DES measured significant shifts in macroinvertebrate populations from non-drawdown to post-drawdown years.

Finally, there may also be a long-term change in plant species composition from "drawdown susceptible" plants to "drawdown-resistant" plants. Several studies show that annual drawdowns can actually influence the growth of these resistant plant species. A study of lake drawdown conducted by Dennis Cooke (1980) found that various aquatic plants responded differently to drawdown. Summary of Winter Drawdown Study Findings (Cooke, 1980)

Decrease in Abundance Increase in Abundance No Change
Water shield (*Brasenia*) Bulrush (*Scirpus*) Bladderwort (*Utricularia*)
Pondweed (*Potamogeton*) Arrowhead (*Sagittaria*) Bur-reed (*Sparganium*)
Yellow water lily (*Nuphar*) 3-way sedge (*Dulichium*) Tape grass (*Vallisneria*)
White water lily (*Nymphea*)
Spike rush (*Eleocharis*)
Water milfoil (*Myriophyllum spp*)
Pickerelweed (*Pontedaria*)

Summary

Water level drawdown may be an effective technique for at least the short-term control of susceptible aquatic plants, and can be accomplished at low costs without the introduction of chemicals or machinery. However, this technique may or may not affect target species with a predictable outcome, it requires careful identification of the target plants before drawdown to avoid rapid establishment of resistant species, and it could have long-lasting effects on non-target biota like freshwater mussels, macroinvertebrate populations, the fishery, and other organisms.

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Boating Safety

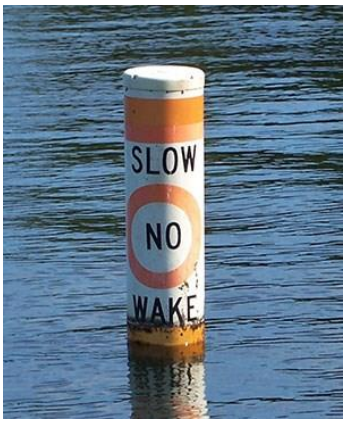
The New Jersey Department of Environmental Protection is responsible for providing all of the lake markings and the Marine Police are responsible for policing the lake and handing our citations when necessary.

Safe Boating Aids to Navigation

Understanding the special markers and signage is important, as these will identify safe waters, convey important information to boat operators, and assist in navigation.

Controlled Area

A white buoy or sign with an orange circle and black lettering indicates a controlled or restricted area on the water. The most common controlled area within our lake is 'Slow-No Wake' speeds. 'Slow-No Wake' means operating your boat at the slowest possible speed necessary to maintain steerage, but not greater than five miles-per-hour.



Danger

A white buoy or sign with an orange diamond warns watercraft operators of dangerous rocks or underwater structures. The source of the danger will also be lettered in black.

Rocks are abundant in Cranberry Lake, please use caution when traveling in the lake. *Not all rock hazards are marked due to changing water levels*.

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Water Hazards

Some remnants of the lake's history can still be seen today and can be considered water hazards. Use caution when entering and leaving the old lake because some old concrete peers are located just below the water surface depending on the current lake levels.

Dead heads, a partially submerged log or trunk, can be found anywhere in the lake and can cause damage to boats, motors and most importantly skiers. Always be scanning the water for any hazards around you and report them immediately.

Swimming Safety

Cranberry Lake offers two beaches (Clubhouse Beach and Roses Beach) for the enjoyment of our members. Swimming is possible at both beaches as well as off of one of our many floating docks throughout the lake. We ensure proper "No Swimming" signage is place in and around the lake where appropriate.

Through our Executive Board appointed Water Supervisor; we ensure that our swimmers are safe by providing certified Lifeguards at both our beaches. The lifeguards are on duty at the Clubhouse Beach and Rose's Beach. Hours of operations can be found on both the printed calendar as well as the website. Lifeguards are also on duty at all club events that involve members bathing in the water.

Lake Security

The CLCC Executive Board is committed to ensuring our community is kept safe as possible by appointing a security officer for the lake who are responsible for communicating new security measures to the community as well as being the single point of contact if there is ever a need to report any suspicious activity.

Shoreline Maintenance

The CLCC Executive Board is committed to ensuring the lake shorelines are maintained and safe for our community members. We manage and maintain the boat ramp in Cabin Springs allowing our community members a much safer and easier way to launch and remove their boats each year as opposed to doing so at the state ramp. We

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maintain and are responsible for the several community bulkheads and docks around the lake.

Some recent years club led maintenance initiatives include:

- Funded and led the effort to fix the beach erosion problem at Rose's Beach.
- The Cabin Springs boat ramp is scheduled for repair during the next drawdown.
- Funded and led the effort to replace the seawall in Cabin Springs about 8 years ago.
- Funded and led the effort to replenish the sand at the Clubhouse Beach, Roses Beach and Weaver House Cove Beach.
- The seawall at the club is going to need a major repair or replacement very soon. (It has a few very large cracks.)

Some future club maintenance initiatives include:

- The Cabin Springs boat ramp is scheduled for repair during the next drawdown.
- The seawall at the club is scheduled for major repair or replacement. (Timeline TBD)

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COASTAL
ENVIRONMENTAL SERVICES INC.

R. CONNER

CRANBERRY LAKE
DIAGNOSTIC FEASIBILITY STUDY

Prepared for:

Township of Byram
Municipal Building
10 Mansfield Drive
Stanhope, New Jersey 07874

Prepared by:

Coastal Environmental Services, Inc.
2 Research Way
Princeton, New Jersey 08540
(609) 987-0966

2 April 1992

CRANBERRY LAKE
DIAGNOSTIC FEASIBILITY STUDY

PREPARED FOR:

TOWNSHIP OF BYRAM
MUNICIPAL BUILDING
10 MANSFIELD DRIVE
STANHOPE, NEW JERSEY 07874

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2 APRIL 1992

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EXECUTIVE SUMMARY

As a result of community concern over the perceived decline in the quality of Cranberry Lake, action was taken at both the local and state levels to more fully understand the lake's problems. In 1988, the Township was awarded a 314 Clean Lakes Program grant to conduct a Diagnostic/Feasibility Study of the waterbody and its attendant watershed. The purpose of this study was not only to characterize the lake, but to identify and quantify the causes of the lake's decline and to develop a plan for its restoration and long-term management.

The data and conclusions presented herein detail the findings of that study. The final section of this report consists of a lake Restoration/Management Plan. Based on the findings of the Diagnostic/Feasibility Study, the activities described in the plan represent the best course of action to enhance and/or improve Cranberry Lake. The specified measures and their order of implementation reflect the most feasible, technically appropriate, and fiscally acceptable approach to improvement of the quality and recreational opportunities of the lake.

In summary, the results of this study conclude that long-term management of the lake will require implementation of measures that emphasize nutrient and sediment load reduction. This will be best accomplished through:

- Septic Management
- Soil Erosion Control
- Stormwater Quality Management
- Land Use Ordinances
- Product Modification

In addition, measures that ameliorate the impacts of eutrophication (weed growth, algae blooms, sedimentation) must also be implemented. This is important given the lake's recreational status. For Cranberry Lake, those in-lake measures which were determined to be the most feasible and impart the greatest benefits are:

- Harvesting of Aquatic Weeds
- Spot Dredging of Selected Coves and Shallow Embankments
- Judicious Use of Herbicides
- Hypolimnetic Application of Alum

Of the watershed management and in-lake restoration measures listed above, it was concluded that septic management and aquatic weed harvesting should be prioritized. Details are provided in Chapter 9 of this report of the feasibility analysis, costs and implementation schedule for the prescribed plan.

1.0 General Description and Identification

Cranberry Lake is located in Byram Township, Sussex County, in the northwest (Highland) region of New Jersey. Byram Township is bordered by Andover Township to the north, Sparta Township to the east, Mount Olive Township to the west and southwest, and the Boroughs of Stanhope and Hopatcong to the south. The lake lies in the west central portion of the township with its center at approximately 40° 57'00" north latitude, 74°44'40" west longitude (Figure 1.1).

The lake is a very irregularly shaped waterbody with numerous coves and embayments. A large peninsula (Strawberry Point) essentially divides the lake into two (north and south) basins. Pytlar (1976) reports that Cranberry Lake attained its present depth, volume and configuration as a result of the construction of the dam in 1830. This, in essence, connected the two basins, which prior to the construction of the dam were two separate ponds. Water from the lake was used at that time to supply the nearby Morris Canal.

Two major tributaries provide inflow to Cranberry Lake (Figure 1.1). Both are un-named and enter the lake's northwest and southwest arms, respectively. The majority of inflow is typically from the southwest tributary which drains the Allamuchy Tract.

Cranberry Lake itself is classified by the NJDEPE as FW2-TM(C1) (N.J.A.C. 7:9-4.1 et seq.). The lake's outlet streams within Cranberry Lake State Park are classified FW2-NT(C1), while outside the park the streams are classified FW2-NT. A definition of the state classifications are provided in Appendix G which accompanies this report.

Cranberry Lake provides a variety of recreational opportunities for area residents. Fishing, boating, and swimming are three of the most popular lake uses. Public access is provided through Cranberry Lake State Park. A boat launch and fishing area, adjacent to the lake's main spillway, are the major features of the park. The Cranberry Lake Community Club (CLCC), a private organization, provides two beach areas with several rafts and docks for its patrons. There are a host of amenities associated with the club including a club house and concession stand. Throughout the communities which surround Cranberry, small beaches and boat docks can be found in great number. Although direct access to the lake is somewhat difficult from the Allamuchy Tract, this large expanse of undeveloped state owned land represents another public access point to Cranberry Lake.

Eutrophication of the lake over the past years has led to an increase in the proliferation of weeds and algae. This has affected, to some degree, the overall quality of the lake. Most complaints have focused on the increased density of weeds and algae which, at times, impedes boating and swimming. In addition, as a result of storm runoff and/or septic related loading, bacterial counts (coliform) at times reach excessive levels, suggesting potential health effects for those who use the lake for contact recreation. This was evidenced even during one of the lake's earlier studies (Pytlar, 1976).

TABLE 1.1

CHARACTERISTICS OF CRANBERRY LAKE, NEW JERSEY
AND THE ATTENDANT WATERSHED

OFFICIAL NAME:	Cranberry Lake
LOCATION:	Sussex County, New Jersey 40°57'00" x 74°44'40"
AREA:	77 ha (190 acres)
AVERAGE DEPTH:	2.1 m (7 ft.)
MAXIMUM DEPTH:	4.6 m (15 ft)
VOLUME:	1.617 x $10^6 m^3$ (4.27 x 10^8 gallons)
WATERSHED AREA:	734 ha (1814 acres)
WATERSHED AREA/LAKE AREA:	9.5/1
SHORE LINE DEVELOPMENT (D^L):	3.04 *
HYDRAULIC RETENTION TIME:	0.4 yrs

* As per Pytlar (1976)

2.0 Review of Historical Data

According to the Byram Township Natural Resources Inventory (1976), Cranberry Lake is the largest of the 30 ponds and lakes located within the township's boundaries. However, there is little historical data available for Cranberry Lake. There has been only one detailed investigation of the lake. In 1975, as part of the comprehensive assessment of the Township's major lakes, Pytlar (1976) characterized the trophic status of Cranberry Lake. That study essentially reviewed the condition of Cranberry Lake and projected its future conditions, as based on pollutant loading estimates derived from existing land use activities.

In general, Pytlar categorized Cranberry Lake as a waterbody susceptible to accelerated eutrophication. This conclusion was derived from pollutant loading data which indicated that Cranberry Lake, even in 1975, was subject to an excessive annual influx of nutrients and sediments. Various environmental indicators, such as dissolved oxygen depletion, low secchi disc transparency, algae blooms, and weed growth, were used by Pytlar to support his contention of the lake's accelerated eutrophication.

Pytlar reported the lake to be non-stratified. This means that during the summer, there is fairly uniform temperatures and lack of segregated water layering from surface to bottom. Dissolved oxygen (DO) concentrations at the surface of the lake averaged 7.7 mg, but deep water, summer DO levels periodically declined to less than 1.0 mg/l. DO concentrations are important and represent the available oxygen for fish and other aquatic organisms. The lake's pH ranged from 7.5 to 8.0 spu. Nitrogen and phosphorus compounds represent the building blocks or essential nutrients required for plant and algae growth. Fairly high total phosphate-phosphorus (0.03 to 0.04 mg/l) and total nitrogen (1.0 mg/l) concentrations were measured in the lake or at its outlet. This implies that the lake is susceptible to algae blooms and the development of nuisance densities of aquatic weeds. Coliform bacteria are used by public health specialists as an indicator of water quality impacts related to animal, waterfowl and/or human fecal contamination. Sustained concentrations of fecal coliform >200/100 ml inhibit contact recreation. Coliform concentrations as high as 300 colonies/100 ml were measured by Pytlar. The lake's transparency was reported to average 1.84 m. Approximately 64% of the lake's bottom was covered by weeds, leading Pytlar to conclude that the density of weed growth in the lake's shallow sections required comprehensive management.

In addition to Pytlar's study, the NJDEPE Division of Fish Game and Wildlife has issued a number of short reports on the fishery of Cranberry Lake. The most detailed of these (NJDCED, 1950) provides a generalized history of Cranberry Lake, including information relative to its morphometry, bathymetry, and water quality, as well as its fishery. Zich (1976) prepared a short assessment of the lake's fishery resources and reported the lake to support primarily a warm water fishery. Large mouth bass, pickerel, yellow perch and catfish were listed as the most commonly captured species. Although routinely stocked by the state with rainbow trout, Zich did not consider the lake a natural trout waterbody. Its water quality classification, however, is FWI - trout maintenance. As such, the lake is considered capable of sustaining a population of trout. A compendium of fish species occurring in Cranberry Lake (Table 2.1) was presented in the Byram Township NRI. For comparative purposes, the list of fish species collected by Coastal during the summer of 1989 is also presented in that table. It should be noted

that an exhaustive fishery survey of the lake was beyond the scope of Coastal's study; therefore, the 1989 species list is only partially representative of the lake's current fish community assemblage. Included in Coastal's list are those fish particularly common in Cranberry Lake and fish most susceptible to capture given the type of sampling equipment used in this study.

TABLE 2.1

THE FISH COMMUNITY ASSEMBLAGE OF CRANBERRY LAKE

	Reported in NRI	Collected in Coastal's 1989 Survey
Largemouth bass	X	X
Smallmouth bass	X	
Eastern chain pickerel	X	
Calico bass	X	
White perch	X	
Yellow perch	X	X
Bluegill	X	X
Pumpkinseed	X	X
Red-breasted sunfish	X	
Blue-spotted sunfish	X	
Rock bass	X	
Northern brown bullhead	X	
Eastern creek chubsucker	X	
Golden shiner	X	X
Landlocked alewife	X	
White crappie	X	X

3.0 Characterization of Lake Morphometry

During the Pleistocene Epoch, Sussex County was covered by a glacier. The geological processes associated with this glaciation are responsible for the area's hilly terrain and numerous lakes. Retreat of the glacier resulted in the formation of numerous small kettle hole ponds. The construction of a dam in the early 1830's resulted in the flooding of the lowlands between two small kettle hole ponds and the creation of what is today known as Cranberry Lake.

A survey of the lake conducted in 1950 by the State of New Jersey (NJDCED, 1950) showed the lake as having two semi-deep basins. The northern basin had a maximum depth of 4.6 m (15 feet), while the southern basin's maximum depth reached only 3.6 m (12 feet). These basins are the remnants of the two small kettle hole ponds. Most of the remaining areas of the lake were found to be much more shallow, ranging from only 0.6 m to 2.7 m (2 to 9 feet). A major section of the lake's most southern end was, even in 1950, 0.5 m or less in depth.

During the spring of 1989 Coastal conducted a bathymetric survey of Cranberry Lake. The survey consisted of the measurement of water depth and depth of accumulated sediments along 60 transects (cross-sections) of the lake. The results of that survey show that there has been a significant amount of in-filling in certain sections of the lake resulting in a decrease in overall lake depth relative to the 1950 study. Most of this in-filling is restricted though to, what were even in 1950, shallow embayments.

The lake's northern basin appears to be the least affected by sediment in-filling. Cross-sections of this area show the most significant accumulations of silt to occur in the Laurel Cove area and in the narrow channel directly opposite the public boat launch, in the vicinity of the pedestrian bridge. In these areas, sediment depths of 0.3 to 1 m (1 to 3 feet) were measured. Water depths in the deep section of the north basin are still very close to that measured in 1950, ranging from 4.1 m to 4.6 m (13.5 feet to 15 feet). Sediment accumulation in the Cabin Springs Cove and Strawberry Point Cove of the lake's northern basin ranged from 0.25 to 1 m (< 1 foot to 3 feet).

In the lake's southern basin however, significant amounts of organic sediment were measured. Accumulations of sediment in the 2 to 4 m (7 to 12 feet) range were fairly common along transects surveyed south of Strawberry Point. As would be expected, given the severity of sediment deposition, south basin water depths, as measured in 1989, were much less than those measured in 1950. On average, it appeared that there had been a loss of 1 to 2 m (3 to 6 feet) of total depth in the southern basin. As a result, many of the shallow reaches of the lake's southern basin have become overgrown with emergent macrophytes.

4.0 Watershed Characteristics

Within this section of the report, information is provided relative to the geology, soils, and land use of the lake's watershed. It is well recognized that the quality of a lake is directly a function of the properties and nature of the surrounding drainage basin. As such, there is much to be gained by examining, in detail, the watershed of a lake. Details are thus provided in the following sub-sections of those watershed characteristics which can most significantly affect the quality of a lake.

On a relative scale, the watershed of Cranberry Lake is small, encompassing a total of only 734 hectares. The boundaries of the watershed are defined primarily by ridgelines and geologic formations, the most prominent being Allamuchy Mountain. Basically, the eastern boundary of the lake's watershed is Route 206. To the northwest and south, the watershed extends into Allamuchy State Park. There is a small (< 10 acre) pond west of Frenche's Pond that is part of the Cranberry Lake watershed. Discharge from that pond flows into Cranberry Lake via its main, southwest tributary. The watershed is also characterized by extensive wetlands.

4.1 Geology

The Cranberry Lake watershed is located in the New Jersey Highland physiographic province, which is a portion of the Reading Prong of the New England Province. The watershed is composed of crystallized pre-cambrian gneiss and metasedimentary rocks. Most of the watershed is underlain by hornblende granite and gneiss, complex rock units consisting of metamorphosed igneous and metasedimentary rock.

The dominant structural feature of the rock units in the watershed are the prevailing northeast trend and the presence of foliation. The northeast trend is characteristic of the regional pre-cambrian rocks, and is the primary factor influencing topography.

4.2 Soils

The entire watershed was subject to relatively recent Pleistocene Epoch, Wisconsin glaciation. Overlying the pre-cambrian bedrock is stratified glacial till. The glacial till consists of unsorted materials ranging from fine clays to large boulders that form the most common soil types in the watershed. The glacial till material is predominately stony and often contains large boulders. It may be clayey to silty. The thickness of till varies considerably, ranging from non-existent on steep rock outcrops to two to ten feet on the more gentle slopes. As a result, the soil textures tend to be variable, and depending on their locations in the watershed, range from mulch to loams with varying amounts of gravel and stones. The soil depths range from 3m or greater above bedrock, to zero along the rock outcrop areas. The major soil association within the watershed is the Rockaway-Rock outcrop - Whitman Association. The association consists of steep and very steep, deep, well-drained gravelly to very stony, loamy soils; rock outcrops; and nearly level, deep, very poorly drained extremely stony, loamy soils located on uplands. The

major soil types of the basin are as follows:

Rockaway - rock outcrop
Rock outcrop - rockaway
Rockaway
Riverhead
Whitman
Preakness
Hibernia
Carlisle
Pompton

A brief description of the characteristics of the watershed's predominant soils and their characteristics as defined by the Soil Conservation Service are presented in Table 4.1 and synopsized below:

Rockaway soils are deep, well drained, gently sloping to very steep soils with a fragipan in the lower subsoil. These soils occur largely on hilltops and hillsides often associated with rock outcrops. *Rock outcrop* consists of areas where 25 to 90 percent of the surface is covered primarily by granite rock, that is most likely to occur on hilltops. *Riverhead* soils consist of deep, well-drained gently sloping to steep soils underlain by sand and gravel at a depth of 22-36 inches. *Riverhead* soils are located on glacial outwash plains. *Whitman* soils are deep, nearly level, very poorly drained soils with a fragipan. These soils formed in material derived from gneiss and granite and occupy low positions on glaciated uplands. *Preakness* soils consist of deep, nearly level, poorly and very poorly drained soils located in low positions on glacial outwash plains. These soils formed in material derived from granite rock. *Pompton* soils are deep, nearly level, somewhat poorly drained soils formed on glacial outwash plains. These soils are underlain by thick sand and gravel beds. *Hibernia* soils are deep, gently sloping to steep, somewhat poorly drained soils that contain a fragipan in the lower subsoil. These soils occupy undulating and hilly glacial moraine landscapes and slightly concave drainageways. *Carlisle* soils consist of deep, nearly level, very poorly drained organic soils. These soils formed in depressions or low areas formerly occupied by lakes or ponds. Over a period of thousands of years, these areas filled with an accumulation of plant remains or mixed mineral sediment.

4.3 Land Use

Land use in the Cranberry Lake watershed was identified on the basis of aerial photography and zoning maps. Four land use categories were used to characterize the watershed. The land use categories identified were forested, high density residential, medium density residential and wetland (Table 4.2). The Cranberry Lake watershed was divided into seven sub-watersheds by use of topographic contours (Figure 1.1). The land area and areas of specific land use within the seven sub-watersheds are listed in Table 4.3.

The majority of the watershed is currently forested (82.3%). High density (>4 units/acre) and medium density (2-3 units/acre) residential land use account for 6.5% and 2.4% of

the watershed, respectively. The majority of the residential land occurs around the lake perimeter. Development density is greatest along the northern and western portion of the lake. Many of the residential units are seasonal cottage types that have been modified to accommodate year round residency. An interesting feature of the high residential development areas around the lake is the use of a tier development system. The steep slopes around the lake have enabled the construction of rows of residential units across the slope. In two of the sub-watersheds (sub-watershed 6 and 7) the residential development density is over 50%. These basins are associated with the major residential communities, with housing density greatest immediately adjacent to the lake's shoreline.

No commercial land use was encountered within the lake's total watershed area. Regionally, most of this type of development is confined to the Route 206 traffic corridor which is adjacent to, but outside of, the lake's watershed. No significant amount of acreage within the lake's watershed is utilized for agricultural production. This is most likely attributable to steep slopes and poor soil characteristics that prevail throughout the watershed.

TABLE 4.1

SOIL CHARACTERISTICS OF THE CRANBERRY LAKE WATERSHED

Soil series	Permeability in/hr	Erodibility	Depth to seasonal high water table (ft)	Depth to bedrock (ft)	Septic Suitability
Carlisle	2.0 - > 6.0	slight	0	> 6	severe: seasonal high water table, frequent flooding
Hibernia	0.6 - 2.0	slight	0.5 - 1.5	> 5	severe: permeability, perched water table
Pompton:	0.6 - 6.0	slight	1 - 2	> 5	severe: seasonal high water table
Preakness	2.0 - 6.0	slight	0	> 6	severe: seasonal high water table, flooding
Riverhead	2.0 - 6.0	slight	> 5	> 6	slight: **
Rockaway	2.0 - 6.0	slight	3 - 5	> 4	moderate: lateral seepage over fragipan, stone content
Rock outcrop*					severe: slopes 15-25%
Whitman	0.6 - 2.0	slight	0	> 5	severe: seasonal high water table

* No valid estimates can be made for rock outcrop

** Rapid permeability in substratum may pose groundwater pollution hazard

TABLE 4.2

DEFINITION OF LAND USE AND TYPE

Category	Land Use
High Density Residential	4 or more housing units/acre or 1.6 or more units/hectare.
Medium Density Residential	2 to 3 housing units/acre or .81 to 1.2 units/hectare.
Low Density Residential	Less than 2 housing units/acre or less than .81 units/hectare.
Forested	Areas covered by an appreciable tree canopy.
Wetland	Areas indicated by the U.S. Fish and Wildlife National Wetland Inventory Map to contain wetlands.

TABLE 4.3

CRANBERRY LAKE
SUB-WATERSHED ANALYSIS OF LAND USE

Sub-Watershed	Category	Acres	Hectares
#1	Total	153	61.5
	Wetland	6	2.4
	High density	20	8.1
	Forested	127	51
#2	Total	98	39.5
	Wetland	8	3.2
	High density	18	7.3
	Forested	72	29
#3	Total	735	297
	Wetland	67	27
	High density	63	25
	Medium density	42	17
	Forested	563	228
#4	Total	640	259
	Wetland	76	31
	Forested	564	228
#5	Total	138	56.2
	High density	8	3.2
	Forested	130	53
#6	Total	16	6.4
	High density	8	3.2
	Forested	8	3.2
#7	Total	34	13.8
	High density	20	8.1
	Forested	14	5.7
	TOTAL Surface Area*	1814	733.1

* Excludes lake's surface area.

5.0 Hydrologic Budget

The water balance of a lake, that is, the net difference between total inflow, and total out-flow and evaporation loss, is termed the hydrologic budget. There are a number of sources and losses of water which must be accounted for if an accurate representation of the hydrologic budget is to be obtained. Tributary inflow, surface runoff, precipitation and groundwater infiltration are all sources of water. Evaporation, out-flow and seepage are representative of water loss. The methodology and results of the analysis conducted to quantify each of the above applicable water sources and losses are presented in detail in the following sub-sections.

5.1 Precipitation/Evaporation

The NOAA thirty year average precipitation data, as recorded at the Boonton, New Jersey monitoring station, were used in this study as representative of the normalized monthly amount of rainfall. These data were compared to rainfall records maintained by Cranberry Lake volunteers during 1988 and 1989. Because of differences between the measured and normalized precipitation records, it was concluded that, for long term management purposes, it would be best to use the normalized data in developing the lake's hydrologic budget. As such, hydrologic loading attributable to such sources as surface runoff, direct precipitation on the lake, and tributary inflow, was calculated using the normalized precipitation data. Using this approach it is calculated that the gross hydrologic load resulting from direct precipitation on the lake's surface totals $9.3 \times 10^5 m^3/yr$.

Evaporation from the lake's surface must be accounted for in order to accurately determine the hydrologic budget. Computation of this value was conducted using the evaporation isopleths developed by Hely, et. al (1961). Derived from USGS pan evaporation rates, it can be expected that in this region of New Jersey under average conditions, 75 cm/yr of water will be lost per square meter of lake surface. Given a lake surface of 77 hectares, the hydrologic loss attributable to evaporation totals $7.07 \times 10^5 m^3/yr$ (Table 5.1). Correcting the gross precipitation related load for evaporation loss, yields a net annual direct surface precipitation load of $2.23 \times 10^5 m^3$ (Table 5.1).

5.2 Tributary Inflow and Surface Runoff

Of the seven sub-watersheds that comprise the lake's watershed, only two (sub-watershed 3 and 4) drain to USGS/NJDEPE recognized, permanent streams. Inflow from the remaining sub-watersheds enters the lake via small streams, intermittent streams, drainage swales or as direct surface runoff.

The hydrologic load originating from both tributary and surface runoff sources was computed using the empirical precipitation-stream discharge formula of Dunn and Leopold (1978). This method typically yields reasonably accurate data, comparable in terms of inherent error with field study derived data (Scheider, et al., 1979). Using the thirty year precipitation data and relevant watershed information such as slope, cover, landuse and soils, the monthly volume of

inflow associated with each sub-watershed (Table 5.2). These data were then inturn compared to staff gage measurements maintained by Cranberry Lake volunteers (Appendix B). Although there are some differences between the normalized data computed using the Dunn and Leopold formula and the staff gage interpreted data, there is general agreement both in terms of runoff trends and gross inflow volumes. It was therefore concluded that the average annual tributary/surface runoff load is 2.45 x $10^6 m^3$.

5.3 Ground Water

Groundwater is water that flows sub-surface. For our purposes, only the shallow (0-20 feet) aquifer need be considered as it is unlikely, given the geology, soils and origin of Cranberry Lake, that deeper aquifers directly affect the lake's water balance. There are two components to ground water inputs: that which feeds directly into the lake and that which seeps into tributaries which in turn feed the lake. Ground water which seeps directly into the lake may occur at discrete points (springs) and at diffuse sources (interflow) along the shoreline or in the littoral zone. Both of these sources of ground water constitute part of the lake's hydrologic budget. Precipitation which infiltrates the overlying strata and exceeds soil moisture needs and vegetative evapotranspiration loss, discharges into local aquifers and contributes to the lake's surficial groundwater load. Such groundwater inputs to Cranberry Lake are most significant during the Spring and Fall because evaporation losses and water uptake by plants are low. Thus, rainfall is provided a greater opportunity to seep into the soils and subsequently recharge the surficial aquifer. This increases the volume of groundwater available for inflow into the lake. Winter (1979) discusses the role of these different ground water flows and their interaction in a lake's hydrologic budget. As concluded in that study, and in numerous similar studies, in areas of considerable seeps and fractured bedrock geology, such as Sussex County, an appreciable amount of this ground water can feed a lake and/or its tributaries (Posten, 1982).

To account for this potential component of the hydrologic budget, the ground water runoff methodology of Posten (1982) was applied to each of the Cranberry Lake sub-watersheds. It was assumed that ground water recharge would occur primarily only during those months when soil moisture needs were low, plant uptake minimal and evaporation inconsequential, typically Fall and Spring (Dunn and Leopold, 1978). Based on a rate of 7.2 x $10^2 m^3/d/km^2$, over 210 days, (September through November and March through June), a recharge value of 1.1 x $10^6 m^3/yr$ was obtained. This represents the volume of ground water which feeds the lake (Table 5.3).

5.4 Outflow

Outflow from the lake was monitored routinely by Cranberry Lake volunteers. A staff gage was erected at both spillways and was calibrated on 10 occasions by Coastal personnel. The calibration points were utilized to develop an estimate of lake outflow (Table 5.4). Based on the analysis conducted during this study, outflow from Cranberry Lake is concluded to total the annual inflow, 3.783 x $10^6 m^3/yr$.

5.5 Hydrologic Budget

Summing the various components of the hydrologic budget yields an annual water balance, for Cranberry Lake, of 3.783 x $10^6 m^3$/yr (Table 5.4). Given a lake volume of 1.62 x $10^6 m^3$, the annual flushing rate is calculated to be 2.34 times /year. The inverse of the flushing rate, residence time is 0.43 years. This can be considered a moderate flushing rate. It implies that typical settling processes will favor the deposition of organic and fine grain particulates in the lake. In addition, sufficient contact time will exist for the bio-utilization of dissolved forms of phosphorus and nitrogen by resident algae.

Areal water load (qs) is an important function in the determination of phosphorus retention. As is the case with flushing rate, areal water loading influences the ability of algae and plankton to uptake dissolved nutrients. Lake's with low areal water loading (<30 m/yr) facilitate algal uptake of nutrients. For Cranberry Lake, the ratio of annual lake inflow to lake surface area (Q/SA) was used to compute the lake's annual water load of 4.88 m/yr.

5.6 Summary

As summarized in Table 5.4, the majority of the lake's annual inflow is attributable to watershed runoff. In addition, approximately one third of the lake's water budget is derived from groundwater interflow.

Volumetric exchange (flushing rate) is moderate and areal water loading is low. This implies that the lake's internal physical processes will tend to facilitate the settling of fine sediment particles and increase the bio-uptake of dissolved nutrients. The former is significant in that it promotes sedimentation and lake in-filling as well as increases the propensity for the retention of fine, organic and nutrient rich sediments. Such sediments can provide an internal nutrient source substantial in itself to support algal and weed growth. The later is significant in that it increases the efficiency of nutrient utilization (biouptake) by the microscopic plankton that cause obnoxious blooms.

TABLE 5.1

VOLUME OF PRECIPITATION AND VOLUME OF EVAPORATIVE WATER LOSS OVER THE SURFACE OF CRANBERRY LAKE

Surface Area of Lake	$7.73 \times 10^5 m^2$
Precipitation on lake's surface*	$9.30 \times 10^5 m^3$
Evaporative loss	$7.07 \times 10^5 m^3$
Annual total net gain Due to direct precipitation	$2.23 \times 10^5 m^3$

* Based on historical 30 year average rainfall data

TABLE 5.2

TRIBUTARY AND SURFACE RUNOFF CONTRIBUTIONS TO THE ANNUAL HYDROLOGIC BUDGET OF CRANBERRY LAKE

Precip* cm	*	SUB-BASIN #								
		1	2	3	4	5	6	7	LAKE	TOTAL
7.73	Jan	1.44E+04	1.07E+04	5.75E+04	4.00E+04	1.08E+04	3.00E+03	6.30E+03	1.43E+04	1.57E+05
8.17	Feb	1.52E+04	1.13E+04	6.08E+04	4.23E+04	1.14E+04	3.17E+03	6.75E+03	1.52E+04	1.66E+05
10.08	Mar	1.87E+04	1.40E+04	7.50E+04	5.22E+04	1.41E+04	3.92E+03	8.32E+03	1.87E+04	2.05E+05
10.78	Apr	2.00E+04	1.50E+04	8.02E+04	5.58E+04	1.51E+04	4.19E+03	8.90E+03	2.00E+04	2.19E+05
9.34	May	1.73E+04	1.30E+04	6.95E+04	4.84E+04	1.30E+04	3.63E+03	7.71E+03	1.73E+04	1.90E+05
9.74	Jun	1.81E+04	1.35E+04	7.24E+04	5.05E+04	1.36E+04	3.78E+03	8.04E+03	1.81E+04	1.98E+05
11.05	Jul	2.05E+04	1.53E+04	8.22E+04	5.72E+04	1.54E+04	4.29E+03	9.12E+03	2.05E+04	2.25E+05
12.75	Aug	2.37E+04	1.77E+04	9.48E+04	6.60E+04	1.78E+04	4.95E+03	1.05E+04	2.37E+04	2.59E+05
9.39	Sep	1.74E+04	1.30E+04	6.98E+04	4.86E+04	1.31E+04	3.65E+03	7.75E+03	1.74E+04	1.91E+05
9.39	Oct	1.74E+04	1.30E+04	6.98E+04	4.86E+04	1.31E+04	3.65E+03	7.75E+03	1.74E+04	1.91E+05
11.40	Nov	2.12E+04	1.58E+04	8.48E+04	5.91E+04	1.59E+04	4.43E+03	9.41E+03	2.11E+04	2.32E+05
10.50	Dec	1.95E+04	1.45E+04	7.81E+04	5.44E+04	1.47E+04	4.08E+03	8.67E+03	1.95E+04	2.13E+05
	Totals:	2.24E+05	1.67E+05	8.95E+05	6.23E+05	1.68E+05	4.67E+04	9.93E+04	2.23E+05	2.45E+06

TOTAL = $2.45 \times 10^6 m^3$
or
6.47×10^8 gallons

*
E + 04 = 10,000 m^3 = $10^4 m^3$
E = 05 = 100,000 m^3 = $10^5 m^3$
E + 06 = 1,000,000 m^3 = $10^6 m^3$
$1 m^3$ = 264.2 gallons

TABLE 5.3

CALCULATION OF GROUNDWATER INFLOW TO CRANBERRY LAKE

$7.2 \times 10^2 m^3/d/km^2$ (Using 210 days per year)

Sub-watershed	Area (m^2)	Area (km^2)	Inflow (m^3/yr)
#1	6.192×10^5	.6192	9.36×10^4
#2	3.966×10^5	.3966	6.00×10^4
#3	2.975×10^6	2.975	4.50×10^5
#4	2.59×10^6	2.59	3.92×10^5
#5	5.585×10^5	.5585	8.44×10^4
#6	64.752	.064752	9.79×10^3
#7	137.598	.1376	2.08×10^4
		Total Groundwater Inflow:	$1.11 \times 10^6 m^3/yr$

TABLE 5.4

HYDROLOGIC BUDGET OF CRANBERRY LAKE

• Inputs due to watershed runoff	2.45 x $10^6 m^3/yr$
• Precipitation directly onto lake surface corrected for evaluation	2.23 x $10^5 m^3/yr$
• Ground water recharge and subsequent influx of surplus to tributaries	1.11 x $10^6 m^3/yr$
Total Hydrologic Budget	3.783 x $10^6 m^3/yr$

With an annual water balance of 3.783 x $10^6 m^3/yr$, and a lake volume of 1.617 x $10^6 m^3$, the annual flushing rate is 2.34 times/yr. This gives a residence time of 0.43 years.

6.0 Nutrient Budget

The development of a lake's nutrient budget is the means by which the magnitude of nitrogen, phosphorus, and sediment contributions are identified and quantified. It also is the means by which the trophic state of a lake is determined. Since trophic state is a measure of a lake's productivity, its assessment and quantification is very important. It is through this analysis that it is possible to characterize a lake as oligotrophic (low productivity), mesotrophic (moderate productivity) or eutrophic (high productive). In addition, the nutrient budget is used in developing lake management strategies. This is by far, the most important application of these data. It enables the lake manager to prescribe a restoration plan that focuses on control of the lake's significant sources of nutrient and sediment influx, as well as provide a means of gauging the success of different management strategies.

6.1 Introduction

Landuse practices impact a lake through contributions of sediments and nutrients. Most of this occurs during storm events. It results from runoff, as it flows overland, intercepting and transporting particulate and dissolved pollutants. This includes eroded soils and lawn fertilizers, along with heavy metals and petroleum hydrocarbons from road surfaces. It has been demonstrated in the literature that the majority of pollutants in stormwater is associated, by means of absorption and/or adsorption, to the surface of sediment particles (Wanielista, et al., 1982; Hopkinson and Day, 1980). Increased impervious areas decrease the opportunity for stormwater percolation. The time of concentration of runoff is decreased, and the rate of pollutant transport is increased as the watershed becomes more developed (USEPA, 1980; Wilbur and Hunter, 1975). As such, high density residential areas such as sub-watersheds 6 and 7 and portions of 1, 2 and 3 contribute on a unit areal basis more nutrients than forested areas.

Compounding this are the impacts which arise from the application of fertilizers and from faulty septic systems. Many lake communities such as Cranberry Lake are characterized by high density housing on small lots in locales where soil qualities are marginal for on-site wastewater treatments. Many of the septic systems in lakefront developments such as Cranberry Lake are undersized, particularly in those instances where dwellings have been converted from seasonal to year round use. In addition, because the soils are poor, lawn care products are often over applied. On lots adjacent to and sloping toward the lake, the resulting loading from fertilizers and septic systems can be substantial.

Four main components of Cranberry Lake's nutrient/sediment budget are analyzed in this report.

1. Tributary and overland load
2. Septic-related load
3. Internally recycled load
4. Precipitation and dryfall load

The tributary and overland load represents pollutant inputs transported to the lake by stormwater runoff. The septic load represents the nutrient load that originates from septic systems. It should be noted that a system capable of meeting public health standards may still contribute to the septic load as a result of soil limitations that impede or reduce phosphorus attenuation. The internal load is the nutrients present in the lake's sediments which, as a result of prop disturbance, wind/wave action, and/or chemical/physical effects, become liberated and available for plant and algae uptake. Finally, the precipitation/dryfall load represents dissolved and particulate nutrients present in the rain, snow or dust that falls directly on the surface of the lake.

6.2 Methodology

The tributary and overland runoff contributions were calculated using field validated, USEPA modified unit area loading (UAL) coefficients (Table 6.1).

For each sub-watershed, land use categories were identified and their area quantified (Table 6.2). Four land use categories were identified in the watershed:

1. High density residential
2. Medium density residential
3. Wetland
4. Forested

The unit areal loading coefficients as developed in the Clean Lakes Program Guidance Manual (USEPA, 1983) and modified by Souza and Koppen (1983) were used to compute the lake's annual nitrogen, phosphorus and sediment loads from tributaries and overland runoff.

The role of septic systems in the nutrient loading of the lake was also investigated in this study. A lake's septic load can be calculated using basic housing, population and soils data (USEPA, 1980). According to the recent septic management study (Greeley-Polhemus Group, 1989) of the 728 buildable lots in the lake community area 420 are developed. The per unit occupancy rate is estimated to be three. Rodiek (1979) reports that on a per capita basis, 1.45 kg total phosphorus (TP) and 4.65 kg total nitrogen (TN) are produced annually. However, even with a marginally operating septic system, some degree of treatment is provided by the underlying soils. Given the density of housing, and the slope, soil, and height of seasonal high water data characteristic of the near-shore community (within 100 m of the lake) it was possible to compute typical attenuation rates. It was determined that on average, 60% of the TP and 5% of the TN generated by each system will be attenuated. The remainder will contribute to the lake's nutrient load. For Cranberry Lake, it was calculated that the septic related load is 730.8 kg (1611 lbs) TP/yr and 5566.1 kg (12271 lbs) TN/yr (Table 6.3)

Internal regeneration of nutrients is another source of phosphorus loading to lakes. Examination of the Dissolved Oxygen/Temperature profiles indicated the lake to be weakly stratified and subject to periodic low dissolved oxygen concentrations. Given the instability of the hypolimnion (deep water sections) and the small percentage of lake bottom overlaid by anoxic

(devoid of dissolved oxygen) waters, it was determined that although the internal load was probably a minor nutrient budget component, it should be computed.

It appears only 30% of the lake's bottom actually approaches anoxia during the summer. A number of TP release rates for anoxic sediments were reviewed (Nurnberg, 1982; Mawson, et. al., 1983) and a flux rate of 6.0 mg/m^2/day was selected. Accounting for temperature effects on bacterial activity, and the periodicity of low dissolved oxygen levels, it was determined that TP release from hypolimnetic sediments would most likely occur only from July through mid-September (75 days). This seems to be confirmed by examination of the 1989 data and the conclusions drawn by Pytlar (1976). The resulting load (104 kg TP/yr) is conservative, and is probably somewhat of an underestimate of actual conditions (Table 6.4). Three factors are responsible for this potential underestimation. First, it is not known exactly how long a given area of the lake's hypolimnion remains anoxic. Second, phosphorus release was computed for only 75 days. Regeneration of sediment bound TP occurs throughout the remainder of the year, both in the littoral zone (shallow) and oxic (high DO) sections of the lake as well as in the deep anoxic sections. The sediment release rates for shallow water, oxic sediments, however, is approximately 10% or less of that observed under anoxic peak release rate conditions. Finally, aquatic macrophytes can influence sediment phosphorus reserves, by actually pumping TP from the sediments by the weed's root system. This can result in increased mobilization of sediment bound phosphorus. Given the density of weeds in the lake's southern basin, this TP pumping would add to the lake's internal load. As such, the internal load estimated herein from available information may be $\pm$ 10% of actual conditions.

The final source of nutrients accounted for pertains to precipitation and dryfall (dust) (Tables 6.1 and 6.2). Once again, USEPA loading coefficients were used. This source of nutrients was minor but was included in order to insure the accuracy of the budget.

6.3 Quantification of the Nutrient Budget

The results of the above analyses represent the predicted annual phosphorus, nitrogen and sediment loads.

The predicted tributary and runoff loads of phosphorus, nitrogen and sediment computed using U.A.L. methodology, are presented in Table 6.2. The data indicate that a total of 205.4 kg of phosphorus enter the lake on an annual basis from overload runoff and tributary sources. A substantial amount of the load is contributed from sub-watersheds 3 and 4. As much as 211,400 kg of sediments is annually transported via these same sub-watersheds into the lake. This is equivalent to approximately 62% of the total annual sediment load of 339,055 kg/yr.

In general, those sub-watershed with the greatest percentage of residential land use contributed relatively more phosphorus, nitrogen and sediment per unit area than the more forested sub-watersheds. The sediment load in actuality, is not excessive. This is due to the small total area of the watershed and the lack of agricultural activity or large open-disturbed (bare soil) tracts within the watershed.

Although nutrient loading from tributary and runoff sources is substantial, it is far less than that associated with septic systems. Similarly, the projected internal load represents an important phosphorus source, but its importance in the lake's overall budget is diminished relative to the septic load.

A summary of nutrient and sediment loading from the lake's major internal and external sources is presented in Table 6.4. These data represent the lake's predicted annual nutrient and sediment budget. As shown in Table 6.4, the most important source of nutrient loading to the lake is that attributable to septic systems. Of secondary importance is overland and tributary runoff. However, this source represents the means by which silt, soil and organic debris washes into the lake. The sediment load attributable to runoff is 339,055 kg (745,921 lbs). The internal load of phosphorus amounts to only 104 kg/yr, but most of this is in a dissolved form and, as such, is immediately available for algal uptake and utilization.

As will be discussed in the final two sections, these nutrients and sediments are contributing to the demise of Cranberry Lake. The nutrients promote plant growth whereas the sediments cause the silting and in-filling of the lake's shallower bays. Corrective actions, formulated in part from these data, will be developed with the objective of promoting an overall reduction in loading and a subsequent improvement in lake water quality.

TABLE 6.1

CRANBERRY LAKE
Non-Point Source (NPS) Loading Coefficients

	TN****	TP	TSS
Forest	2.5	0.2	250
Low Density	2.5	0.4	1000
Medium Density	5.0	0.8	2000
High Density	7.5	1.2	3000
Precipitation on lake*	10.0	0.25	----
Dryfall on watershed**	0.4	0.002	----
Wetland	---	-0.25***	-200***

* Precipitation related pollutant load that falls directly on the lake's surface.

** Dust and other atmospheric-borne dryfall pollutants deposited on the watershed.

*** Negative coefficient due to wetland attenuation.

**** TN = Total Nitrogen, TP = Total Phosphorus, TSS = Total Suspended Solids.

TABLE 6.2
ANNUAL POLLUTANT LOADING (kg) TO CRANBERRY LAKE FROM TRIBUTARIES, RUNOFF, DIRECT PRECIPITATION AND DRYFALL

Sub-watershed	Category	Acres	Hectares	TN	TP	TSS
#1	Wetland	6.0	2.40	----	-0.60	-480.0
	High density	20.0	8.10	61.0	9.70	24,300.0
	Forest	127.0	51.00	127.0	10.00	12,750.0
	Total	153.0	61.50	188.0	19.10	36,570.0
#2	Wetland	8.0	3.20	---	-0.80	-640.0
	High density	18.0	7.30	55.0	8.80	21,900.0
	Forest	72.0	29.00	72.0	5.80	7,250.0
	Total	98.0	39.50	127.0	13.80	28,510.0
#3	Wetland	67.0	27.0	---	-6.75	-54000.0
	High density	63.0	25.0	188.0	30.00	75,000.0
	Medium density	42.0	17.0	85.0	14.00	34,000.0
	Forest	563.0	228.0	570.0	46.00	57,000.0
	Total	735.0	297.0	843.0	83.25	160,600.0
#4	Wetland	76.0	31.0	---	-7.75	-6200.0
	Forest	564.0	228.0	570.0	46.00	57,000.0
	Total	640.0	259.0	570.0	38.25	50,800.0
#5	High density	8.0	3.20	24.0	3.80	11,400.0
	Forest	130.0	53.00	132.0	11.00	13,250.0
	Total	138.0	56.20	156.0	14.80	24,650.0
#6	High density	8.0	3.20	24.0	3.80	11,400.0
	Forest	8.0	3.20	8.0	0.60	800.0
	Total	16.0	6.40	32.0	4.40	12,200.0
#7	High density	20.0	8.10	61.0	9.70	24,300.0
	Forest	14.0	5.70	14.0	1.10	1,425.0
	Total	34.0	13.80	75.0	10.80	25,725.0
Tributary and runoff total		1814.0	733.40	1991.0	184.40	339,055.0
Direct Precipitation Load		191.0	77.0	770.0	19.0	-------
Dryfall Load		2005.0	810.40	294.0	2.0	-------
TOTAL		2005.0	810.40	3005.0	205.40	339,055.0

TABLE 6.3

CALCULATION OF THE SEPTIC RELATED NUTRIENT LOAD FOR CRANBERRY LAKE

Number of developed lots	420
Per capita occupancy	3
TP loading rate	1.45 kg/capita/yr
TN loading rate	4.65 kg/capita/yr
TP assimilation rate	60%
TN assimilation rate	5%
Annual TP load 420 x 3 x 1.45 x 0.4 =	730.8 kg/yr
Annual TN load 420 x 3 x 4.65 x 0.95 =	5566.1 kg/yr

TABLE 6.4

PREDICTED ANNUAL PHOSPHORUS, NITROGEN AND SEDIMENT LOADS TO CRANBERRY LAKE

ANNUAL LOAD KG.

SOURCE	NITROGEN	PHOSPHORUS	SEDIMENT
Tributary and Runoff Load	1991	184.4	339,055
Direct Precipitation	770	19.0	-------
Dry Fall	294	2.0	-------
Internal Regeneration	----	104.0	-------
Septic	5566.1	730.8	-------
Total	**8621.1**	**1040.2**	**339,055**

7.0 Limnological Survey

As well as investigating the lake's key morphological features and modelling its nutrient and hydrologic loading characteristics, effort was placed in this study relative to the monitoring of the lake's water quality. Essentially this consisted of the following activities:

1. In-lake Water Quality Sampling
2. Tributary Water Quality Sampling Under Non-Storm Conditions
3. Tributary Water Quality Sampling Under Storm Conditions
4. Macrophyte Survey
5. Fishery Survey
6. "Septic Snooper" Survey
7. Sediment Quality Analysis

7.1 Water Quality

The station locations for in-lake and tributary sampling were selected as so to be consistent with those sampled by Pytlar (1976) and/or the Byram Environmental Commission (1982) studies. Four in-lake stations were monitored; the North Basin, the South Basin, the South Shore dam, and the main spillway near Route 206. The North Basin station (station 4) was sampled at two depths; slightly below the surface and 0.5m above the bottom. At the other in-lake stations, samples were collected from slightly below the water's surface. In addition to in-lake sampling, water quality was also monitored at two tributary stations (Figure 5).

Samples were collected at the in-lake and tributary stations under baseflow (non-storm) conditions on the following dates:

22	March	1989
25	April	1989
30	June	1989
12, 26	July	1989
10, 24	August	1989
14, 29	September	1989

Sample collection, handling and analysis was in accordance with Standard Methods for Water and Wastewater Analysis, 15th Edition (APHA, 1985). Each sample was analyzed for the following:

- Soluble reactive phosphate-phosphorus (SRP)
- Total phosphate-phosphorus (TP)
- Nitrate-nitrogen (NO^3)
- Ammonia-nitrogen (NH^3)
- Total Kjeldahl nitrogen (TKN)
- Chlorophyll a, b, c and phaeophytin (In-lake stations only)

Secchi disk transparency was also measured at each station, as were water column profiles of temperature, dissolved oxygen, pH and conductivity. Cranberry Lake volunteers also monitored staff gage, rain gage and secchi disk transparency on an approximate daily basis as part of the project's in-kind match requirements.

The data compiled by Coastal are tabulated and presented in Appendix A and presented graphically in Figures 6, 7, 8, 9, 10 and 11. The results of the survey can be summarized as follows:

1. The in-lake TP concentrations (stations 4 and 5) are generally elevated (> 0.03 mg/l) in respect to the promotion of algal blooms. Near bottom, TP concentrations are at times 10x greater than surface concentrations. This verifies sediment release of TP into the water column and indicates that internal recycling of phosphorus is a potentially important factor in the lake's eutrophication process.

2. Secchi transparency declines from spring into the summer and then increases in the fall. The decline in transparency is primarily a function of an increase in the density of algae and phytoplankton. However, the volunteer data also indicates that lake clarity declines somewhat after periods of high power boat usage. This suggests that prop wash and prop related disturbance of the lake's shallow embayments suspends sediments into the water column thereby causing turbid conditions.

3. Filamentous algae (Spirogyra sp.) is common and observed throughout the lake in the spring. Planktonic algae (phytoplankton) concentrations tend to remain somewhat low (< 10 ug/l chlorophyll *a*) throughout the year. The concentration of chlorophyll *a* was occasionally higher at the 3m (9 foot) depth at station 4, than at the surface. This condition was attributable to blue green algae, specifically Oscillatoria.

4. The lake does not stratify, but at times there is a depletion of dissolved oxygen to near anoxic levels. It is theorized that the lake undergoes weak resistance to mixing during non-storm periods due to minor thermal differences between surface and bottom waters. Although not truly stratified, these density differences are enough to impede total water column circulation. When this occurs, near bottom oxygen levels become exhausted due to bacterial respiration and sediment oxygen demand. Once established, anoxic conditions persist until the lake is mixed by a major storm. During periods of anoxia, as documented by the data, significant amounts of TP are released from the sediments.

5. In-lake pH values, as measured at stations 3, 4, 5, 6 are slightly elevated relative to the stream pH values. This is probably a function of in-lake productivity and photosynthetic induced pH shifts.

6. Storm sampling was conducted on 2 May, 16 May and 2 October. The most significant observation associated with these sampling events was the turbid nature

of the runoff during the early stages (first-flush) of the storm. Laboratory analysis confirmed these samples to contain high TP concentrations (>0.2 mg/l). These data signify the importance of road runoff and storm water loading in the transport of pollutants into the lake. These data support the need for stormwater quality management.

7.2 Macrophytes

Surveys of the lake's macrophyte community were conducted in the spring and summer of 1989. Coastal observed the early development (late March) of dense blooms of Spirogyra, a bright green, filamentous, mat forming algae. Spirogyra was most prevalent in the lake's small coves and shallow embayments, such as Strawberry Point, Laurel Cove, Cabin Springs and Frenche's Grove. By April a dense bloom of Pithophora, another filamentous, benthic algae, was also observed. Most of the mats attributable to this species formed along the western shore of the lake (Cabin Springs area). Nuphar advena, the water lily, had also begun to develop in the south basin and dense, but sporatic, patches of Potomogeton crispus, curly leaf pond weed, were sighted throughout the lake.

In August, a more concerted quantitative analysis of macrophyte growth was conducted. Biomass samples (dry weight) were collected from 0.25m^2 quadrats at three locations in the lake. The densest sample (0.934 kg) was collected from the north end of the lake (Laurel Cove). The pond weed Potomogeton amplifolius and Heteranthera dubia, water star grass, dominated that sample, but minor amounts of Myriophyllum sp. were also present. The second quadrat, collected from south of Strawberry Point, had a total biomass of 0.730 kg. Nuphar advena and Brasenia schreberi, the water shield, were the dominant species. However, Myriophyllum sp. and Heteranthera dubia were also present. The final quadrat, collected near the lake's main spillway, had a total biomass of 0.485 kg., was comprised almost exclusively of Heteranthera dubia.

Additional observations conducted during the late summer surveys of the lake disclosed the presence of Potomogeton cordata, a pond weed, and Najas flexilis, a naiad. The occurrence and total coverage of these species was sporadic. But, in those locations where they were observed it was noted that although these species were present at fairly high densities, they formed patches rarely greater than ¼ acre.

7.3 Fishery Survey

In July of 1989 Coastal conducted a limited scope fishery survey of Cranberry Lake. Both trap nets (passive gear) and a 50' bag seine (active gear) were used to sample the lake's fishery. The results of that effort are presented in Table 2.1. As stated previously, an exhaustive survey was not conducted and as such, the results are not truly comprehensive. The sampling gear was effective only in the shallow sections of the lake. In general, however, this sampling effort does reveal two important factors relative to the lake's fishery community.

1. The lake is a warm water fishery. Although capable of temporarily maintaining stocked trout, the lake is best suited if managed as a large mouth bass lake. There appears to be ample forage and habitat to support a healthy large mouth bass population, and the water quality of the lake is most ammendable for such a fishery. Thus, the put-and-take trout program should continue, but effort should be concentrated in enhancing the lake's ability to sustain a healthy bass population.

2. The lake's weed densities need to be reduced, but not eliminated. That is, an improvement in predation of stunted sunfish could be achieved if overall weed densities were decreased. Present weed densities are probably impeding efficient predation by the lake's top predators. This leads to an imbalance, as evidenced in this study, in the ratio of predator to prey fish.

7.4 Septic Snooper Survey

As part of the lake's overall investigation, it was determined that a survey of the lake's shoreline for the purpose of septic leachate contamination was warranted. Such a survey would address concerns relative to the influence of septic systems on the lake's nutrient budget and help identify areas where septic breakout was most significant.

A septic leachate detector (Septic Snooper™) was employed for this purpose. This unit is essentially a portable conductivity meter and fluorimeter that is capable of detecting minor diversions in dissolved solids relative to background conditions. Confirmatory samples, analyzed for nitrate, chloride and bacteria, aid in the identification of whether the detected deviation from background conditions is septic related. The detection of these parameters in significant concentrations verifies the existence of septic breakout (i.e., septic contaminated groundwater.

On June 21 and 22 a septic survey of the lake's entire shoreline was conducted. Six areas where meter readings were substantially greater than background levels were detected (Figure 12). The location of these plumes is as follows:

1. Laurel Cove, western shore, North Shore Trail
2. Cabin Springs, near Cabin Springs Trail
3. Weaver House Cove, near Division Lane
4. Strawberry Point, north side of canal
5. Strawberry Point, south side of canal
6. Eastern Shore, vicinity of main spillway

Confirmatory samples were taken at the first five locations as both an increase in the Snooper's organic and inorganic scales were observed. The last site was not sampled as only the inorganic scale deviated from background levels. This observed deviation was attributable to turbulence which caused localized sediment resuspension.

The results of the survey are presented in Table 7.1. At all five sampled stations, total coliform bacteria levels were elevated. At stations 1, 3 and 5 the total coliform levels exceeded

state standards for contact recreation (> 200 colonies/100 ml). At these same three stations, fecal streptococcus levels were also high. Nitrate and chloride levels were low at all five stations and fecal coliform counts were high only at station #3.

In conclusion, these data indicate the existence of a broad based septic plume at all five locations. However, the severity of the problem is greatest at stations 1, 3 and 5. The extent of the problem at station 3 should be more closely examined as the laboratory results demonstrate conditions prohibitive of contact recreation. The data signify the existence of numerous marginally operating systems, and support the contention that septic systems are negatively affecting the lake's water quality. The laboratory results also indicate that this problem has health related ramifications given the detection of high bacteria counts.

7.5 Sediment Quality

The final component of the Limnological Survey entailed collection and laboratory analysis of sediment cores collected from nearshore, heavily silted sections of the lake. The sediments were tested for the presence of various pollutants with the objective of classifying them as toxic or non-toxic. Such information is needed in order to properly evaluate the feasibility of dredging the lake, and to assess if dredge spoils require special handling.

The results of these analyses (Appendix B) show the sediments to be free of measurable amounts of organic or inorganic contaminants. As such, sediment dredged from the lake can be classified as non-toxic and not subject to special handling or disposal requirements. The analysis also showed the sediments to be largely sand (74%) with very trace amounts of clay. Physical properties such as these will facilitate dredging operations by speeding spoil dewatering and decreasing potential turbidity impacts. It may also be possible to identify a market for these spoils. That is, the dredged sediment could possibly be sold or used by the township for non-structural fill or for top soil dressing purposes.

TABLE 7.1

RESULTS OF THE SEPTIC SNOOPER CONFIRMATORY LAB ANALYSIS

Cranberry Lake

	Sample #1	Sample #2	Sample #3	Sample #4	Sample #5	NJDEPE Standards
Fecal Coliform (# colonies/100/ml)	<2	<2	20	2	<2	200
Total Coliform (# colonies/100 ml)	4250	82	350	48	1300	N/A
Fecal Streptococcus (# colonies/100 ml)	2800	50	200	14	1000	N/A
Nitrate-N (mg/l)	<0.01	<0.01	<0.01	<0.01	0.02	N/A
Chloride (mg/l)	3.0	24	23	22	22	250

Trophic state modeling essentially consists of quantification of a lake's relative potential productivity by regression analysis of nutrient, hydrologic and morphometric data. A number of different models have been developed for this purpose, but most are very similar in their mathematical origin. In general, with these models it is possible to cost-effectively evaluate the effects of land use and various pollutant sources on a lake's water quality without relying on extensive field studies (Coffey, et. al., 1988). The models generate a concise value and are less subjective and more precise than the USEPA classification technique. They also allow for the easy prediction of water quality impacts arising from changes in land use, pollutant loading or lake management strategies. As such, they can be used as planning and management tools.

Most of the trophic state models are based on field measurements and empirical data. Since such data can be very site specific, the use of a model in a region other than where it has been verified can generate erroneous information. Four different models, each verified for use with northern temperate lakes, were used in this study. The morphometric, hydrologic, and nutrient loading data were used to model Cranberry Lake's phosphorus retention (Kirchner-Dillon, 1974), trophic state and spring phosphorus concentration (Walker, 1977), and chlorophyll-*a* productivity equivalent (Jones and Lee, 1986).

Emphasis was placed on the role of phosphorus in determining the productivity of Cranberry Lake. In New Jersey, phosphorus is usually the limiting nutrient and its availability will determine a lake's potential primary productivity. Typically, the greater the annual influx of phosphorus, the greater the amount of algae or aquatic plant growth. The importance of phosphorus stems from its low availability relative to the photosynthetic phosphorus requirements of algae and aquatic plants. That is, the amount of phosphorus present in the water column limits the amount of potential algal growth. As more phosphorus is added to the system, algal densities increase. Theoretically, this continues until the amount of phosphorus available in the water column becomes so excessive as to cause another trace element (silica, nitrogen, etc.) to become the limiting factor. This, however, is preceded by massive algae blooms and significant water quality impacts.

The first step in the modeling process involved calculation of the phosphorus retention coefficient; that is, the percentage of phosphorus entering the lake from all external sources that annually remains in the lake. This value is important in that it largely determines the amount of phosphorus that is actually available for plant and algae uptake. Lakes that flush frequently typically have a lower phosphorus retention rate and support a less dense assemblage of plants and algae then do infrequently flushing lakes.

The importance of lake flushing on phosphorus availability and lake trophic state stems from its relationship with areal waterload (q_s). Areal waterload, the amount of water which is exchanged in the lake during the course of a year, is a function of the lake's surface area and the annual amount of water inflow. For those lakes with a short hydraulic retention time (less than approximately 34 days) flushing is fairly frequent and the associated areal waterload is usually high (greater than 30 meters/year). Under such circumstances, the bio-uptake of available phosphorus is reduced due to the quick passage of water through the lake. Thus, much of the available phosphorus entering such lakes may pass through the system only partially utilized. The magnitude of the lake's productivity is therefore less than would be expected on the basis of

phosphorus loading alone.

For this study, the model of Kirchner and Dillon (1974) was used to predict phosphorus retention (equation 1). The R value represents the average percentage of the annual phosphorus load retained in the lake. The higher the R value, the greater the likelihood that algae and plants will have sufficient opportunity to assimilate available phosphorus. As a result, lakes with high R values (>60%) should be productive and be prone to algae blooms and nuisance densities of weed growth.

Equation 1: $R = 0.426e^{(-0.271qs)} + 0.574e^{(-0.00949qs)}$

Where:
- R = Phosphorus Retention
- qs = Areal Waterload = $\frac{\text{Annual Outflow from Lake}}{\text{Surface Area of Lake}}$
- e = 2.718 (natural log)

The second step in the modeling process involved prediction of the spring total phosphorus concentration using the empirical model developed by Walker (1977). This model is considered to be very robust. That is, the model is capable of generating reasonably accurate results even when used with a limited database. In addition, this model was specifically developed for north temperate waterbodies.

Equation 2: $[P_s] = \frac{LT}{Z} \times \frac{1}{1 + 0.824T^{0.454}}$

Where:
- $[P_s]$ = Spring phosphorus concentration (g/m^3)
- L = Areal phosphorus load ($g/m^2/yr$)
- T = Hydraulic retention time(yr) = $\frac{\text{volume of lake}}{\text{volume inflow}}$
- Z = Mean depth (m)

The spring total phosphorus data is important in that it provides an estimate of the amount of TP available for utilization by primary producers at the onset of the growing season. It is a more representative estimate of potential lake productivity than the mean summer total phosphorus concentration used in the previously discussed USEPA classification technique.

It is possible to quantify potential productivity by using the predicted spring TP concentration data with an appropriate model, such as equation 3 (Walker, 1977):

Equation 3: $X = L\,(q_s(1 + 0.824 \times T^{0.454}))^{-0.815}$

Where:
- X = Trophic state value
- L = Areal phosphorus load ($g/m^2/yr$)
- T = Hydraulic retention time (yr) = $\frac{\text{volume of lake}}{\text{Lake outflow}}$

$$Q_s = \frac{\text{Inflow } (m^3/yr)}{\text{Surface area } (m^2)} = \quad (m/yr)$$

The Log_{10} of the resulting X value was plotted on a curve that determines the probability of a particular degree of biological productivity, the lake's trophic state classification. It must be emphasized that this model calculates the probability of a lake being eutrophic, mesotrophic or oligotrophic. This is a very important distinction, and data derived from this model should not be interpreted as a definition of the degree of eutrophication. As previously discussed, eutrophic lakes span a wide range of conditions. With this model it is possible for two lakes to have the same classification probability but to have much different water quality, algae growth, and weed growth conditions. This may in part be due to specific lake characteristics such as volume, surface area, mean depth and flushing rate.

Although limnologists and lake managers routinely use phosphorus concentrations as an indicator of lake quality, a more illustrative interpretation of trophic state can be achieved by determining the amount of productivity that can be sustained by a given amount of phosphorus loading. It is expected that the greater a lake's potential productivity, the "greener" the lake. Thus, lake managers often use additional models to convert phosphorus loading values into an indicator of algae growth. The predicted maximum summer chlorophyll-*a* concentration of Cranberry Lake was derived from the data generated by Equation 4 (Jones and Lee, 1986):

Equation 4: $$C = \frac{L/qs}{1+\sqrt{T}}$$

Where:

	L	=	areal TP load
	qs	=	areal waterload
	T	=	flushing rate
	C	=	maximum chlorophyll-*a* concentration

The C value for a lake is interpreted using a log-log nomograph, and is expressed as maximum chlorophyll-*a* concentration. It should be indicated that the predicted maximum chlorophyll-*a* concentration is really a measure of potential primary productivity. Other factors that affect primary productivity such as water color, shading, grazing, and competition for nutrients by macrophytes and benthic algae mats are not accounted for in the model. Thus, one expects discrepancies between actual measured phytoplankton chlorophyll-*a* and predicted values. It may therefore be more appropriate to consider these values estimates of total potential lake productivity.

8.2 Trophic State Modeling Results

The data developed in Sections 4, 5, 6 and 7 of this study were integrated using the above models to quantify the trophic state of Cranberry Lake. The results of these analyses are presented in Tables 8.1, 8.2 and 8.3, and Figures 13 and 14.

The phosphorous retention coefficient generated for Cranberry Lake using Equation 1 is 0.66. This indicates that on average 66% of this phosphorous entering the lake is retained. As previously mentioned, R values greater than 0.6 are usually associated with lakes that support excessive densities of algae and macrophytes.

Calculation of the mean spring TP concentration involved the use of Equation 2. This model predicts that the mean concentration of TP in Cranberry Lake during the spring should be 0.176 mg/l. The mean concentration measured in April and May 1989 by Coastal at the two in-lake stations (4 and 5) was 0.107 mg/l. As such, there is fairly good (60%) agreement between the measured and predicted values.

Based on this value, Equation 3 predicts the probability of the lake being eutrophic to be approximately 98%. This means that with utmost certainty, Cranberry Lake can be properly classified as a eutrophic waterbody. The magnitude of the lake's eutrophic condition is best represented by assessment of the lake's potential productivity as represented by the maximum summer concentration of chlorophyll *a*. In 1989, a maximum concentration of 15.4 ug/l was measured at station 4. Using Equation 4, it is predicted that the lake's productivity can be as high as 18 ug/l. This value best represents productivity equivalents, that is, the total amount of in-lake plant productivity whether in the form of macrophyte, algae or phytoplankton.

8.3 Conclusions

A lake's trophic state is a direct reflection of its ecological "health". Excessively eutrophic water bodies can be expected to display most of the symptoms of lake degradation. The trophic analysis predicts the relative condition of the lake. More important, however, it can also be used to predict improvements in tropic state resulting from in-lake or watershed management programs.

Using the model developed by Walker (1977) the trophic potential of Cranberry Lake was computed. That model predicts that, with a high degree of probability ($p > 0.95$), the lake is eutrophic. The model's prediction concludes that given the lake's morphometry, hydrologic properties and annual load, Cranberry Lake has a very high propensity toward a eutrophic condition.

The important ramification of the trophic state analysis is not so much that the lake has a high probability of being eutrophic. Rather, it is that, under existing phosphorus loading conditions, Cranberry Lake can be expected to support excessive primary production. As previously discussed, the greater the influx of phosphorus, the greater the potential for the eutrophication process to be accelerated and the various negative symptoms manifested under such conditions to be promoted.

These data also indicate that even with a sound management program it will take some time to correct the lake's problems. The high retention rate of TP has undoubtably led to a substantial build up of internal nutrient pools. In-lake techniques appear to be one of the mechanisms needed to manage Cranberry Lake. This will be elaborated upon in the final section

of the report along with other measures which can be used to improve the quality of Cranberry Lake.

TABLE 8.0

EPA LAKE TROPHIC STATE CLASSIFICATION CRITERIA

	Spring TP (mg/l)	Summer CHL*a* ug/l	Average Secchi Transparency (m)	Relative Productivity
Oligotrophic	<0.005	<2.0	>8	Low
Mesotrophic	0.005-0.030	2.0-6.0	4-8	Moderate
Eutrophic	0.030-0.100	6.0-40.0	2-4	High
Hypereutrophic	>0.100	>40.0	<2	Excessive

TABLE 8.1

PHOSPHORUS RETENTION COEFFICIENT OF CRANBERRY LAKE

Equation 1

$$R = 0.426e^{(-0.271qs)} + 0.574e^{(-0.00949qs)}$$

where qs $= \frac{\text{Annual Inflow } m^3/yr}{\text{Lake Surface Area } m^2}$

$$= \frac{3.783 \times 10^6 m^3/yr}{7.7 \times 10^4 m}$$

$$= 4.88 \text{ m/yr}$$

$$R = 0.66$$

TABLE 8.2

PREDICTION OF THE SPRING TP CONCENTRATION OF CRANBERRY LAKE

Equation 2

$$P_s = LT \times \frac{1}{Z \quad 1 + 0.824T^{0.454}}$$

where:

L = Area TP load = $\frac{\text{Annual Phosphorus Load}}{\text{Lake Surface Area}}$

T = Hydraulic Retention Time

Z = Mean Depth

P_s = 0.176 g/m^3 = mg/l

TABLE 8.3

PREDICTED MAXIMUM SUMMER CHLOROPHYLL *A* CONCENTRATION OF CRANBERRY LAKE

Equation 4

$$C = \frac{L/qs}{1+\sqrt{T}}$$

where:

L	=	Areal TP Load
qs	=	Areal Water Load
T	=	Hydraulic Retention Time
C	=	Concentration Value*

C = 131.4

* Conversion of the C value into a chlorophyll *a* concentration entails interpretation of the value using Figure 8.2.

Predicted maximum chlorophyll *a* concentration

18 mg/m^3 = ug/l

9.0 Development of the Cranberry Lake Restoration and Management Plan

The ultimate goal of this study was to prepare a plan by which the lake's quality could be improved. The resulting restoration and management plan presented here provides the steps by which the lake can be enhanced and future potential impacts properly mitigated or avoided.

9.1 Introduction

The data base developed in the diagnostic portion of this study identified the problems affecting Cranberry Lake. Nutrient and sediment loading were quantified and then utilized to establish the lake's trophic state. Water quality data were reviewed and the lake's general environmental condition was determined. As well as documenting the current status of the lake, these data provide the means by which the factors responsible for the lake's degradation were identified and prioritized. Based on this information, a management plan has been developed. The measures presented in the plan represent the most appropriate and most feasible techniques given the site specific conditions of Cranberry Lake. Implementations of these measure will help insure that the proper amount of effort and money are allocated to each factor currently impacting the lake.

9.2 Development of the Feasibility Analysis

Once the lake's problems were identified and prioritized, a feasibility analysis was conducted to determine which restoration/management technique would be most applicable for Cranberry Lake.

In general, the lake's eutrophication can be attributed to watershed urbanization and the subsequent increase in sediment and nutrient loading. The lake's morphometry exacerbates the effects of increased sediment and nutrient loading. First, its generally shallow depth is favorable to the growth of macrophytes. Second, the lake's moderate flushing rate and high phosphorus retention rate promote the accumulation of phosphorus rich organic sediments. From the results of the diagnostic evaluation, it appears that the restoration/management plan should address the following:

1. Control excessive aquatic macrophyte growth
2. Reduction of accumulated organic sediment and silt in the shallow embayments
3. Improvement in hypolimnetic (deep water) dissolved oxygen concentrations

Although various measures can be implemented to address the above problems, unless action is taken to curb nutrient and sediment loading, long-term management of the lake will not be successful. Nutrient and sediment control tactics should therefore focus on:

1. Septic inputs
2. Non-point source loading of sediments and nutrients caused by watershed urbanization

3. Internal regeneration of nutrients

9.3 Management Plan

The most pervasive cause of the lake's problems is excessive nutrient loading. Based on data compiled in the diagnostic sections, it is evident septic sources, as well as erosion-related and non-point vectors of nutrients need to be controlled. It appears that this is best achieved through septic management, stormwater management, and land-use management practices. In addition, certain in-lake techniques appear to be needed to aid in the restoration of the lake and to specifically improve water quality and aesthetics. Most of the in-lake measures should not be viewed as means of controlling the causes of eutrophication but as means of reducing the impacts of eutrophication. The combination of in-lake and watershed management measures will allow for the maintenance of the lake as a viable recreational water body while providing for its long-term management.

The recommendations presented in the management plan will require the integration of many water resource programs, government agencies and funding sources. The full implementation of the plan will require a number of years to complete. To achieve the goal of restoring and managing the lake, such activities will have to be well coordinated. The Township's Environmental Commission has the demonstrated ability and has expressed the eagerness to manage such an effort.

The following sections provide a detailed explanation of the recommended components of the management plan.

9.3.1 Watershed Management

As the most significant source of the lake's nutrient load originates from septic systems, emphasis must be placed on activities that will reduce this load. Ideally, sewering the lake's immediate watershed would alleviate this problem. However, sewering is not feasible either in terms of cost or implementation. As such, this approach is not pursued in this report.

A more feasible approach to the reduction of septic loading is the implementation of a watershed-wide septic management program. This concept has been investigated in detail by the Sussex County Planning Department. The Planning Department conducted a septic waste load reduction pilot program using the Cranberry Lake community as a case study. That study's report provides a comprehensive analysis and discussion of the steps necessary for the development, implementation and institutional arrangements of a septic management program for the Cranberry Lake community (Greeley-Polhemus Group, 1989B). It is highly recommended that action be taken to implement this program. It should be emphasized that this program can be very beneficial to the long-term maintenance of the lake even if it is only partially successful in curbing the septic related phosphorus load. For example, a reduction of the septic related load by only 25% would result in a phosphorus reduction of 182.7 kg/yr. This is approximately equivalent to the total amount of phosphorus that is generated from existing runoff related non-point source load.

In addition, since approximately 50% of the lake's developable watershed is yet undeveloped (Greeley and Polhemus, 1989a), it would be prudent to invoke stricter requirements relative to the design of new systems. Recent changes in Chapter 199 of the State's Septic Code and improvements in Byram Township's Septic Ordinance (Section BH: 9-4.2, BH: 9-10) will help meet this objective. Care should also be taken by Board of Health or Planning Board personnel in reviewing additions to existing dwellings, particularly those that are located in marginally functional soils or those suspected of having sub-standard septic systems.

Another major objective of the Cranberry Lake watershed management plan is to reduce storm runoff related nutrient and sediment loading. If done properly, this will effectively slow the rate of the lake's eutrophication. Nutrient and sediment control can be achieved through a variety of methods, so it is important to thoroughly evaluate the merits, applicability and cost of various options. The following should be considered as part of this evaluation:

- Practicality of non-point source control
- Cause-effect relationship between existing load, lake response, and load reduction following management/control
- Performance characteristics and cost
- Required maintenance
- Ease of implementation

Both structural and non-structural methods can be used to decrease stormwater related nutrient and sediment loading. Structural methods include catch basins, silt traps or other devices that intercept, divert, or reduce nutrient/sediment inputs. Non-structural methods include conservation techniques, product modification (e.g., use of non-phosphorus fertilizers and detergents), and ordinances designed to reduce loading and to regulate activities responsible for nutrient/sediment influx.

In order to objectively evaluate the applicability of various watershed management methods, a feasibility matrix was developed (Table 9.1). An ordinal ranking, based on a score of 1 to 5, was assigned to each alternative based on the ability of that particular technique to successfully meet the needs of Cranberry Lake. Those alternatives scoring the highest were given priority consideration. The feasibility of each option was judged on the basis of:

- Cause-effect - how effective would this method be in immediately contributing to a noticeable improvement in lake conditions

- Degree of load reduction - once implemented how substantial a decrease in nutrient and/or sediment loading could be expected

- Practicality - can the method be practically implemented

- Performance characteristics - based on the scientific literature, how effective is this measure in abating nutrient/sediment loading

- Cost - is the cost of the method, its implementation, or its maintenance prohibitive relative to the expected returns

Although, of these criterion, each was given equal weight relative to scoring, attention was focused on the scores associated with load reduction, practicality and cost. The higher the score for each of these three matrix components, the more favorable was the management option viewed.

Review of the matrix scores indicate that the top five watershed management options are:

- Septic management
- Erosion control
- Stormwater Quality Management
- Land use ordinances
- Product modification

Each of these management options are feasible, cost-effective means by which loading can be reduced and the lake's water quality improved. Implementation recommendations for the above options (other than Septic Management which was previously discussed) are as follows (Table 9.1).

Erosion Control

Sediment influx to the lake has occurred primarily at the mouth of natural and man made inflows. In some cases the amount of accumulative sediment is significant and signals the need for better soil erosion control. Since most of the sedimentation in the lake's south basin is from the deposition of organic plant detritus as well as sediment from primarily forested tracts, the cost-benefit to passively treating these inflows by detention, retention or biofiltration is low. However, sedimentation problems in the north basin appear to be more a function of development related soil loss. Implementation of erosion control measures to curtail future loading appears to be more suitable and cost-effective in relation to the north basin inflows.

The first measure which would be taken is to more vigorously enforce county and local soil erosion control requirements. Basically, this entails the erection of silt control devices, such as haybales, silt fence and diversion berms, at sites undergoing land disturbance. All disturbances in excess of 1000 feet^2 should be considered significant and should be required to implement some form of erosion control.

The second step in decreasing sedimentation should be existing erosional areas. Disturbed but undeveloped parcels, roadway cuts, eroded swales, and stream or drainage way banks are all prime examples of erosional areas. An inventory should be made of each of these areas and an implementation schedule developed for their restoration. Based on observations made of such sites during Coastal's 1989 study, it would appear that the majority could be corrected by simple grading and seeding. Such problematic sites were observed in the Laurel Cove and Frenche's Grove sections of the community along Meteor Trail, Frenche's Grove Trail, Rose Trail and

North Shore Road.

The third step in abating this problem would entail the modification of some of the inflows to the lake. Construction of small check dams and biofilters along these drainage ways would aid in the overall sediment load reduction. Based on Coastal's site inspections it would appear that constraints imposed by the availability of land may hinder the use of detention, retention and biofiltration on most of the major inlets. However, it appears possible that some of the more intermittent storm drainage ways could be modified to provide some form of passive treatment. Inflows from Frenche's Grove, Laurel Cove, the eastern section of Cabin Springs and Strawberry Point could be somewhat modified. Although it may not be possible to construct full scale stormwater quality management structures (1 year storm design), it should be possible to elicit at least come degree of treatment. It would appear that most of the feasible measures would be lost cost types of storm water quality enhancement applications. Costs for such installations as check dams, small vegetated biofilters, and improved vegetated swales should range from $3,000 to $10,000 per system, particularly if construction labor is provided by the Township road crew.

The fourth step would involve limitations placed on boat speed and wake zones so as to prevent or reduce motor boat related shoreline erosion. Although this erosion source is not as significant as the previously discussed factors, boat wakes have caused localized erosion problems. In addition, prop and wake related disturbances suspend sediments, and induce plant fragmentation. Controls would consist of identification, posting and enforcement of low speed and no wake zones. These zones should be developed in cooperation with the Cranberry Lake Community Club, but should focus on each of the lake's shallow embayments.

Land Use Ordinances

As previously mentioned, stricter enforcement of existing regulations and ordinances governing septic design and soil erosion control is an integral component of the lake's long-term management. In addition, better land use ordinances should be developed and enforced.

In order to protect the lake from future nutrient, erosion and pollutant loading, sensitive environment land use planning is required. This relates specifically to development limitations placed on building on slopes in excess of 20%, soils of limited stability and septic suitability, and wetlands. These areas are sensitive and must be protected by limiting their disturbance. This includes not only large scale sub-divisions, but other forms of development such as minor sub-divisions, single lot development and even certain types of additions to existing dwellings, particularly those with sub-standard septic systems. Prime examples of undeveloped sections of the watershed requiring such protection are Weaver House Heights (off Hawthorne Trail), areas along North Shore Road, and Cranberry Ledge Road. The proximity of these areas to the lake, the presence of small intermittent streams which channel runoff, and of steep to moderate slopes, all enhance the environmental sensitivity of these areas. By designating these areas as environmentally sensitive, a legal basis will exist by which future development can be either restricted or conducted in such a manner that the environmental impacts are minimized.

It is recommended that as an extension of the Township's Natural Resource Inventory (NRI), that a Sensitive Lands Management Plan be prepared. The basic element of this plan would be an inventory and sensitivity analysis of the watershed using Geographic Information System (GIS) techniques. GIS enables multi-function environmental, soil, geologic, and topographic information to be compiled and interpreted in a format suitable for decision making needs. It enables planners, engineers and environmental professionals to examine the impacts on each individual factor or the cumulative impacts resulting from site disturbance, development and urbanization. Such information would serve as the database for the development of a Sensitive Lands Management Ordinances or to simply provide guidance relative to the need for special site preparation measures. The cost to conduct such an analysis, develop the necessary supporting data and maps, and prepare the ordinances should be approximately $42,000.

Stormwater Quality Management

Measures must be imposed to control stormwater runoff from all new development to the lake. In essence, this requires the creation of Stormwater Management Ordinances. Such ordinances require that stormwater management provisions be incorporated into all new sub-divisions, roadway, and commercial property construction activities. Stormwater quality enhancement provisions are different from flood control measures in that they are designed to reduce sediment/nutrient loading. Attention is focused on small storms and the first flush of major storms. Such storm events transport the highest concentrations of pollutants to the lake. These events also have a greater frequency of occurrence and therefore, are more likely to routinely impact a lake as opposed to larger, less frequent storms. Detention basins, retention basins, catch basins and grassed swales are commonly employed techniques. When the situation allows, dry wells, infiltration swales and created wetlands (biofilters) are other viable stormwater management techniques. In the preparation of such ordinances, emphasis should be placed on managing and improving the quality of stormwater runoff using such design criteria as the 1 year storm or the first flush (0.5" of runoff).

Product Modification

At the grass roots level, there are measures that have been proven effective in decreasing nutrient loading. These include the use of non-phosphorus detergents and non-phosphorus fertilizers, low flow water devices and public education in septic system maintenance. It is strongly recommended that non-phosphorus fertilizer, manufactured specifically for lake front communities be used by homeowners in the watershed. Such fertilizers are locally available through a regional distributor located in Gladstone, NJ (Allied Biological). This material could be made available through the Cranberry Lake Community Club or local hardware/garden supply stores. Some lake associations have even used the sale of low phosphorus fertilizers as a fund raising activity and a means of increasing public awareness. The use of such fertilizers is highly recommended and will be emphasized as part of the Phase II public education program.

The Borough of Mountain Lakes has successfully instituted a program that emphasizes, on a voluntary basis, the use of non-phosphorus fertilizers. That program has been so well received

and the cooperation been so broad based that the Borough avoided the need for passage of an ordinance banning the use of phosphorus fertilizers.

Public Education and Involvement Program

An integral component of the Restoration and Management plan is public education. In order to maintain public interest and support, it is important that the public be kept informed of all lake restoration activities. Equally important is the fact that they must know what is being done, and how they, the lake users, will benefit. In addition, they must become educated as to what they can do as individuals to improve the lake. This can all be accomplished through several avenues, including:

1. News releases to local newspapers

2. Special quarterly public meetings or seminars to discuss the issues that affect the lake, the progress being made, and proposed activities

3. Monthly public meetings of the Byram Township Environmental Commission

4. Presentation of papers at conferences and Technology Transfer Seminars

5. The involvement of local government, particularly the Environmental Commission, Board of Health and Planning Board, in all projects that may impact the lake or its tributaries

6. Special presentations to the various officials and professionals who are involved in various watershed management activities. This includes the Planning Board, Township Committee, DPW and County Planning Board.

7. Active participation in data-gathering activities and Phase II monitoring

8. Dissemination of information to watershed residents concerning Best Management Practices and grass roots activities which help reduce pollutant loading to the lake.

It should also be recognized that, as well as being informed, the public has to be involved. The residents of the watershed will be requested to support the plan. To date, volunteers have provided assistance in the monitoring of rain and staff gages and the collection of transparency data. Public involvement of this type identifies the community as being sincerely concerned and interested in the lake's restoration. It is important that the public thinks of the plan and the lake as theirs and that they are obligated to provide for the lake's future management.

Local citizens can be especially helpful in contacting their elected representatives and gaining support for the project. The public and public officials at all levels of government must become more fully aware that Cranberry Lake is one of the township's most important natural resources. This effort has to be continued and intensified if the plan is to be successful.

9.3.2 In-Lake Restoration Measures

Given Cranberry Lake's recreational and aesthetic attributes, the development of an in-lake restoration program is necessary. Unlike watershed management techniques, in-lake measures are usually easier to implement, somewhat less expensive, and provide much more noticeable and rapid improvements in lake quality and utilization. Although some in-lake management measures are primarily cosmetic, they can lead to substantial reductions in nutrient loading as well as to an improvement in the appearance and recreational opportunities of the lake.

As was performed with the watershed management techniques, a feasibility matrix of standard in-lake management techniques was conducted. Matrix components and scoring were similar to that utilized for watershed management. The results of the analysis are presented in Table 9.2. Of the numerous techniques assessed, the following proved to have the highest scores:

- Aquatic macrophyte harvesting
- Spot dredging
- Judicious herbicide applications
- Hypolimnetic application of alum

Each of these promises to yield the greatest potential, restoration benefits to the lake. Interestingly, lake conditions are somewhat dissimilar between the two basins. As such, different in-lake management options are prescribed for each basin. In the south basin, intensive macrophyte control is greatly needed. In the north basin, spot dredging and selective weed harvesting are recommended. The lake-wide selective use of herbicides could also benefit the lake.

The use of alum, or some form there of, to control deep water generation of phosphorus appears reasonable, but should be approached cautiously given the lake's general shallow nature. These in-lake techniques are detailed in the following sections.

Aquatic Macrophyte Harvesting

Dense beds of mixed macrophytes including *Potomogeton sp.* (pond weed), *Heteranthera sp.* (water star grass) and *Myriophyllum sp.* (milfoil) occur throughout the north basin. In the south basin, those areas shouth of Strawberry Point are heavily infested with three species of water lilies, but primarily *Nuphar advena*. All of these plants impede recreational use of the lake, especially boating and fishing. The seasonal dieback of the weeds also contributes to the lake's internally regenerated nutrient and sediment loads.

The implementation of an intensive weed harvesting program would greatly aid in the control of macrophyte densities (Nichols, 1974). In addition to increasing the total weed free surface area of the lake, harvesting could greatly influence, on a lake-wide basis, the internal regeneration of nutrients in the north basin (Souza, et al 1987, Carignan, 1985). The objective of the harvesting operation should be management of macrophytes to acceptable levels and not their elimination. Therefore, in the south basin, areas of appreciable standing crop of macrophytes

should be allowed as the area no doubt provides valuable fishery habitat.

The majority of the macrophyte harvesting will occur in the north basin. Designated areas should be cut at lease twice during the season. Harvesting could be effectively accomplished using a mid-size Harvester such as the UMI HP7-400. Although appreciable densities of macrophytes exist in the south basin, water depth and obstructions may inhibit extensive harvesting. In addition, harvesting in the north basin will yield the greatest cost benefits given the high use of this area by boaters and bathers. Approximately $35,000/year should be allotted for the purpose of weed harvesting.

Spot Dredging

The sediment accumulation study indicates that the majority of accumulated sediment is in the south basin. However, considerable quantities (1-3 feet) of sediments were measured in the Frenche's Grove, Laurel Cove, and Cabin Springs areas. Dredging, on a limited or spot basis, of these lake areas would improve the lake's recreational use and decrease weed densities (albeit for a limited time), as well as improve circulation and flushing of these restricted coves and embayments. Spot dredging is definitely much less expensive than total lake dredging and is more appropriate for the situation that exists at Cranberry Lake.

It is recommended that the dredging be done under dry conditions using conventional equipment. This will entall lowering the lake approximately 4-5 feet so as to expose the large expanses of accumulated sediment. This should be done in late October and the dredging conducted in early December through mid-March. Given the volume of accumulated sediment in each cove (3000 to 6000 yd^3), the total cost of dredging each area, including trucking, should range from $45,000 to $150,000. The wide range in costs is largely a function of trucking. If the disposal site is nearby (< 5 miles round trip) the lower estimate is more appropriate. As the distance of the disposal site from the project site increases, an increase in overall dredging costs can be anticipated. It is also possible to stage the dredging such that only two coves are done per year. This would obviously extend the duration of the overall dredging effort, but would allow for better fiscal planning. Using this approach, it would also be possible to conduct dredging projects in coordination with stormwater management or erosion control projects. This would decrease the likelihood of re-sedimentation by correcting the cause of the lake's in-filling. The analyses of the sediment conducted by Coastal conclude the physical and chemical properties of the lake's sediments to be non-hazardous and to be ammendable to dredging and disposal.

Alum Treatment

Approximately 10% of the lake's total phosphorus load is generated from anaerobic sediment. The majority of sediment regeneration of phosphorus probably occurs in the north basin. The deep water injection of alum could effectively reduce this internal load by binding available phosphorus in the sediments.

Alum, in the form of aluminum sulfate, would be added to the hypolimnion using a submergible manifold. The correct concentration of alum would be determined on the basis of analyses conducted just prior to the application. The concentration of phosphorus, the pH, and the alkalinity of the hypolimnion will determine the dosage rate and concentration of the alum. Application should occur in mid-June, before hypolimnetic phosphorus release has commenced. In this manner, adequate precautions could be taken to help insure that the sediment-liberated phosphorus is de-activated before it is circulated into the trophogenic zone. Based on previous studies, the cost for an operation of this magnitude may exceed $25,000 in the cost of alum alone. Conversely, a single treatment could yield as much as 5 or 6 years of control of the internal phosphorus load (Cooke et al., 1982).

Algicide/Herbicide Application

Although the lake is routinely treated with algicides, the concentrations of algae monitored by Coastal were fairly low and did not require control via application of such materials. It would be a better practice to control algae growth through decreasing the nutrient load to the lake than through continued treatments of the lake with algicides. Harvesting is greatly preferred to herbicide application as the means of macrophyte control, particularly in the lake's northern basin.

The density of water lilies in the south basin needs to be better controlled. Harvesting is not feasible in this area due to rocks, stumps and shallows. It may be possible to control some of this growth through lake drawdown and subsequent freezing and/or desiccation. This approach should be tested and the effects quantitatively measured. However, it appears the best approach to controlling weed growth in the south basin may be the selective, and judicious application of herbicides. In particular, the use of Rodeo or Sonar, two very effective but safe materials, should yield the types of benefits needed to meet recreational demands. Once again, as was the case with weed harvesting, the objective of any herbicide treatment should be the control, rather than the elimination of weeds. Herbicide application costs are estimated to be approximately $12,000 to $18,000/yr.

Power Boat Limitations

Some concern has arisen relative to the effect of power boats on the quality of the lake. There exists some evidence to support the contention that nuisance plants are being spread by prop disturbance and the boats may at times increase the lake's turbidity. In order to curtail the spread of weeds by boats a speed restriction (no wake, <5 mph) should be applied to the entire area south of Strawberry Point. Although water skiing is popular in the north basin, most activity is confined to the main basin, south of Frenche's Grove and the narrow channel adjacent to the boat launch. Consideration should be given to limiting boat speeds in all other coves to less than 5 mph. These boating limitations could help reduce the spread of aquatic plants by fragmentation and decrease the disturbance of the lake's silty, nutrient rich sediments. As previously mentioned, speed and wake limitations will also aid in curtailing shoreline and beach erosion.

9.4 Summary of Restoration and Management Plan

The following is a synopsis, in outline form, of the recommended Restoration and Management Plan for Cranberry Lake.

Watershed Management

1. Septic management
2. Erosion control
3. Development of land use ordinances
4. Development of stormwater management ordinances
5. Public education
6. Product modification (non-phosphorus fertilizers)

In-Lake Management

1. Spot dredging
2. Aquatic weed harvesting
3. Deep water alum injection
4. Herbicide treatment
5. Power boat restriction

Total project Phase II funding requirements

• Spot dredging	$450,000
• Erosion control measures	$160,000
• Aquatic weed harvesting	$ 35,000/year
• Sensitive lands management ordinance	$ 42,000
• Alum treatment	$ 35,000
• Herbicide treatment	$ 18,000/year
• Public education	$ 10,000
• Environmental monitoring	$ 32,000
TOTAL	**$782,000**

It is recommended that a Phase II application be submitted to conduct the following elements of the above plan as part of the initial 24 month effort managing the lake.

• Aquatic harvesting (1 year)	$ 35,000
• Spot dredging of one cove	$ 60,000
• Erosion control demonstration project	$ 10,000
• Sensitive lands management ordinance	$ 42,000
TOTAL	**$147,000**

The necessary match for these funds could be developed as follows:

• Limited herbicide application	$ 12,000
• In-kind services provided by Borough DPW in implementing erosion control demonstration project	$ 18,000
• Lake lowering (in-kind)	$ 8,000
• In-kind fiscal management	$ 15,000
• Implement Septic Management Plan (in-kind)	$ 25,000
• Environmental monitoring	
In-kind	$ 15,000
Consultant	$ 8,000
• Disposal of harvested weeds	$ 12,000
• Project management (in-kind)	$ 10,000
• Develop ordinances (in-kind)	$ 12,000
• Public education (in-kind)	$ 12,000
TOTAL	**$147,000**

Following the above implementation scenario, it would be possible to initiate major in-lake restoration and watershed management activities over the first 24 months of Phase II effort at a minimal overall project cost.

TABLE 9.1

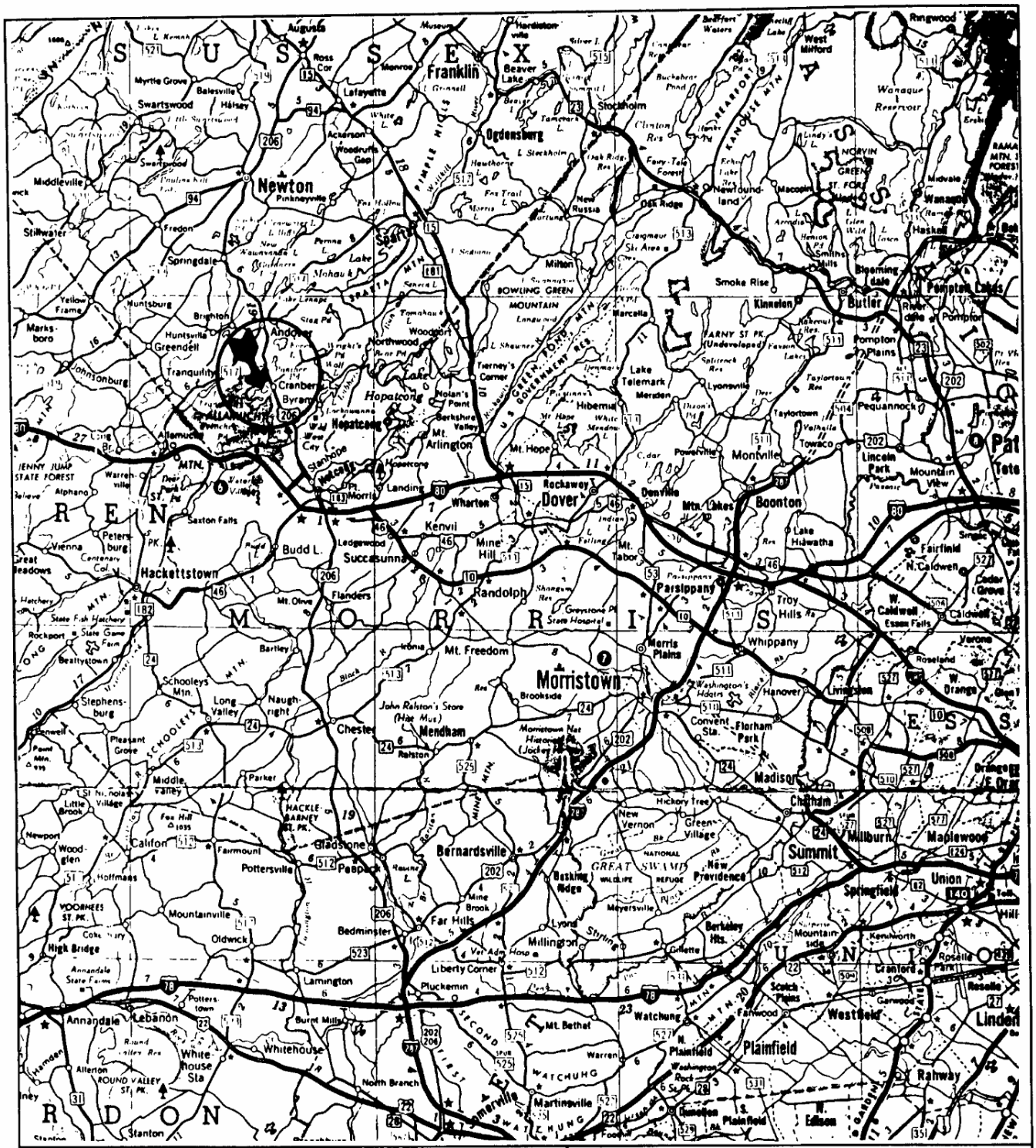
WATERSHED MANAGEMENT FEASIBILITY MATRIX

METHOD	CAUSE/ EFFECTIVE	DEGREE OF LOAD REDUCTION	PRACTICALITY	PERFORMANCE CHARACTERISTICS	COST	TOTAL
Diversion of inflow	5	2	1	1	1	10
Treatment of inflow	5	1	1	1	1	9
Stormwater Detention-Retention	5	3	3	4	2	17
Erosion Control	4	4	5	4	3	20
Land Use Ordinances	4	2	5	3	5	19
Product Modification	2	2	4	3	5	16
Public Education	2	2	5	4	5	18
Septic Management	5	2	4	4	5	20

TABLE 9.2

IN-LAKE MANAGEMENT FEASIBILITY MATRIX

METHOD	CAUSE/ EFFECT	DEGREE OF LOAD REDUCTION	PRACTICALITY	PERFORMANCE CHARACTERISTICS	COST	TOTAL
Macrophyte harvesting	3	3	5	5	3	19
Spot dredging	3	3	4	4	1	15
Alum treatment	3	2	2	2	2	11
Use of macrophyte barriers	1	1	1	4	3	10
Algicide/ herbicide	3	1	5	5	3	17
Lake lowering	1	1	2	2	5	11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Morristown
Dover
Parsippany
Randolph
Mendham
Chester
Bernardsville
Summit
Plainfield
Somerville
Ogdensburg
Franklin
Sparta
Butler
Boonton
Montville
Pompton Plains
Pompton Lakes
Wanaque Reservoir
Greenwood Lake
Kinnelon
Smoke Rise
Lake Telemark
Lake Hopatcong
Budd L.
Succasunna
Kenvil
Mt. Freedom
Mt. Arlington
Mt. Hope
Mine Hill
Mt. Tabor
Troy Hills
Whippany
Morris Plains
Hanover
Madison
Chatham
Millburn
Maplewood
Springfield
Union
Roselle
Linden
Rahway
Westfield
Scotch Plains
Fanwood
Watchung
Berkeley Hts.
New Providence
Basking Ridge
Far Hills
Bedminster
Peapack
Gladstone
Pottersville
Califon
Oldwick
Mountainville
Lebanon
Annandale
Whitehouse
Whitehouse Sta.
Lamington
Pluckemin
Liberty Corner
Millington
Mt. Bethel
Martinsville
Watchung
North Plainfield
Dunellen
S. Plainfield
W. Edison
Edison
Metuchen
Woodbridge
Perth Amboy
Sayreville
Old Bridge
Jamesburg
Monroe
Cranbury
Hightstown
Princeton
Trenton
Lambertville
Flemington
Clinton
Califon
Long Valley
Chester
Mendham
Morristown
Madison
Summit
Plainfield
Somerville
Flemington
Lambertville
Trenton
Princeton
Hightstown
Cranbury
Monroe
Jamesburg
Old Bridge
Sayreville
Perth Amboy
Woodbridge
Metuchen
Edison
Rahway
Linden
Roselle
Union
Springfield
Millburn
Chatham
Madison
Morristown
Chester
Long Valley
Califon

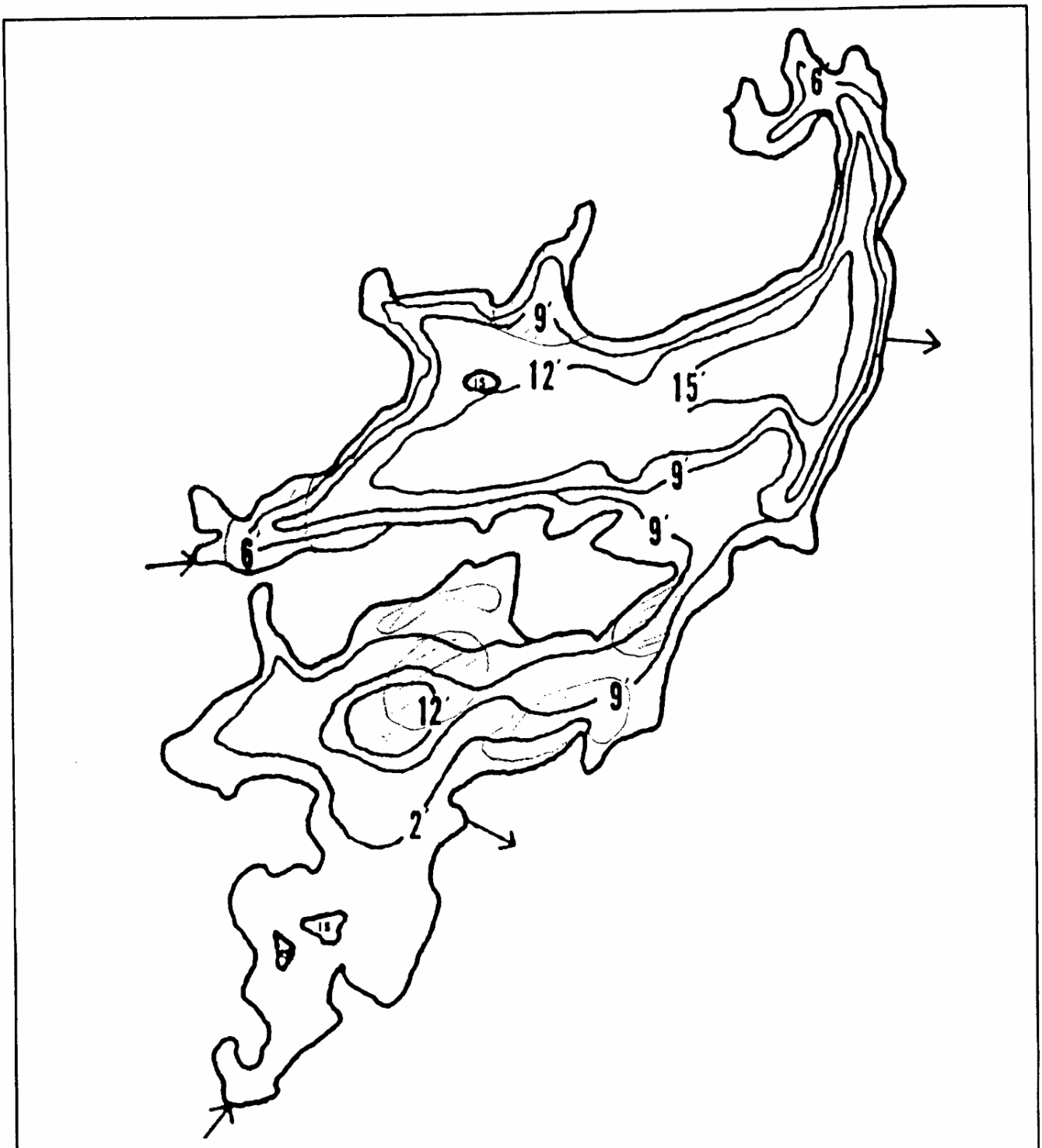

FIGURE 2
CRANBERRY LAKE
BATHYMETRIC CONTOURS

Original Source: New Jersey Department of Conservation and Economic Development, 1950
Bathymetry verified by: Coastal Environmental Services, Inc.
October 1989

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Scale:

0 400 YARDS

COASTAL
ENVIRONMENTAL SERVICES INC.

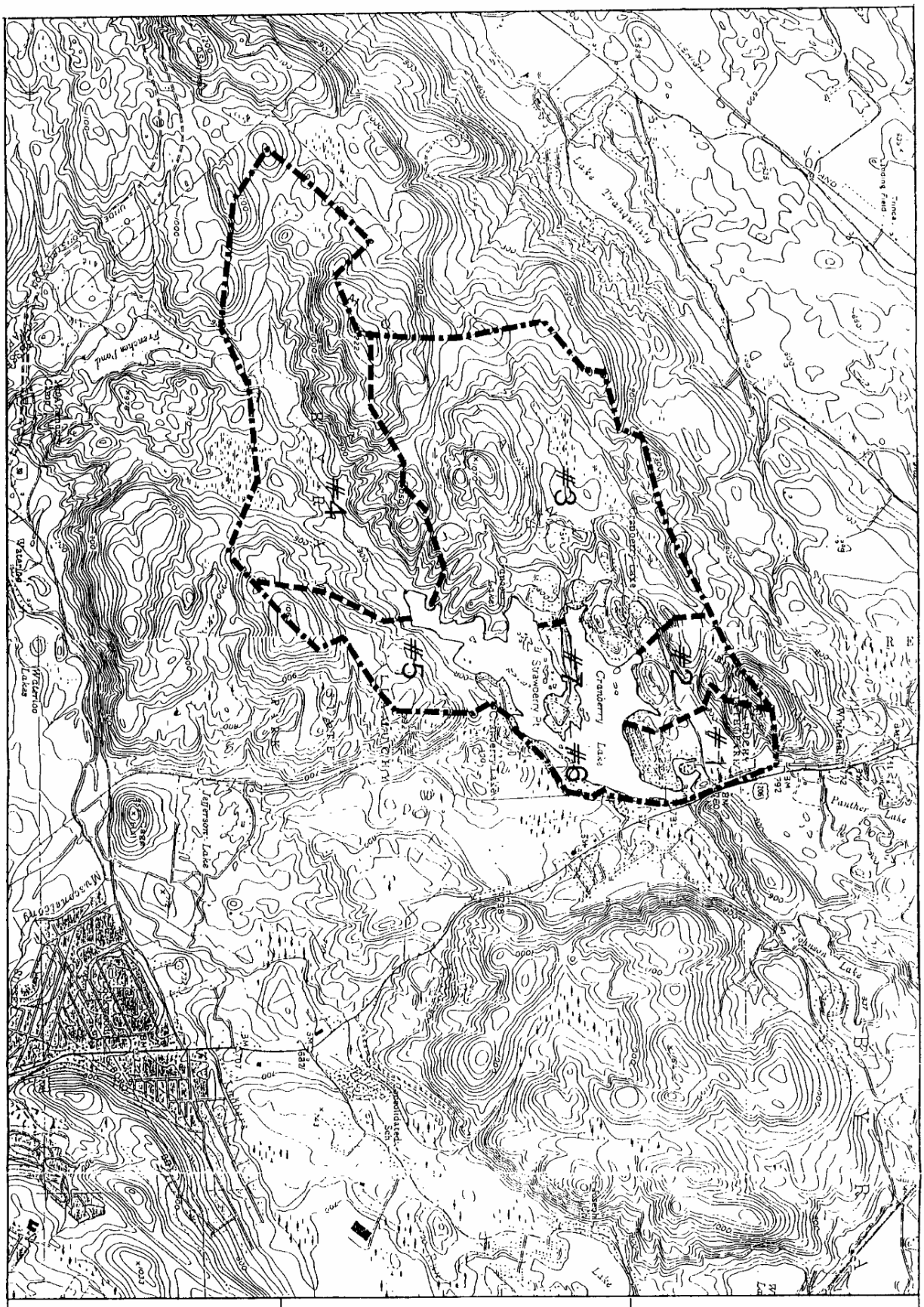

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FIGURE 3
CRANBERRY LAKE
WATERSHED DELINEATION MAP

Legend:

Watershed Boundary

Sub-basin Boundary

Scale:

Base Map Source: USGS, Stanhope and Tranquility Quandrangles

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ENVIRONMENTAL SERVICES INC

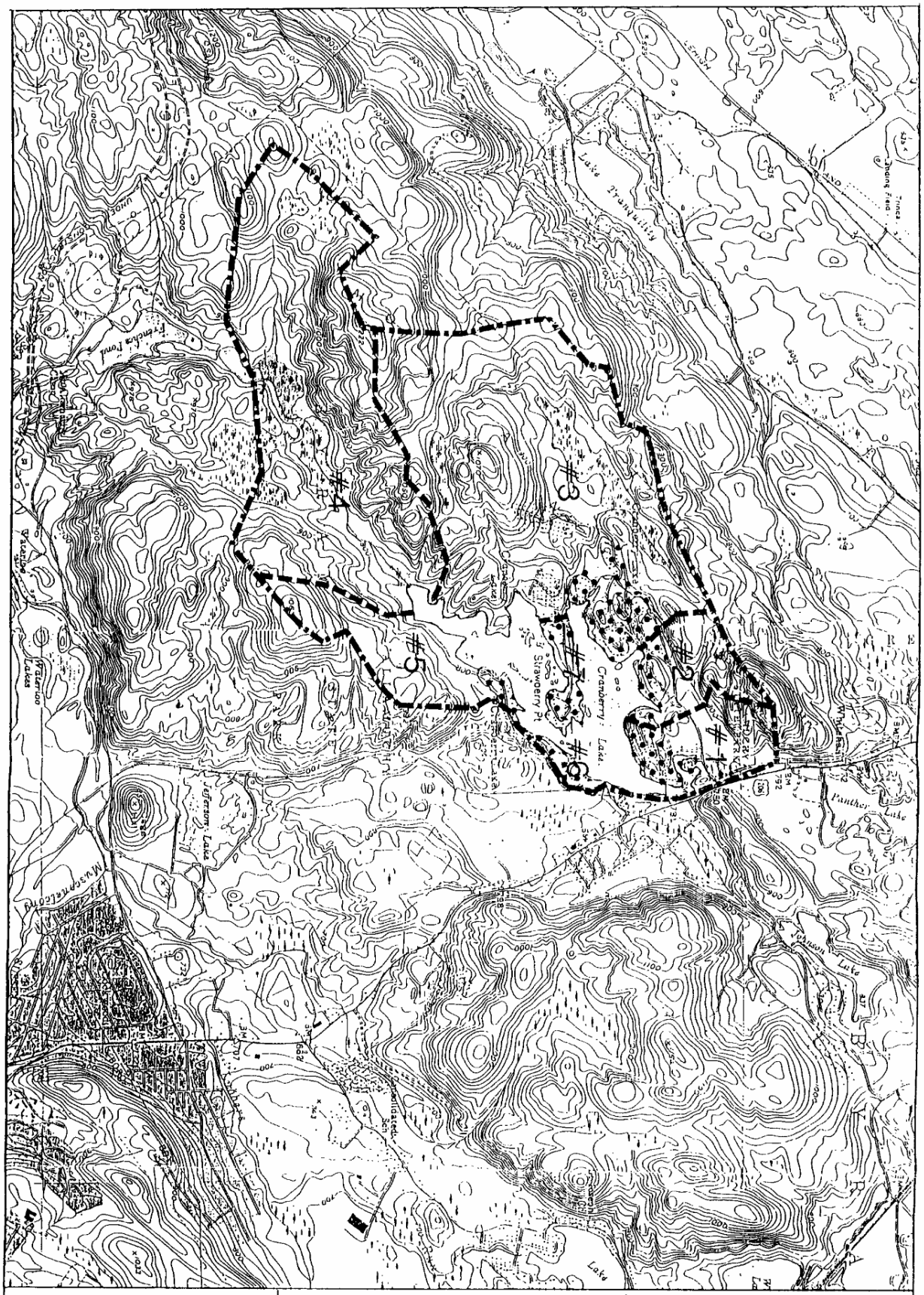

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FIGURE 4
CRANBERRY LAKE
LAND USE MAP

Legend:

- High density residential
- Medium density residential
- Forested
- Wetlands

Scale:

Base Map Source: USGS, Stanhope and Tranquility Quadrangles

COASTAL
ENVIRONMENTAL SERVICES INC

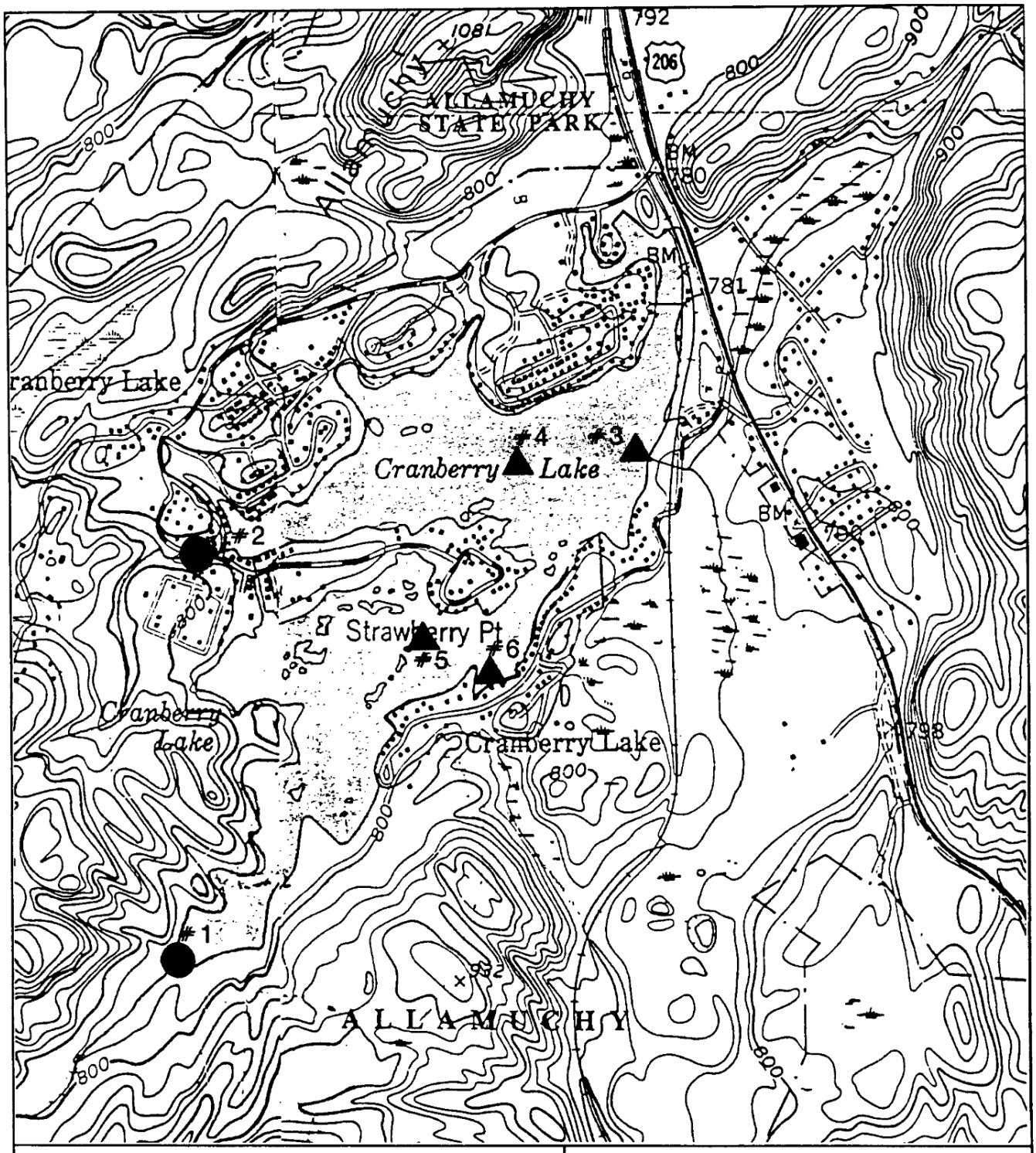


FIGURE 5
CRANBERRY LAKE
WATER QUALITY SAMPLING
LOCATIONS

Legend:

▲ In-lake station

● Tributary station

N

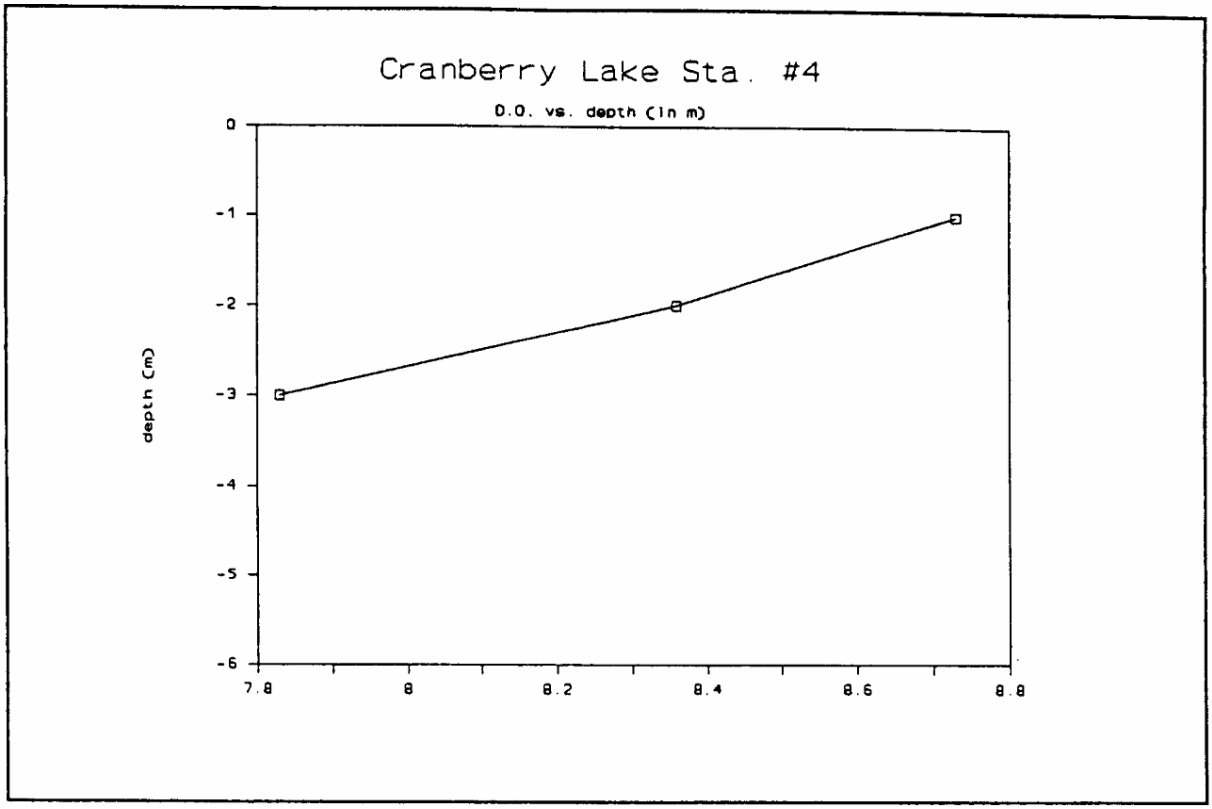
Scale:

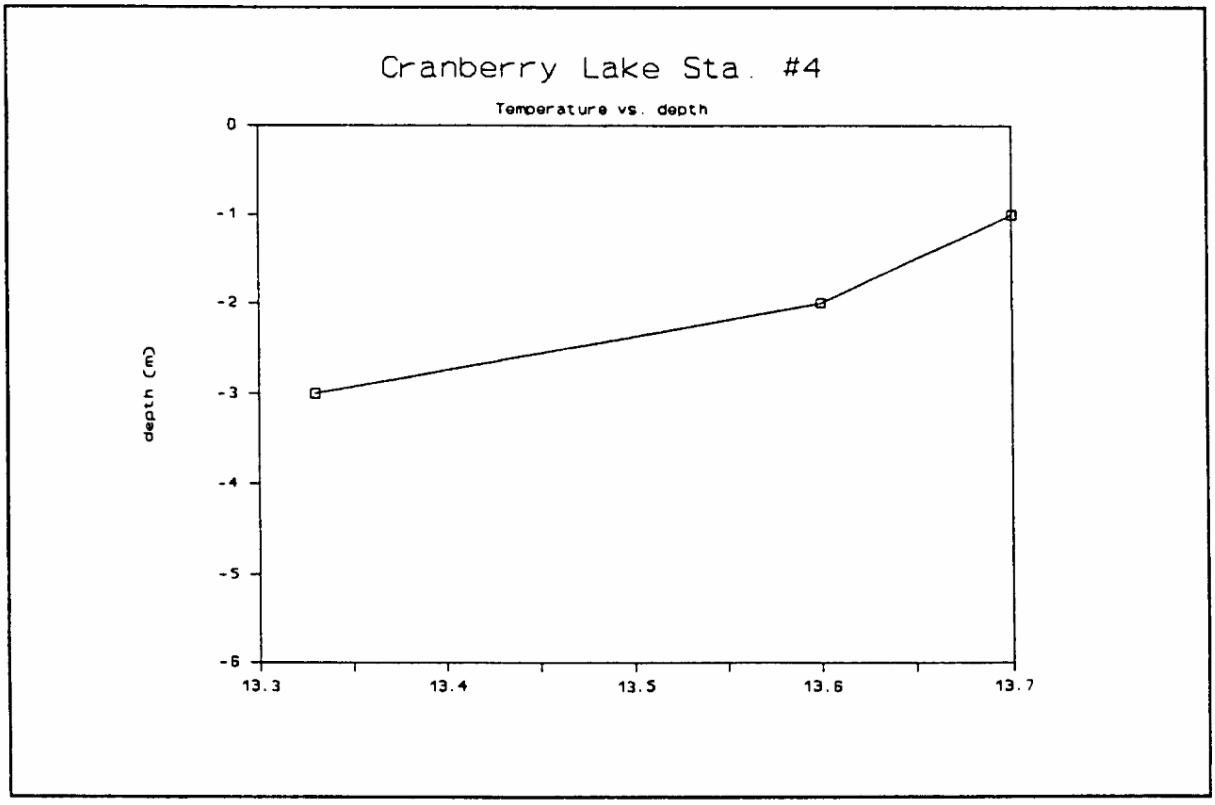
1000 0 1000 2000

Base Map Source: USGS, Stanhope and Tranquility Quandrangles

COASTAL
ENVIRONMENTAL SERVICES INC.

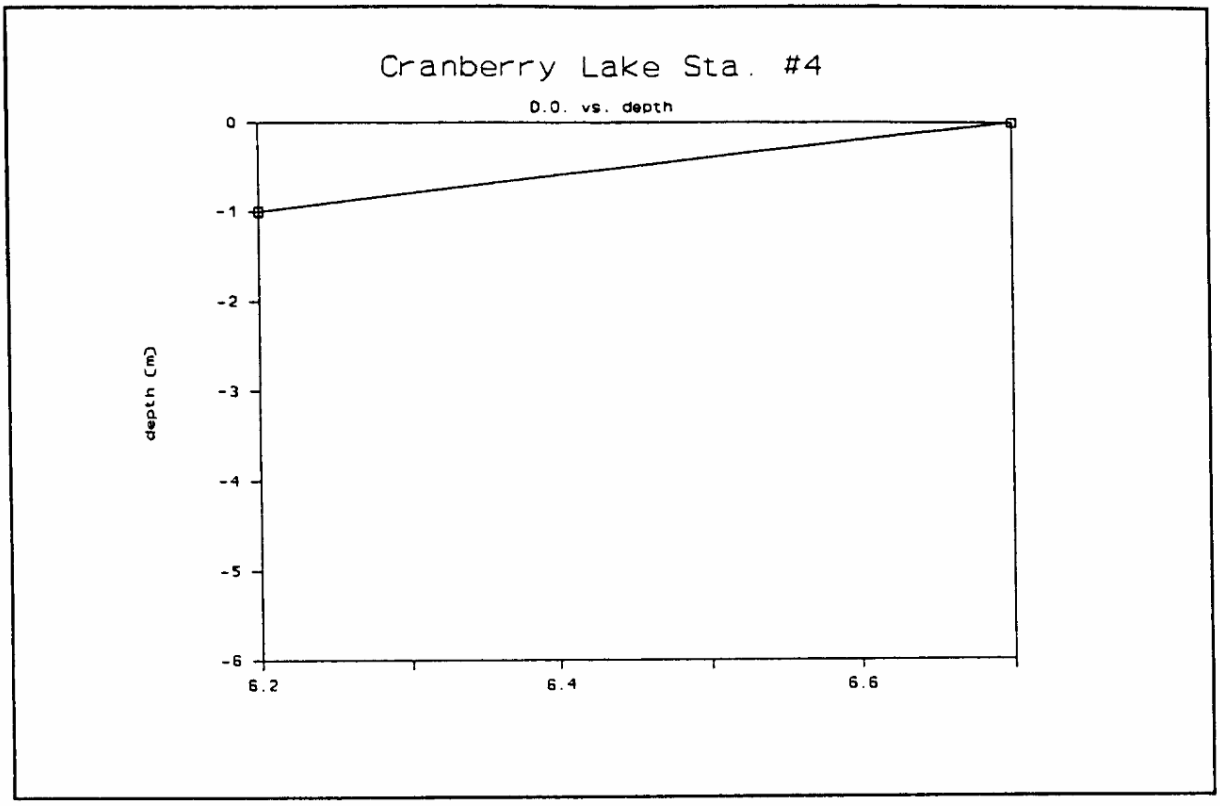
Figure 6A

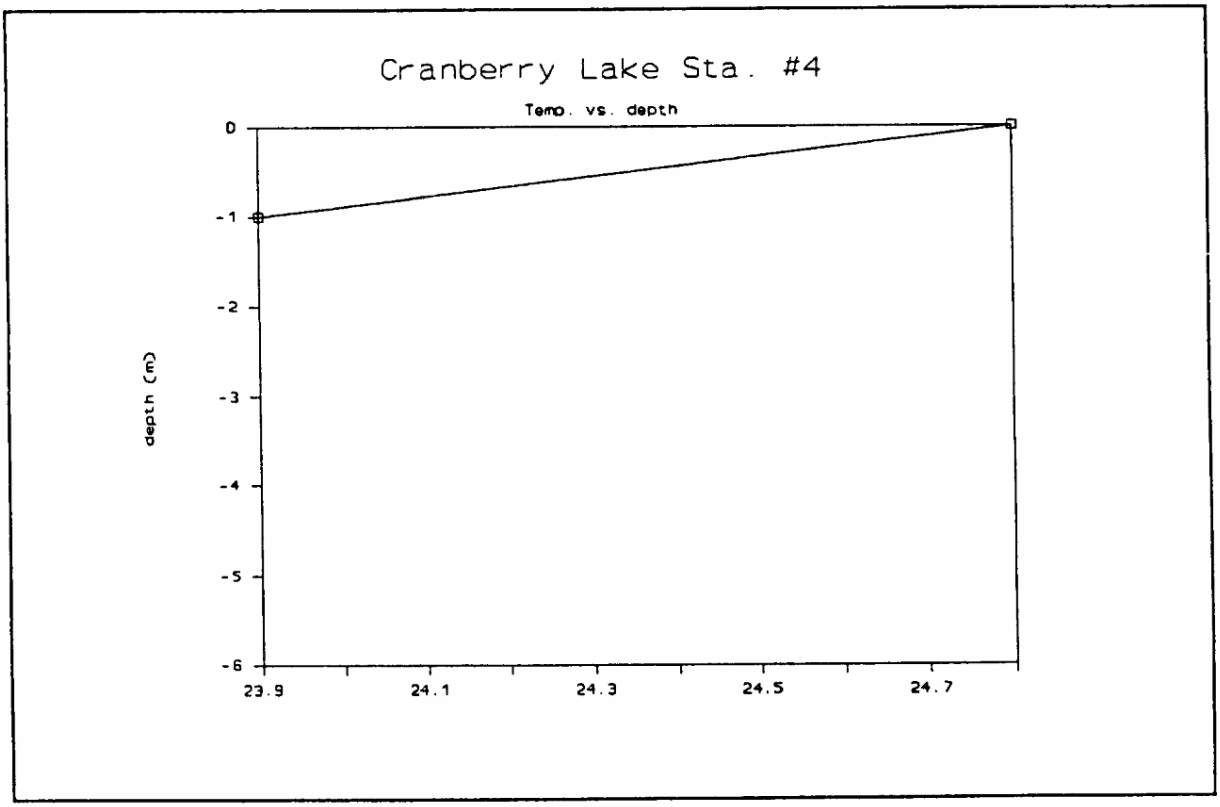




D.O. and Temperature profiles for April 25, 1989

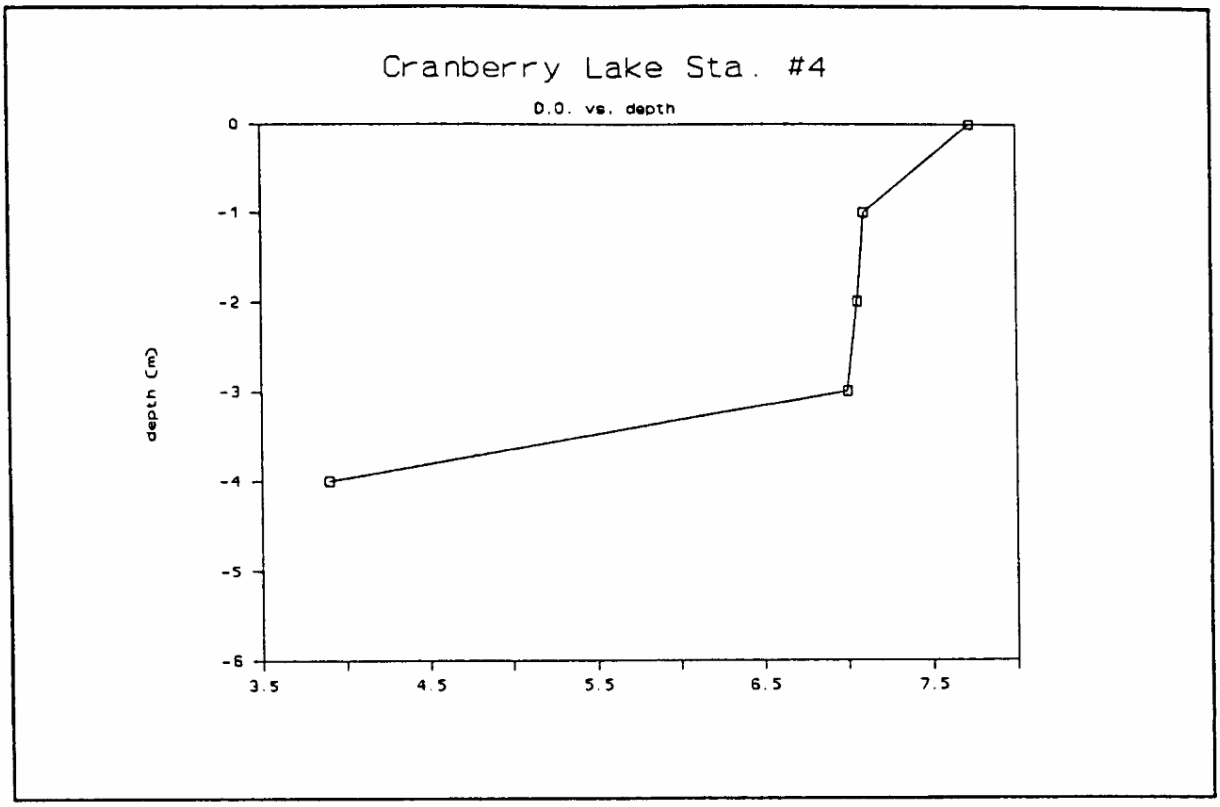
Figure 6B

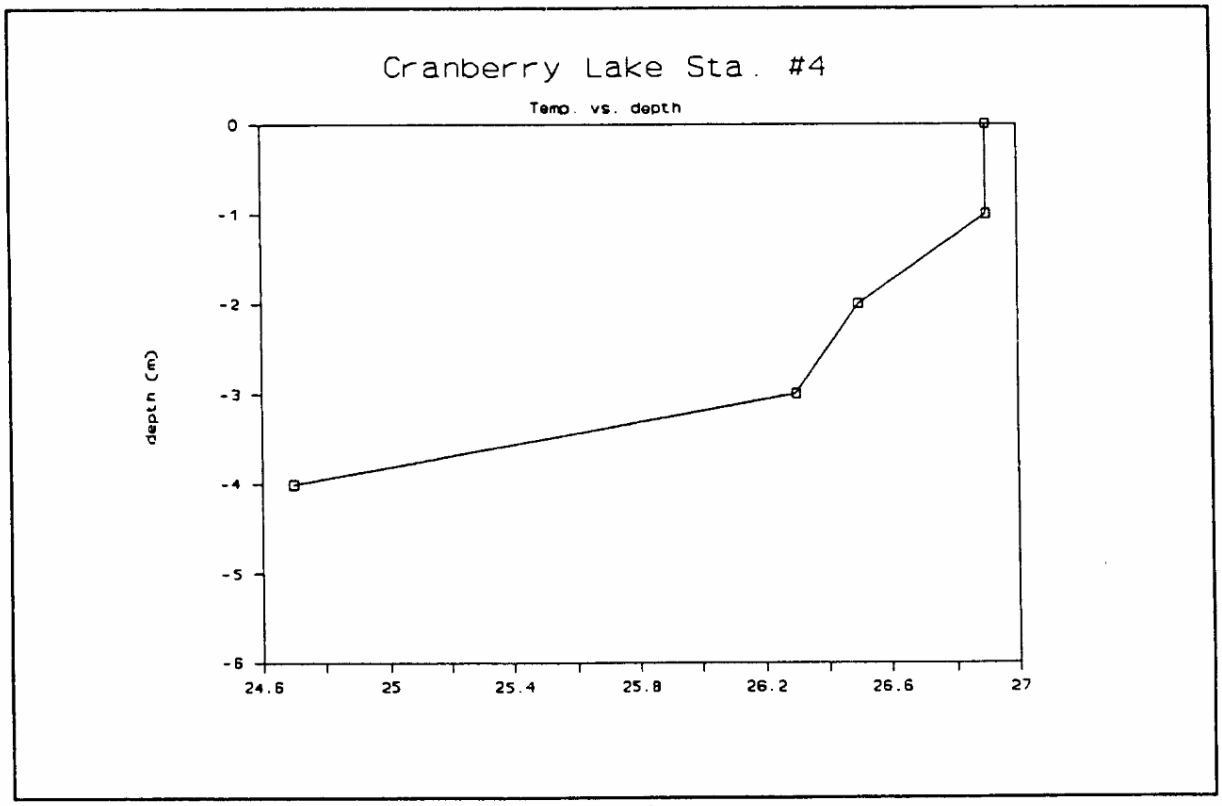




D.O. and Temperature profiles for June 30, 1989

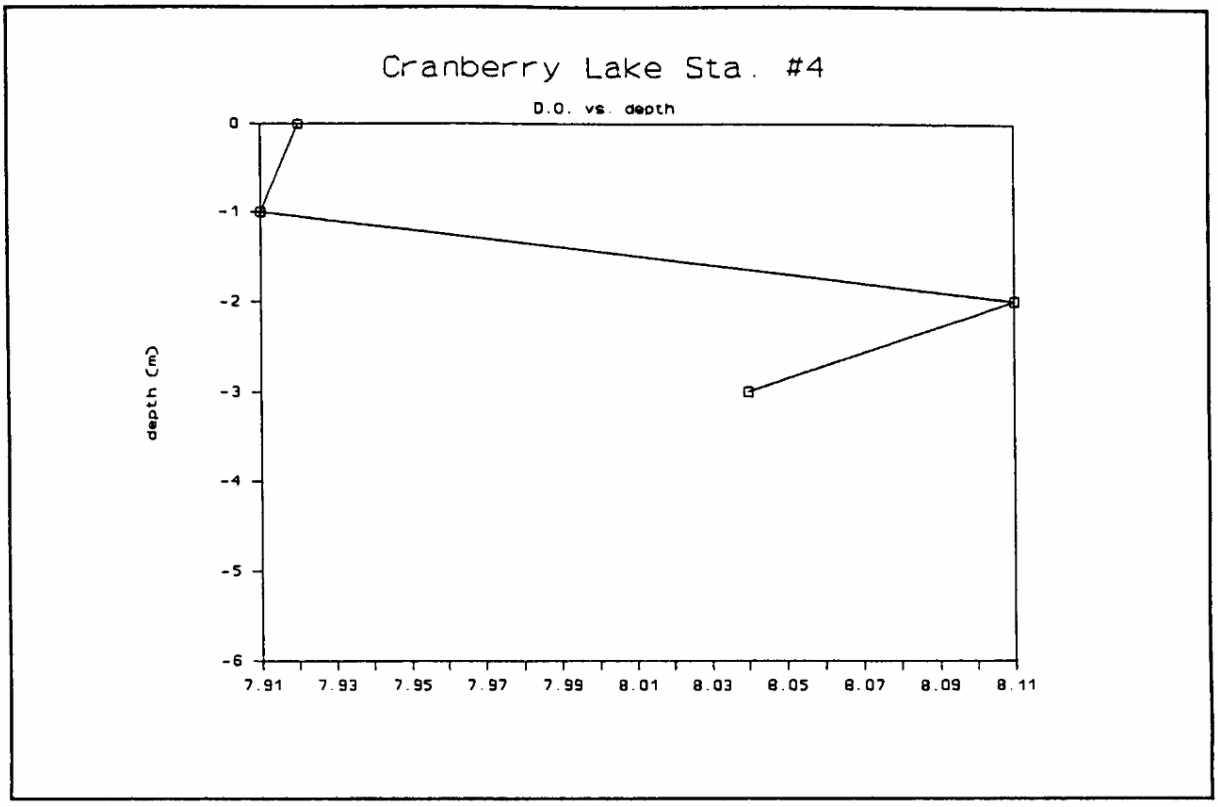
Figure 6C

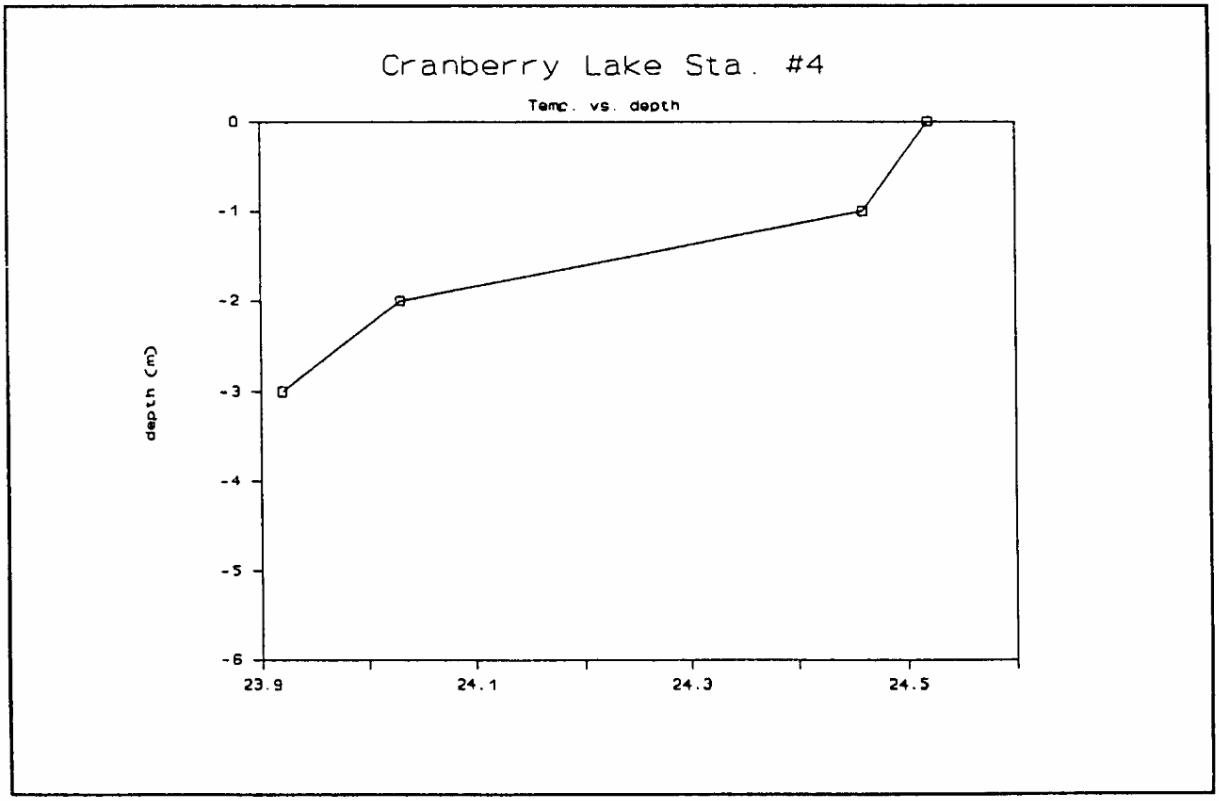




D.O. and Temperature profiles for July 12, 1989

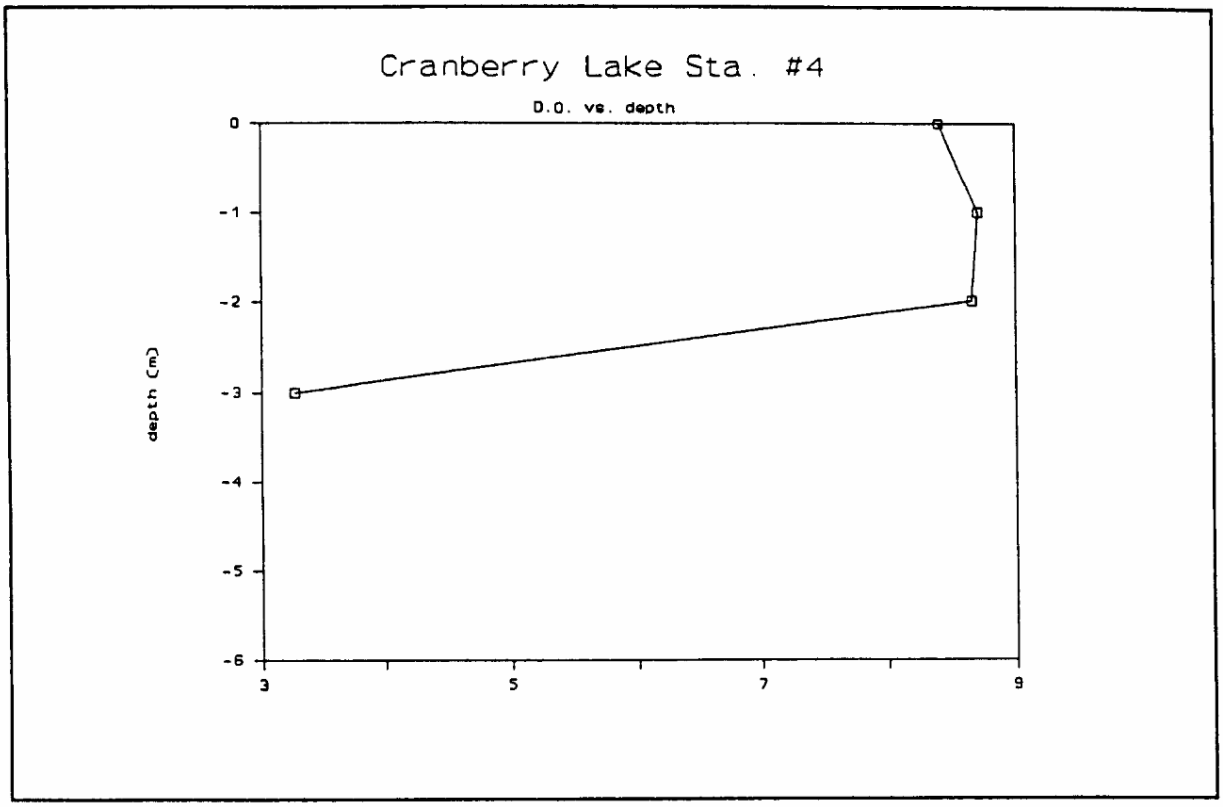
Figure 6D

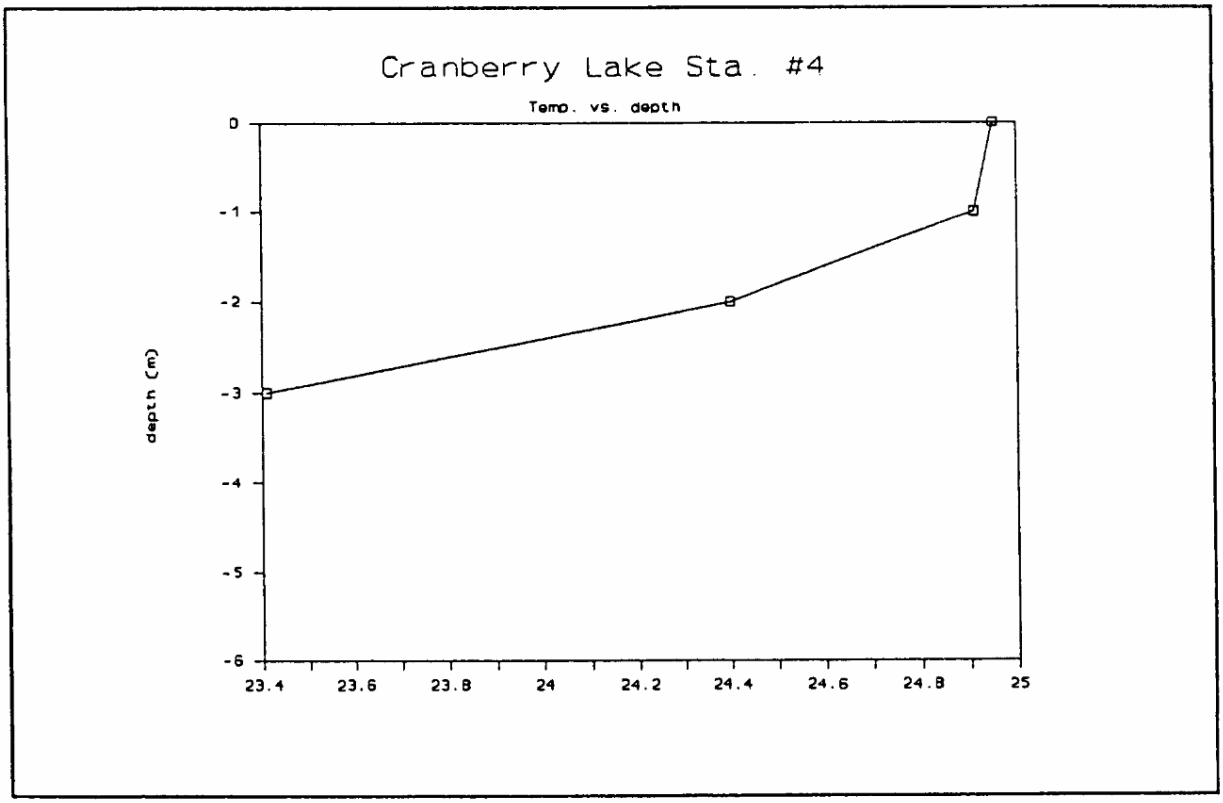




D.O. and Temperature profiles for August 10, 1989

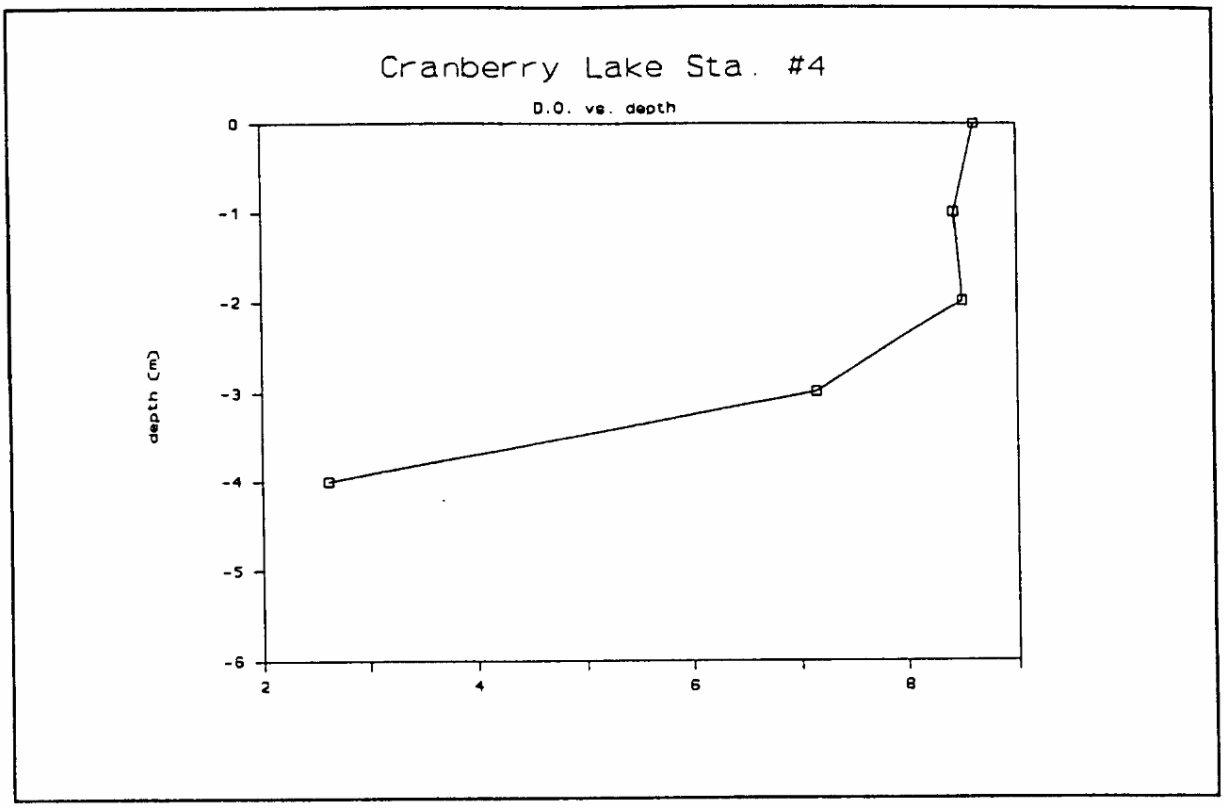
Figure 6E

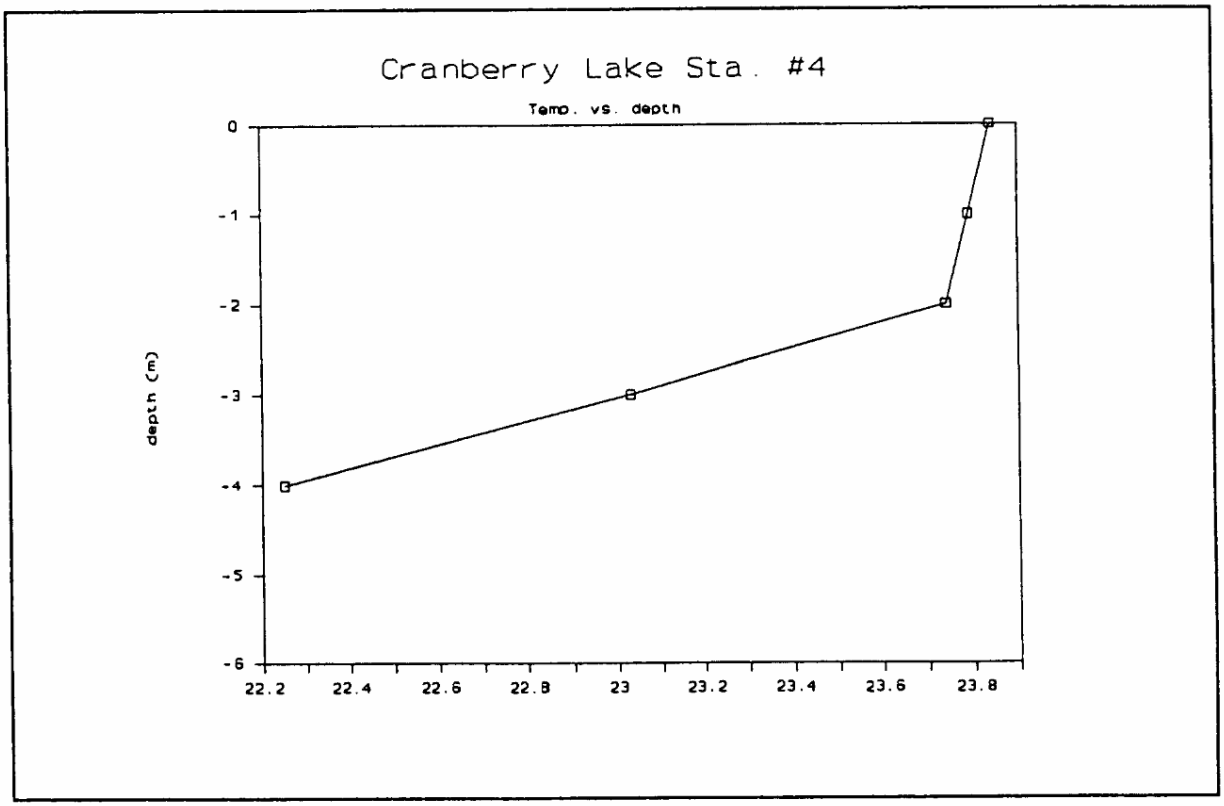




D.O. and Temperature profiles for August 24, 1989

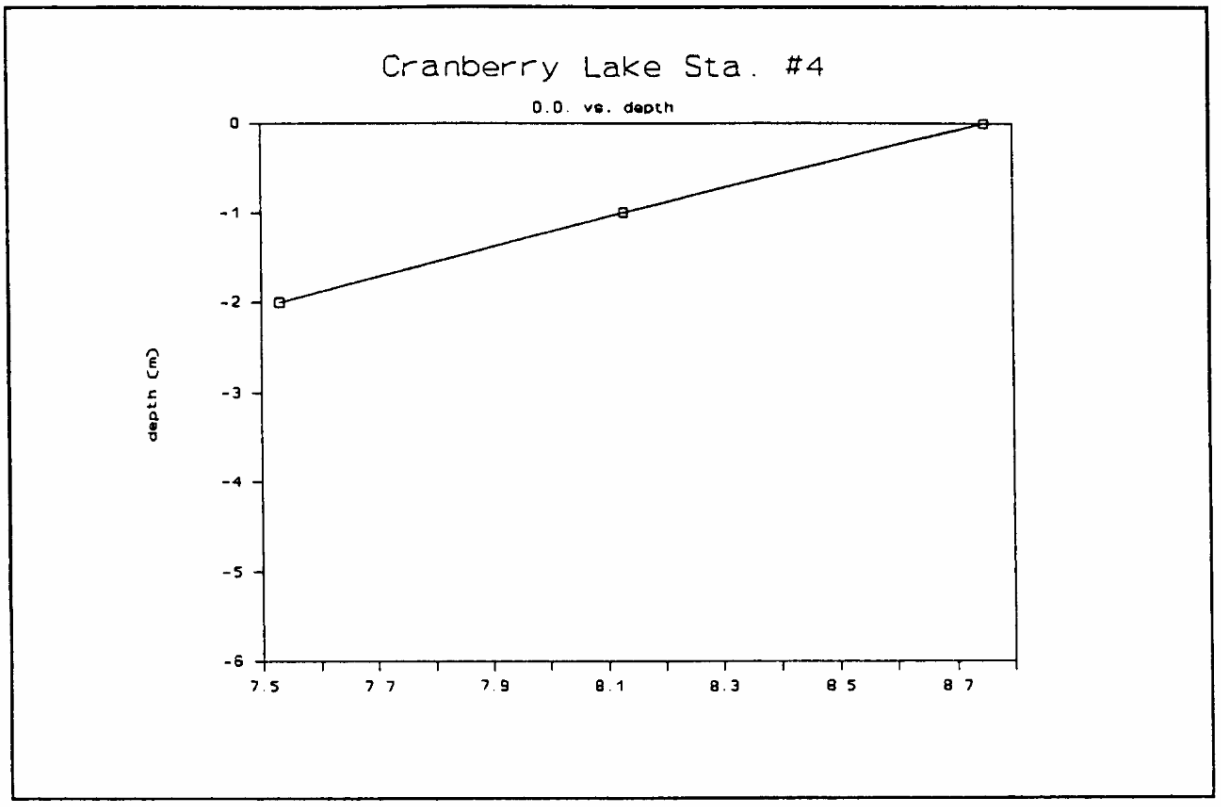
Figure 6F

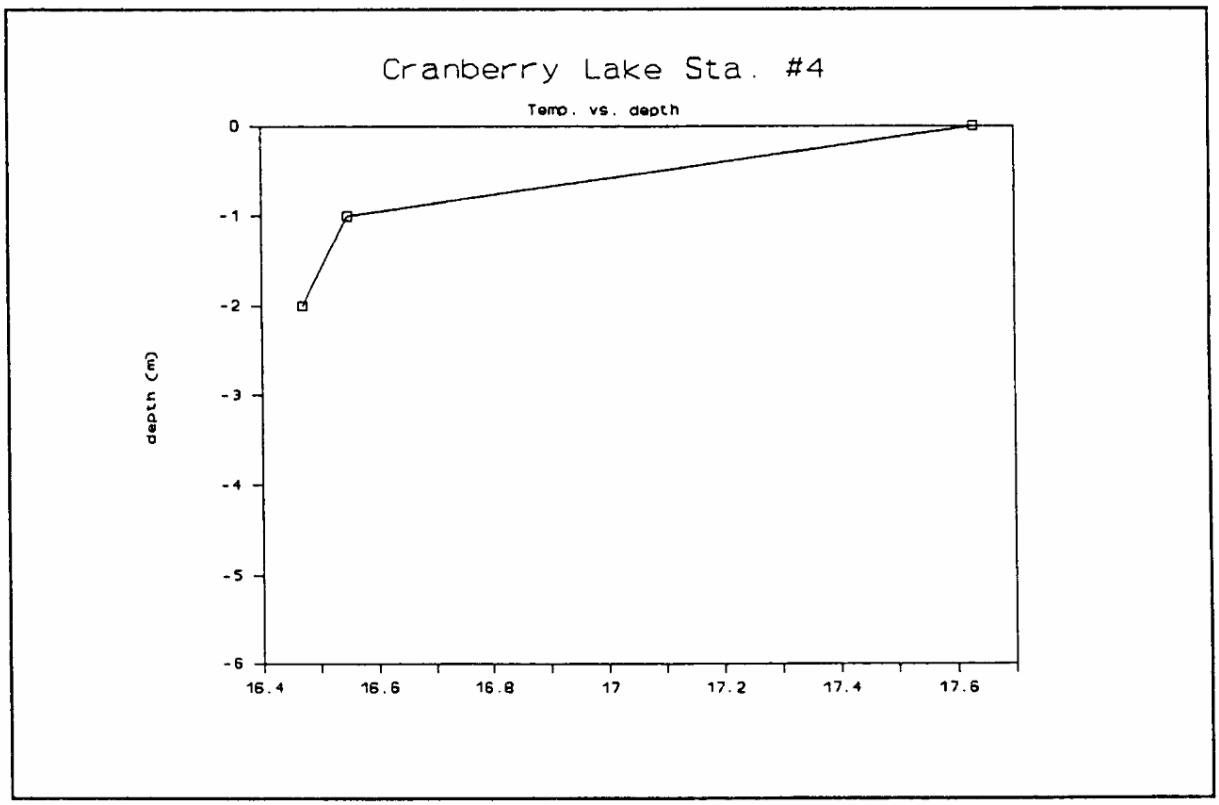




D.O. and Temperature profiles for September 14, 1989

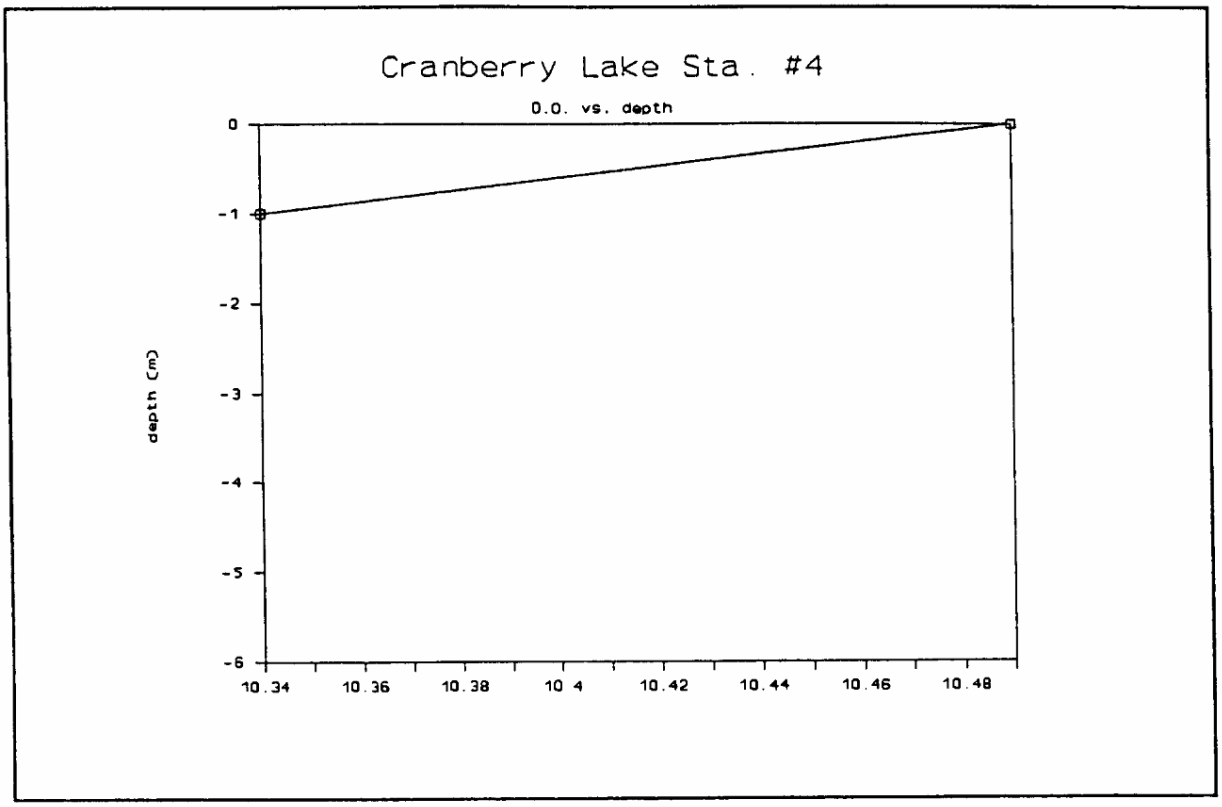
Figure 6G

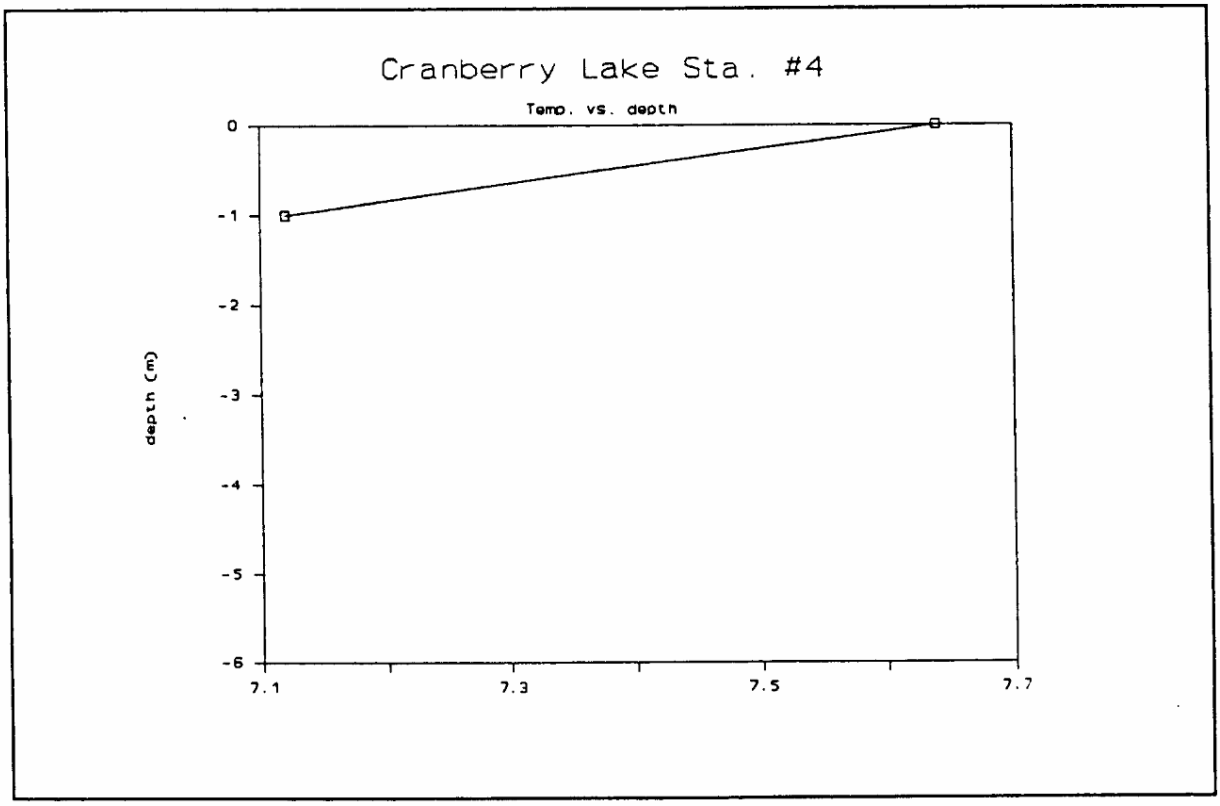




D.O. and Temperature profiles for September 29, 1989

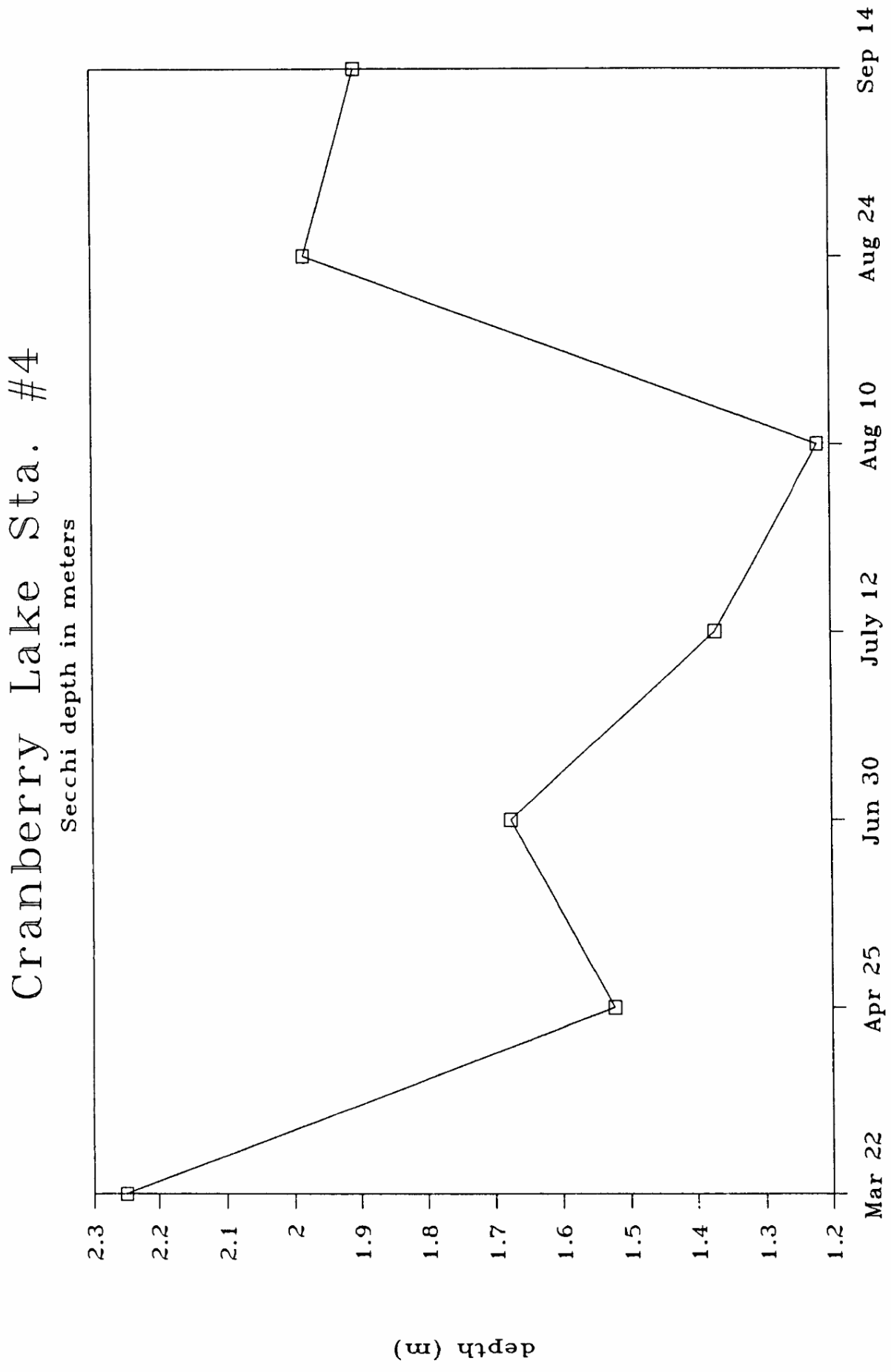
Figure 6H





D.O. and Temperature profiles for October 25, 1989

Figure 7


Cranberry Lake Sta. #4
Secchi depth in meters
depth (m)
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
Mar 22
Apr 25
Jun 30
July 12
Aug 10
Aug 24
Sep 14

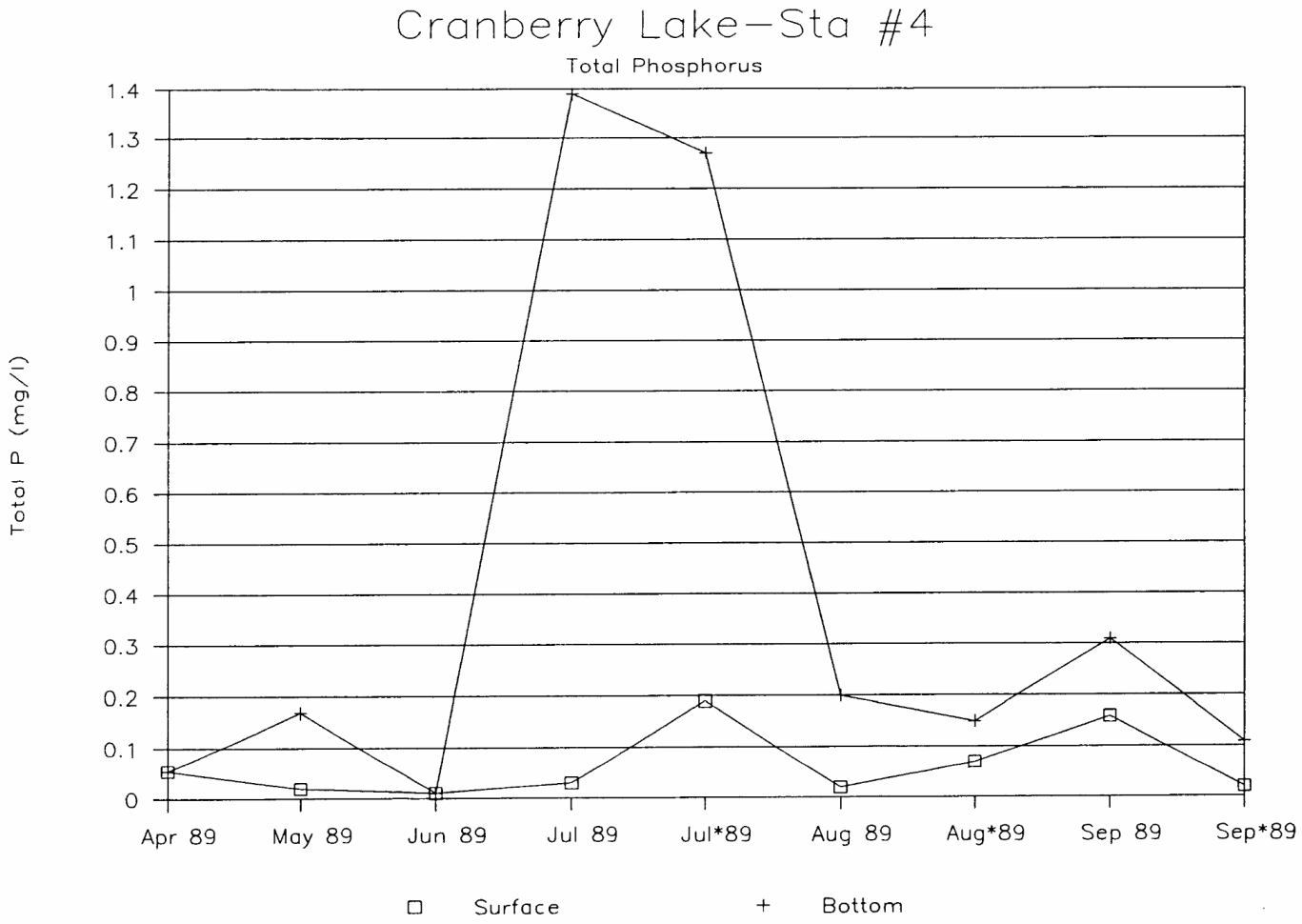

Cranberry Lake—Sta #4
Total Phosphorus
Total P (mg/l)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Apr 89
May 89
Jun 89
Jul 89
Jul*89
Aug 89
Aug*89
Sep 89
Sep*89
Surface
Bottom

Figure 8

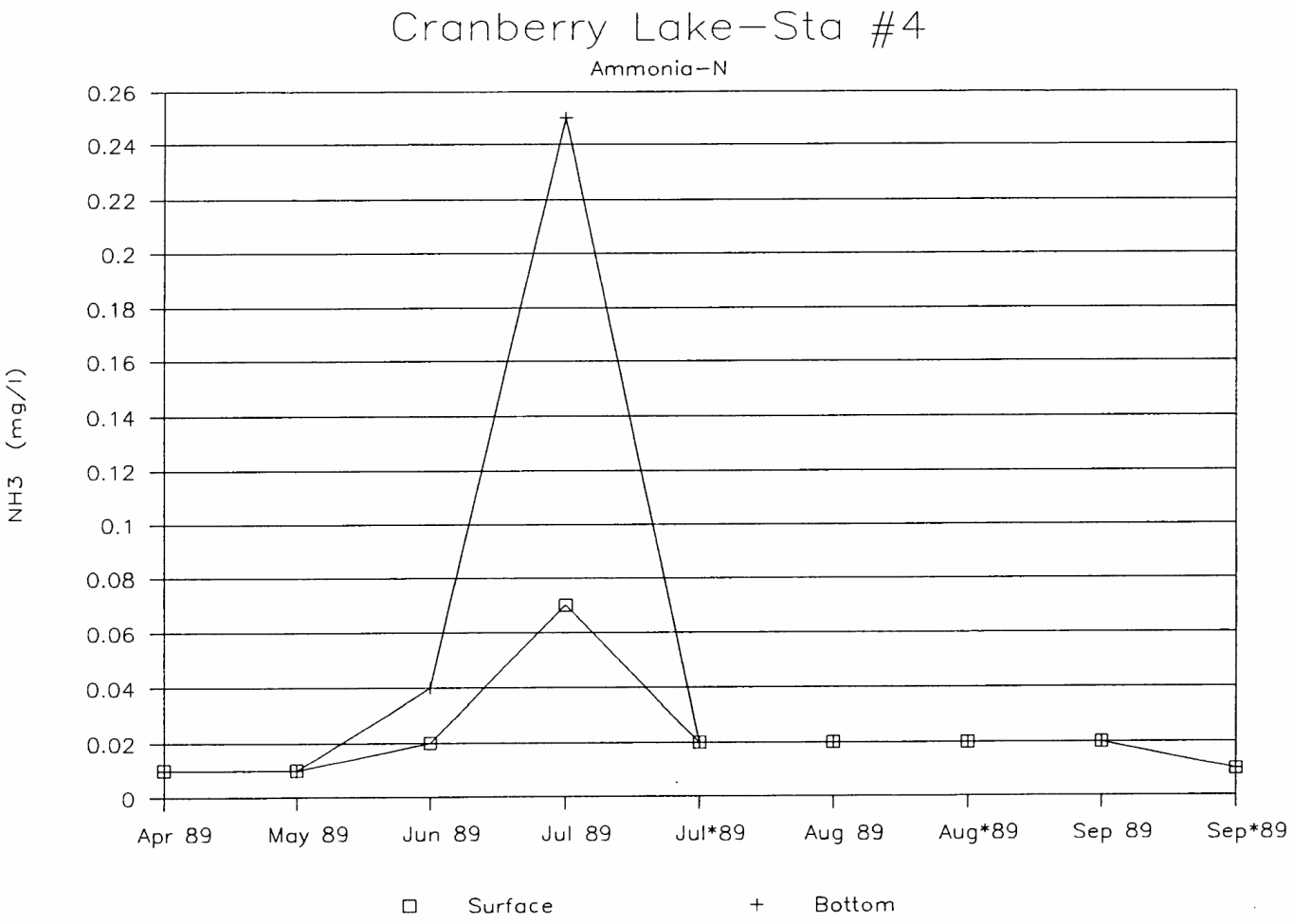

Cranberry Lake—Sta #4
Ammonia—N
NH3 (mg/l)
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Apr 89
May 89
Jun 89
Jul 89
Jul*89
Aug 89
Aug*89
Sep 89
Sep*89
Surface
Bottom

Figure 9

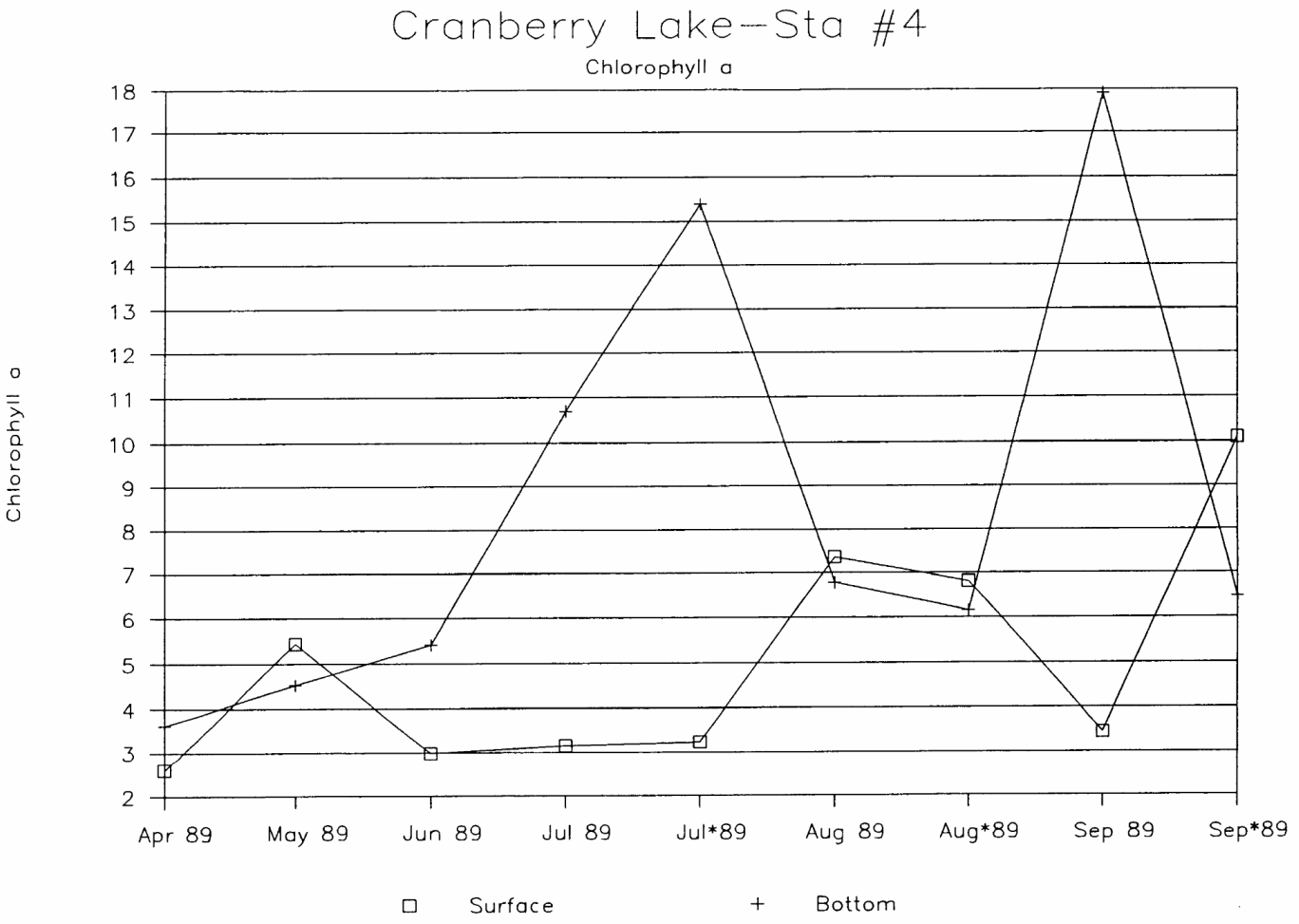

Cranberry Lake—Sta #4
Chlorophyll a
Chlorophyll a
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
Apr 89
May 89
Jun 89
Jul 89
Jul*89
Aug 89
Aug*89
Sep 89
Sep*89
Surface
Bottom

Figure 10

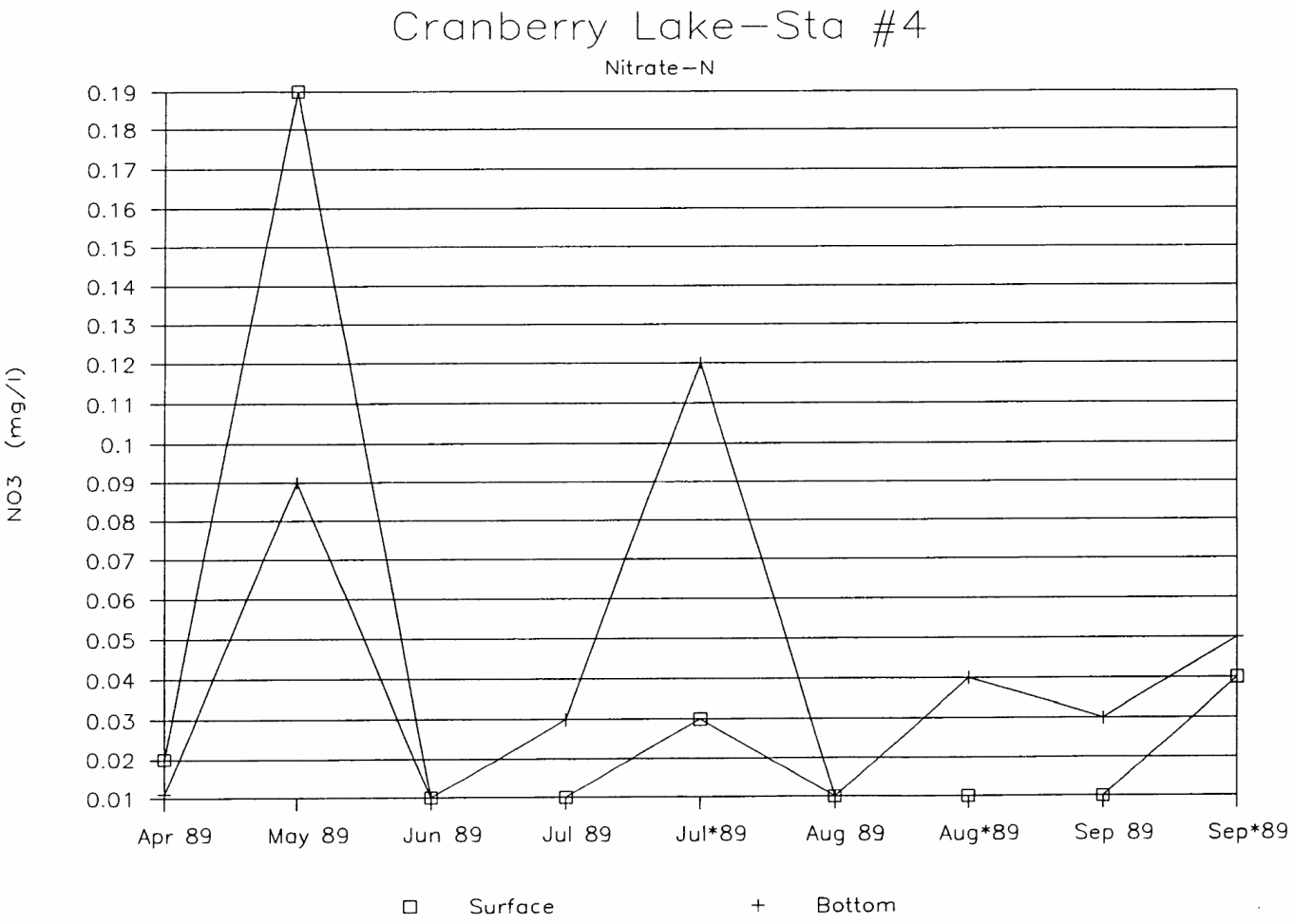

Cranberry Lake—Sta #4
Nitrate—N
NO3 (mg/l)
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
Apr 89
May 89
Jun 89
Jul 89
Jul*89
Aug 89
Aug*89
Sep 89
Sep*89
Surface
Bottom

Figure 11

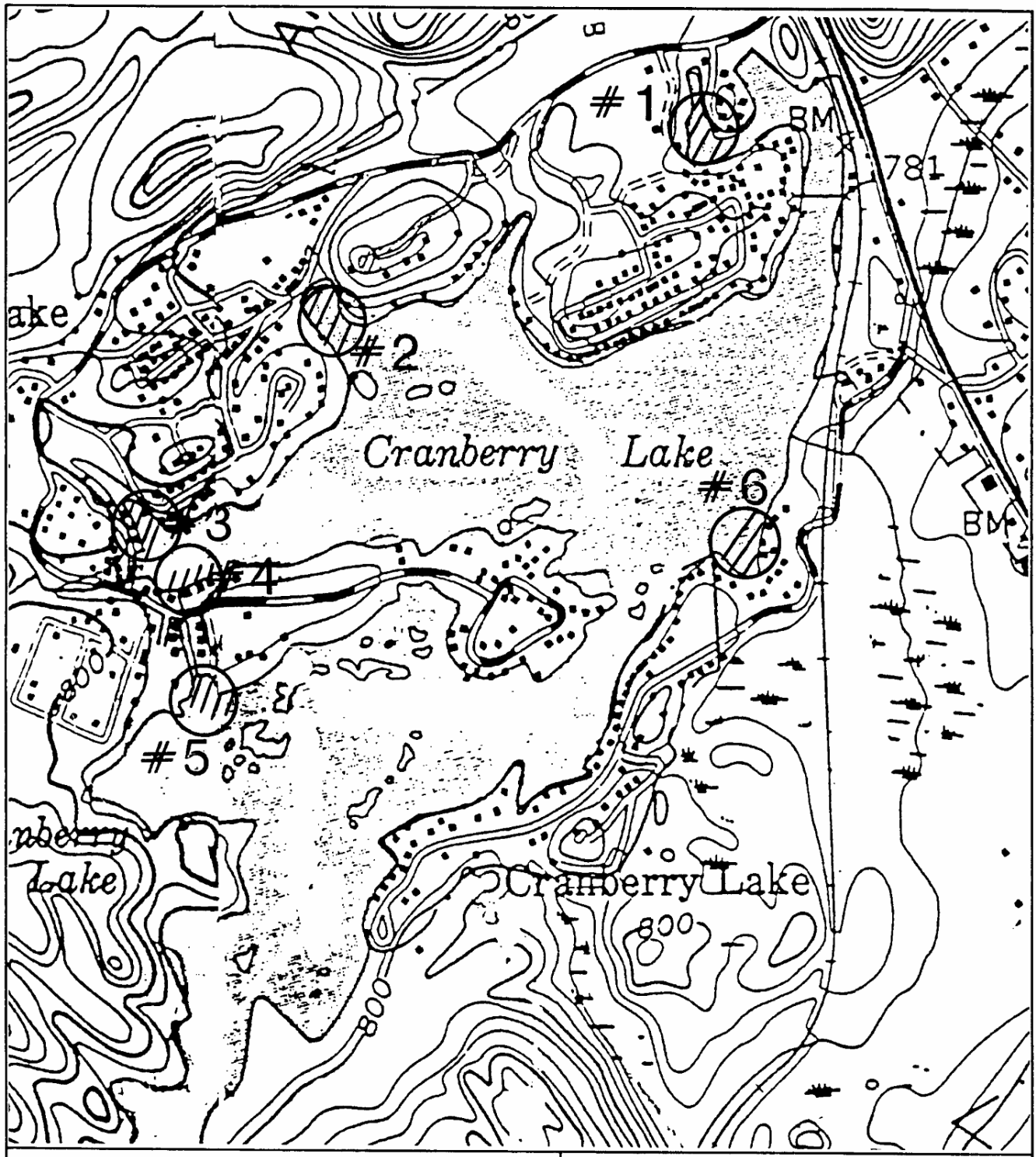


FIGURE 12
CRANBERRY LAKE
SEPTIC LEACHATE SURVEY

Legend:

Area of suspected septic leachate intrusion

N

1000 Scale: 0 1000

Septic leachate survey conducted by:
Coastal Environmental Services, Inc.
June 1989

COASTAL
ENVIRONMENTAL SERVICES INC.

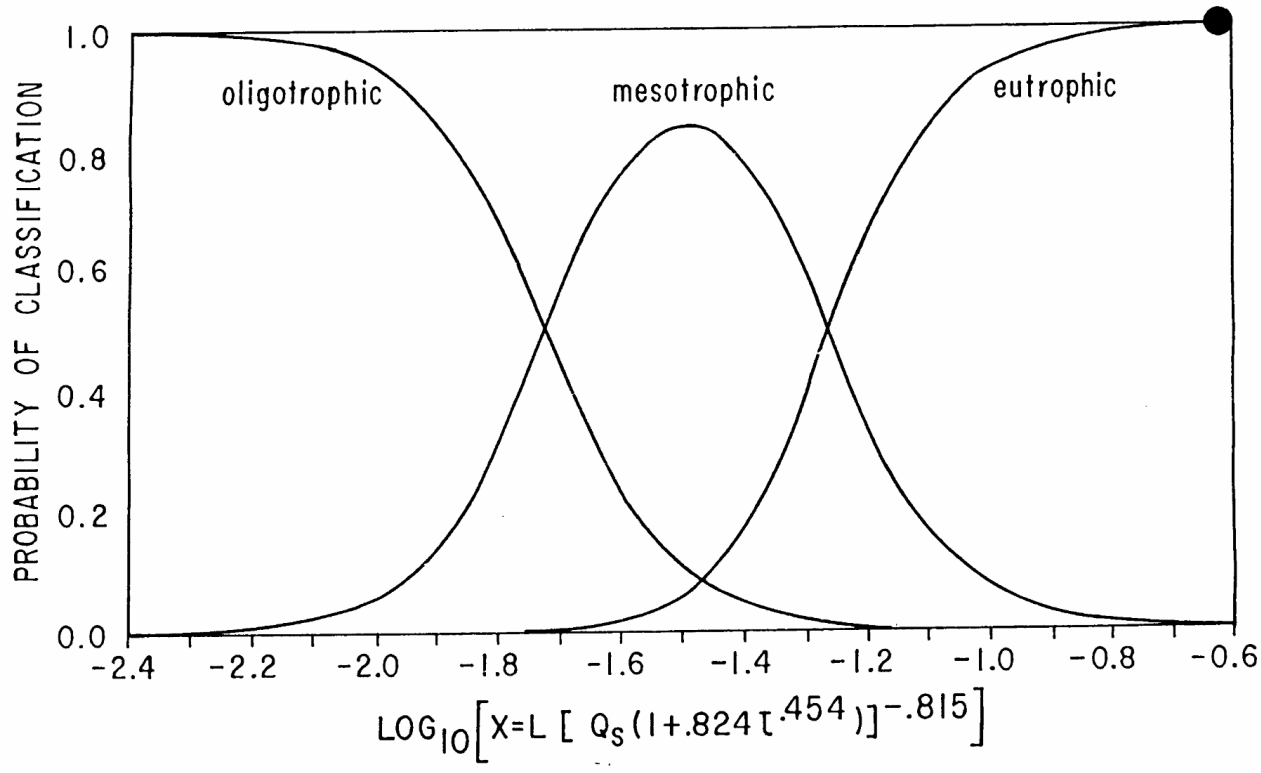


FIGURE 13
CRANBERRY LAKE
TROPHIC STATE CLASSIFICATION
AS PER WALKER EQUATION

COASTAL
ENVIRONMENTAL SERVICES INC

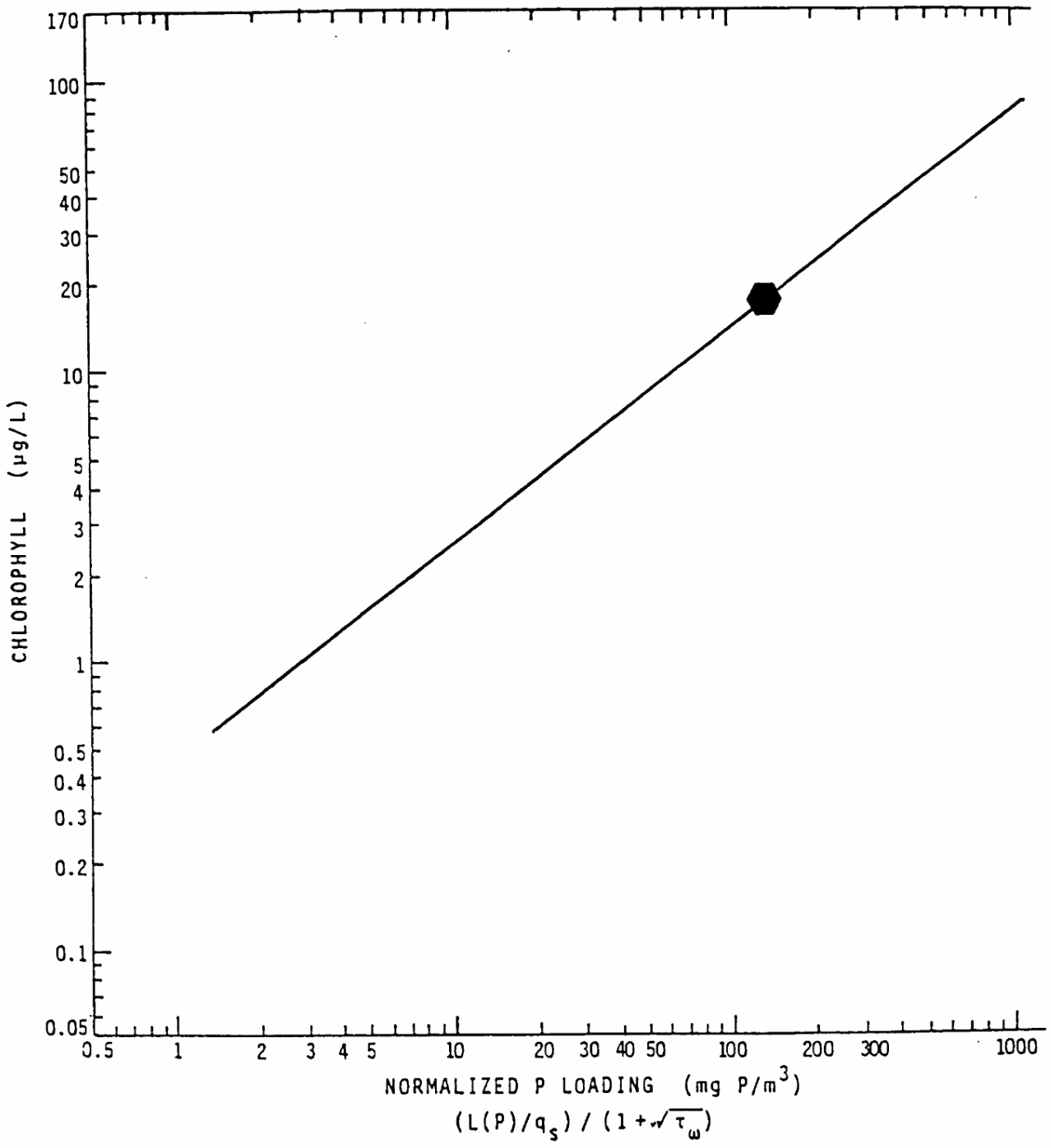


FIGURE 14
CRANBERRY LAKE
OECD NORMALIZED P LOADING / CHLOROPHYLL RESPONSE RELATIONSHIP

Source: Jones and Lee, 1986

COASTAL
ENVIRONMENTAL SERVICES INC

APPENDIX A
IN-SITU SAMPLING SUMMARY BY STATIONS

Cranberry Lake In situ quality data (all data from 1989)

	Mar 22	Apr 25	Jun 30	July 12	Aug 10
Station 1					
D.O.	9.75	6.87	6.58	5.14	7.73
pH	7.97	7.53	7.21	7.13	7.06
Temp	4.7	15	16.8	17.9	15.6
Cond	0.001	0	0.001	0.001	0.032
Gauge Ht.	70	65		60	52
flow (cfs)	1.83		1.625	1.55	0.055
secchi					
Station 2					
D.O.	9.35	8.76	8.7	7.9	8.5
pH	8.02	7.77	7.67	7.44	7.25
Temp	3.2	14.1	16	18.2	15.33
Cond	0.001	0.001	0.002	0.001	0.184
Gauge Ht.	30		16	8.5	2
flow (cfs)	2.864		2.092	0.8086	0.076
secchi					
Station 3					
D.O.	9.6	8.72	7.2	7.18	7.27
pH	7.95	7.39	7.75	7.81	7.24
Temp	5.9	15.4	24.9	26.8	24.68
Cond	0.001	0.002	0.002	0.002	0.163
Gauge Ht.	49		48	47	
flow (cfs)	1.286		2.5	2.23	0
secchi			1.5	1.524	1.0668

Station 4					
D.O.		8.73	6.7	7.72	7.92
B		7.83	6.2	3.9	8.04
pH		7.79	7.71	7.79	7.44
B		7.8	7.48	7.81	7.5
Temp		13.6	24.8	26.9	24.52
B		13.6	23.9	26.5	24.03
Cond		0.002	0.002	0.002	0.163
B		0.002	0.002	0.002	0.16
Gauge Ht.					
flow (cfs)		2.25	1.524	1.6764	1.3716
secchi					
Station 5					
D.O.		9.16	6.6	7.27	8.27
pH		7.36	7.55	7.65	7.6
Temp		15.3	24.4	26.6	24.79
Cond		0.001	0.002	0.002	0.161
Gauge Ht.					
flow (cfs)			1.524	1.3716	1.2192
secchi					
Station 6					
D.O.	9.78	8.51	7.8	7.2	8.98
pH	7.9	7.26	7.58	7.45	7.67
Temp	5.1	16.2	24.6	26.8	24.14
Cond	0.001	0.001	0.002	0.002	0.139
Gauge Ht.	7.5	4.5	7	4	0
flow (cfs)	2.901		1.725	0.4	1
secchi			0.6096	0.762	

Cranberry Lake In situ quality data (all data from 1989)

	Aug 24	Sep 14	Sep 29
Station 1			
D.O.	7.89	No	9.24
pH	6.95	Flow	6.46
Temp	17.59		11
Cond	0.093	No	0.066
Gauge Ht.	54	Sample	72
flow (cfs)	0.275		
secchi			
Station 2			
D.O.	8.86	No	11.44
pH	7.25	Flow	6.75
Temp	17.24		10.4
Cond	0.197	No	0.13
Gauge Ht.	7	Sample	34.5
flow (cfs)	0.2915		
secchi			
Station 3			
D.O.	8.45	8.78	8.69
pH	7.59	7.84	7.19
Temp	24.97	23.89	18.04
Cond	0.16	0.161	0.142
Gauge Ht.		32.5	49.5
flow (cfs)			
secchi	1.0668	0.9144	

Station 4			
D.O.	8.4	8.61	8.75
B	3.26	2.61	7.53
pH	7.84	7.88	7.24
B	7.92	7.79	7.02
Temp	24.95	23.84	17.63
B	24.46	23.74	16.55
Cond	0.159	0.16	0.14
B	0.16	0.16	0.142
Gauge Ht.			
flow (cfs)			
secchi	1.2192	1.9812	1.905
Station 5			
D.O.	8.39	8.28	8.88
pH	7.39	7.29	6.86
Temp	24.53	23.83	16.38
Cond	0.133	0.141	0.104
Gauge Ht.			
flow (cfs)			
secchi	1.524	1.3716	1.3716
Station 6			
D.O.	8.5	9.65	9.89
pH	7.41	7.86	7.08
Temp	24.64	23.66	16.54
Cond	0.134	0.142	0.072
Gauge Ht.			
flow (cfs)	0	0	
secchi	1	0.9144	0.6096

APPENDIX B

SAMPLING SUMMARY BY STATIONS

Cranberry Lake Data (Station 3)

Ammonia-N

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 3	0.01	0.01	0.07	0.02	0.02	0.03	0.05	0.07	0.01

Nitrate-N

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 3	0.023	0.17	0.01	0.05	0.05	0.13	0.04	0.03	0.06

Total Kjeldahl Nitrogen

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 3	0.02	0.08	0.16	0.14	0.02	0.02	0.07	0.03	0.05

Total Phosphate-P

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 3	0.055	0.02	0.21	0.33	0.05	0.02	0.15	0.09	0.02

Soluble Ortho Phosphate-P

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 3	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.02

Chlorophyll a

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 3	2.37	5.38	3.46	6.19	3.96	5.29	8.28	3.01	8.14

Cranberry Lake Data (Stations 4A and B)

	1	2	3	4	5	6	7	8	9
	Ammonia-N								
	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 4A (surface)	0.01	0.01	0.02	0.07	0.02	0.02	0.02	0.02	0.01
Station 4B (bottom)	0.01	0.01	0.04	0.25	0.02	0.02	0.02	0.02	0.01
	Nitrate-N								
	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 4A (surface)	0.02	0.19	0.01	0.01	0.03	0.01	0.01	0.01	0.04
Station 4B (bottom)	0.011	0.09	0.01	0.03	0.12	0.01	0.04	0.03	0.05
	Total Kjeldahl Nitrogen								
	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 4A (surface)	0.02	0.16	0.07	0.02	0.02	0.02	0.02	0.02	0.01
Station 4B (bottom)	0.28	0.12	0.01	0.02	0.02	0.05	0.02	0.03	0.01

Total Phosphate-P

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 4A (surface)	0.055	0.02	0.01	0.03	0.19	0.02	0.07	0.16	0.02
Station 4B (bottom)	0.055	0.17	0.01	1.39	1.27	0.2	0.15	0.31	0.11

Soluble Ortho Phosphate-P

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 4A (surface)	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Station 4B (bottom)	0.01	0.02	0.02	0.04	0.02	0.05	0.08	0.06	0.02

Chlorophyll a

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 4A (surface)	2.6	5.44	2.99	3.16	3.24	7.37	6.82	3.46	10.1
Station 4B	3.64	4.53	5.42	10.7	15.4	6.79	6.15	17.9	6.47

Cranberry Lake Data (Station 5)

Ammonia-N

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 5	0.01	0.01	0.02	0.04	0.02	0.02	0.02	0.02	0.01

Nitrate-N

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 5	0.01	0.19	0.01	0.17	0.03	0.01	0.06	0.01	0.01

Total Kjeldahl Nitrogen

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 5	0.02	0.24	0.11	0.02	0.02	0.02	0.02	0.02	0.02

Total Phosphate-P

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 5	0.037	0.24	0.1	0.02	1.81	0.02	0.09	0.12	0.22

Soluble Ortho Phosphate-P

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 5	0.01	0.02	0.04	0.02	0.02	0.02	0.02	0.04	0.02

Chlorophyll a

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 5	3.26	3.4	3.21	4.38	3.46	4.88	2.92	1.56	3.98

Cranberry Lake Data (Station 6)

Ammonia-N

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 6	0.01	0.01	0.07	0.14	0.02	0.02	0.02	0.03	0.01

Nitrate-N

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 6	0.01	0.19	0.01	0.04	0.08	0.03	0.02	0.14	0.04

Total Kjeldahl Nitrogen

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 6	0.05	0.12	0.25	0.02	0.02	0.02	0.02	0.05	0.01

Total Phosphate-P

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 6	0.046	0.21	0.01	0.25	0.02	0.46	0.02	0.13	0.11

Soluble Ortho Phosphate-P

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 6	0.028	0.02	0.02	0.02	0.02	0.02	0.02	0.06	0.02

Chlorophyll a

	Apr 89	May 89	Jun 89	Jul 89	Jul*89	Aug 89	Aug*89	Sep 89	Sep*89
Station 6	3.2	4.48	3.46	5.61	3.08	4.89	3.16	6.73	2.99

APPENDIX B
TRIBUTARIES AND IN-LAKE BASE LINE DATA

ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State NJ Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 5/29/89
Job #: 1008
Lot #: 1034
P.O. #: 88-017-01
Invoice #: 89039
Sample Date: 4/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 (mg/L)
Fecal Coliform (#col/100 ml)	70
Total Coliform (#col/100 ml)	72
Total Suspended Solids	4.0
Ammonia-N	<0.01
Nitrate-N	0.054
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.138
Soluble Ortho Phosphate-P	<0.01

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Report Date: 5/29/89
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P.O. #: 88-017-01
Invoice #: 89039
Sample Date: 4/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 2 (mg/L)
Fecal Coliform (#col/100 ml)	42
Total Coliform (#col/100 ml)	92
Total Suspended Solids	3.3
Ammonia-N	<0.01
Nitrate-N	0.168
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.073
Soluble Ortho Phosphate-P	<0.01

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Job #: 1008
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P.O. #: 88-017-01
Invoice #: 89039
Sample Date: 4/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.023
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.055
Soluble Ortho Phosphate-P	<0.01
Chlorophyll a (mg/M^3)	3.46
Chlorophyll b (mg/M^3)	2.37
Chlorophyll c (mg/M^3)	0.22
Pheophytin (mg/M^3)	<1.0

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Report Date: 5/29/89
Job #: 1008
Lot #: 1034
P.O. #: 88-017-01
Invoice #: 89039
Sample Date: 4/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4A (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.02
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.055
Soluble Ortho Phosphate-P	<0.01
Chlorophyll a (mg/M^3)	2.60
Chlorophyll b (mg/M^3)	<0.44
Chlorophyll c (mg/M^3)	<0.44
Pheophytin (mg/M^3)	2.11

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To Attn. of: Dr. Steven Souza

Report Date: 5/29/89
Job #: 1008
Lot #: 1034
P.O. #: 88-017-01
Invoice #: 89039
Sample Date: 4/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4B (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.011
Total Kjeldahl Nitrogen	0.28
Total Phosphate-P	0.055
Soluble Ortho Phosphate-P	<0.01
Chlorophyll a (mg/M^3)	3.64
Chlorophyll b (mg/M^3)	1.92
Chlorophyll c (mg/M^3)	1.33
Pheophytin (mg/M^3)	3.83

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Report Date: 5/29/89
Job #: 1008
Lot #: 1034
P.O. #: 88-017-01
Invoice #: 89039
Sample Date: 4/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 (mg/L)
Ammonia-N	<0.01
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.037
Soluble Ortho Phosphate-P	<0.01
Chlorophyll a (mg/M^3)	3.26
Chlorophyll b (mg/M^3)	1.00
Chlorophyll c (mg/M^3)	2.92
Pheophytin (mg/M^3)	<1.0

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Report Date: 5/29/89
Job #: 1008
Lot #: 1034
P.O. #: 88-017-01
Invoice #: 89039
Sample Date: 4/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 (mg/L)
Ammonia-N	<0.01
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	0.05
Total Phosphate-P	0.046
Soluble Ortho Phosphate-P	0.028
Chlorophyll a (mg/M^3)	3.20
Chlorophyll b (mg/M^3)	2.84
Chlorophyll c (mg/M^3)	2.75
Pheophytin (mg/M^3)	<1.0

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Company Coastal Environmental Services, Inc.
Address 909 State Road
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To Attn. of: Dr. Steven Souza

Report Date: 6/9/89
Job #: 1008
Lot #: 1038
P.O. #: 88-017-01
Invoice #: 89042
Sample Date: 5/11/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 South Tributary (mg/L)
Fecal Coliform (#col/100 ml)	<10
Total Coliform (#col/100 ml)	34
Total Suspended Solids	0.5
Ammonia-N	<0.01
Nitrate-N	0.38
Total Kjeldahl Nitrogen	0.07
Total Phosphate-P	0.15
Soluble Ortho Phosphate-P	<0.02

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Report Date: 6/9/89
Job #: 1008
Lot #: 1038
P.O. #: 88-017-01
Invoice #: 89042
Sample Date: 5/11/89

REPORT OF ANALYSIS

	Cranberry Lake Station 2 West Tributary (mg/L)
Fecal Coliform (#col/100 ml)	<10
Total Coliform (#col/100 ml)	74
Total Suspended Solids	2.5
Ammonia-N	< 0.01
Nitrate-N	0.25
Total Kjeldahl Nitrogen	0.16
Total Phosphate-P	< 0.02
Soluble Ortho Phosphate-P	< 0.02

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Report Date: 6/9/89
Job #: 1008
Lot #: 1038
P.O. #: 88-017-01
Invoice #: 89042
Sample Date: 5/11/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 Main Outlet (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.17
Total Kjeldahl Nitrogen	0.08
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	5.38
Chlorophyll b (mg/M^3)	2.70
Chlorophyll c (mg/M^3)	2.73
Pheophytin (mg/M^3)	<1

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Report Date: 6/9/89
Job #: 1008
Lot #: 1038
P.O. #: 88-017-01
Invoice #: 89042
Sample Date: 5/11/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4A North Basin Surface (mg/l)
Ammonia-N	<0.01
Nitrate-N	0.19
Total Kjeldahl Nitrogen	0.16
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	5.44
Chlorophyll b (mg/M^3)	0.26
Chlorophyll c (mg/M^3)	2.68
Pheophytin (mg/M^3)	8.97

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Report Date: 6/9/89
Job #: 1008
Lot #: 1038
P.O. #: 88-017-01
Invoice #: 89042
Sample Date: 5/11/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4B North Basin Bottom (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.09
Total Kjeldahl Nitrogen	0.12
Total Phosphate-P	0.17
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	4.53
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<1

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To Attn. of: Dr. Steven Souza

Report Date: 6/9/89
Job #: 1008
Lot #: 1038
P.O. #: 88-017-01
Invoice #: 89042
Sample Date: 5/11/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 South Basin (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.19
Total Kjeldahl Nitrogen	0.24
Total Phosphate-P	0.24
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	3.40
Chlorophyll b (mg/M^3)	<0.33
Chlorophyll c (mg/M^3)	3.83
Pheophytin (mg/M^3)	<1

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Company Coastal Environmental Services, Inc.
Address 909 State Road
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To Attn. of: Dr. Steven Souza

Report Date: 6/9/89
Job #: 1088
Lot #: 1038
P.O. #: 88-017-01
Invoice #: 89042
Sample Date: 5/11/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 South Outlet (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.19
Total Kjeldahl Nitrogen	0.12
Total Phosphate-P	0.21
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	4.48
Chlorophyll b (mg/M^3)	4.06
Chlorophyll c (mg/M^3)	<0.35
Pheophytin (mg/M^3)	<1

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ECM
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Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State N.J. Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 8/4/89
Job #: 1008
Lot #: 1046
P.O. #: verbal
Invoice #: 89049
Sample Date: 6/30/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 South Tributary (mg/L)
Fecal Coliform (#col/100ml)	66
Total Coliform (#col/100ml)	2850
Total Suspended Solids	0.8
Ammonia-N	0.04
Nitrate-N	0.05
Total Kjeldahl Nitrogen	0.07
Total Phosphate-P	0.23
Soluble Ortho Phosphate-P	<0.02

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Report Date: 8/4/89
Job #: 1008
Lot #: 1046
P.O. #: verbal
Invoice #: 89049
Sample Date: 6/30/89

REPORT OF ANALYSIS

	Cranberry Lake Station 2 West Tributary (mg/L)
Fecal Coliform (#col/100ml)	102
Total Coliform (#col/100ml)	2600
Total Suspended Solids	1.0
Ammonia-N	<0.02
Nitrate-N	0.10
Total Kjeldahl Nitrogen	0.14
Total Phosphate-P	0.19
Soluble Ortho Phosphate-P	<0.02

ECM
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To Attn. of: Dr. Steven Souza

Report Date: 8/4/89
Job #: 1008
Lot #: 1046
P.O. #: verbal
Invoice #: 89049
Sample Date: 6/30/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 Main Outlet (mg/L)
Ammonia-N	0.07
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	0.16
Total Phosphate-P	0.21
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	3.46
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<0.3

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Report Date: 8/4/89
Job #: 1008
Lot #: 1046
P.O. #: verbal
Invoice #: 89049
Sample Date: 6/30/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4A North Basin Surface (mg/L)
Ammonia-N	<0.02
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	0.07
Total Phosphate-P	<0.01
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	2.99
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	0.9

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Job #: 1008
Lot #: 1046
P.O. #: verbal
Invoice #: 89049
Sample Date: 6/30/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4B North Basin Bottom (mg/L)
Ammonia-N	0.04
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	<0.01
Total Phosphate-P	<0.01
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	5.42
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<0.3

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Report Date: 8/4/89
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Lot #: 1046
P.O. #: verbal
Invoice #: 89049
Sample Date: 6/30/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 South Basin (mg/L)
Ammonia-N	<0.02
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	0.11
Total Phosphate-P	0.10
Soluble Ortho Phosphate-P	0.04
Chlorophyll a (mg/M^3)	3.21
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	0.34

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P.O. #: verbal
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Sample Date: 6/30/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 South Outlet (mg/L)
Ammonia-N	0.07
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	0.25
Total Phosphate-P	<0.01
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	3.46
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<0.3

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ECM
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Company: Coastal Environmental Services, Inc.
Address: 909 State Road
City: Princeton State: N.J. Zip: 08540
To Attn. of: Dr. Steven Souza

Report Date: 8/24/89
Job #: 1008
Lot #: 1047
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/12/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 South Tributary (mg/L)
Fecal Coliform (#col/100ml)	30
Total Coliform (#col/100ml)	450
Total Suspended Solids	6.0
Ammonia-N	0.04
Nitrate-N	0.12
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.29
Soluble Ortho Phosphate-P	<0.02

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Report Date: 8/24/89
Job #: 1008
Lot #: 1047
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/12/89

REPORT OF ANALYSIS

	Cranberry Lake Station 2 West Tributary (mg/L)
Fecal Coliform (#col/100ml)	216
Total Coliform (#col/100ml)	1700
Total Suspended Solids	30
Ammonia-N	<0.02
Nitrate-N	0.06
Total Kjeldahl Nitrogen	0.36
Total Phosphate-P	0.08
Soluble Ortho Phosphate-P	<0.02

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Report Date: 8/24/89
Job #: 1008
Lot #: 1047
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/12/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 Main Outlet (mg/L)
Ammonia-N	<0.02
Nitrate-N	0.05
Total Kjeldahl Nitrogen	0.14
Total Phosphate-P	0.33
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	6.19
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<0.3

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ECM
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To Attn. of: Dr. Steven Souza

Report Date: 8/24/89
Job #: 1008
Lot #: 1047
P.O. #: 88-107-01
Invoice #: 89052
Sample Date: 7/12/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4A North Basin Surface (mg/L)
Ammonia-N	0.07
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.03
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	3.16
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<0.3

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Report Date: 8/24/89
Job #: 1008
Lot #: 1047
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/12/89

REPORT OF ANALYSIS

Cranberry Lake
Station 4B
North Basin Bottom
(mg/L)

Ammonia-N	0.25
Nitrate-N	0.03
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	1.39
Soluble Ortho Phosphate-P	0.04
Chlorophyll a (mg/M^3)	10.7
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	2.92

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Job #: 1008
Lot #: 1047
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/12/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 South Basin (mg/L)
Ammonia-N	0.04
Nitrate-N	0.17
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	4.38
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<0.3

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Sample Date: 7/12/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 South Outlet (mg/L)
Ammonia-N	0.14
Nitrate-N	0.04
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.25
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	5.61
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<0.3

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To Attn. of: Dr. Steven Souza

Report Date: 8/25/89
Job #: 1008
Lot #: 1049
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 South Tributary (mg/L)
Fecal Coliform (#col/100ml)	8
Total Coliform (#col/100ml)	800
Total Suspended Solids	6.0
Ammonia-N	<0.02
Nitrate-N	0.14
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.49
Soluble Ortho Phosphate-P	<0.02

PO Box 427 Neahanic Station, New Jersey 08853

ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State N.J. Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 8/25/89
Job #: 1008
Lot #: 1049
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 2 West Tributary (mg/L)
Fecal Coliform (#col/100ml)	16
Total Coliform (#col/100ml)	1600
Total Suspended Solids	53
Ammonia-N	<0.02
Nitrate-N	0.23
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.17
Soluble Ortho Phosphate-P	<0.02

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ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Addreas 909 State Road
City Princeton State N.J. Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 8/25/89
Job #: 1008
Lot #: 1049
P.O. #: 88-017-17
Invoice #: 89052
Sample Date: 7/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 Main Outlet (mg/L)
Ammonia-N	<0.02
Nitrate-N	0.05
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.05
Soluble Ortho Phosphate-P	< 0.02
Chlorophyll a (mg/M^3)	3.96
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	2.47

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ECM
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Company: Coastal Environmental Services, Inc.
Address: 909 State Road
City: Princeton State: N.J. Zip: 08540
To Attn. of: Dr. Steven Souza

Report Date: 8/25/89
Job #: 1008
Lot #: 1049
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4A North Basin Surface (mg/L)
Ammonia-N	<0.02
Nitrate-N	0.03
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.19
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	3.24
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	1.29

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ECM
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Company Coastal Environmental Services, Inc.
Address 909 State Road
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To Attn. of: Dr. Steven Souza

Report Date: 8/25/89
Job #: 1008
Lot #: 1049
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4B North Basin Bottom (mg/L)
Ammonia-N	<0.02
Nitrate-N	0.12
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	1.27
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	15.4
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	20.4

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To Attn. of: Dr. Steven Souza

Report Date: 8/25/89
Job #: 1008
Lot #: 1049
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 South Basin (mg/L)
Ammonia-N	<0.02
Nitrate-N	0.03
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	1.81
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	3.46
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	2.64

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To Attn. of: Dr. Steven Souza

Report Date: 8/25/89
Job #: 1008
Lot #: 1049
P.O. #: 88-017-01
Invoice #: 89052
Sample Date: 7/26/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 South Outlet (mg/L)
Ammonia-N	<0.02
Nitrate-N	0.03
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.46
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	4.89
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	1.18

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Company Coastal Environmental Services, Inc.
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To Attn. of: Dr. Steven Souza

Report Date: 9/15/89
Job #: 1008
Lot #: 1053
P.O. #: 88-017-01
Invoice #: 89055
Sample Date: 8/10/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 South Tributary (mg/L)
Fecal Coliform (#col/100ml)	68
Total Coliform (#col/100ml)	2350
Total Suspended Solids	5.5
Ammonia-N	<0.02
Nitrate-N	0.24
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.10
Soluble Ortho Phosphate-P	0.02

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ECM
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Company Coastal Environmental Services, Inc.
Address 909 State Road
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To Attn. of: Dr. Steven Souza

Report Date: 9/15/89
Job #: 1008
Lot #: 1053
P.O. #: 88-017-01
Invoice #: 89055
Sample Date: 8/10/89

REPORT OF ANALYSIS

	Cranberry Lake Station 2 West Tributary (mg/L)
Fecal Coliform (#col/100ml)	12
Total Coliform (#col/100ml)	650
Total Suspended Solids	3.0
Ammonia-N	<0.02
Nitrate-N	0.20
Total Kjeldahl Nitrogen	0.04
Total Phosphate-P	0.30
Soluble Ortho Phosphate-P	<0.02

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To Attn. of: Dr. Steven Souza

Report Date: 9/15/89
Job #: 1008
Lot #: 1053
P.O. #: 88-017-01
Invoice #: 89055
Sample Date: 8/10/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 Main Outlet (mg/L)
Ammonia-N	0.03
Nitrate-N	0.13
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	5.29
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	2.43

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To Attn. of: Dr. Steven Souza

Report Date: 9/15/89
Job #: 1008
Lot #: 1053
P.O. #: 88-017-01
Invoice #: 89055
Sample Date: 8/10/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4A North Basin Surface (mg/L)
Ammonia-N	<0.02
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	7.37
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	3.49

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To Attn. of: Dr. Steven Souza

Report Date: 9/15/89
Job #: 1008
Lot #: 1053
P.O. #: 88-017-01
Invoice #: 89055
Sample Date: 8/10/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4B North Basin Bottom (mg/L)
Ammonia-N	<0.02
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	0.05
Total Phosphate-P	0.20
Soluble Ortho Phosphate-P	0.05
Chlorophyll a (mg/M^3)	6.79
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	<0.3

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To Attn. of: Dr. Steven Souza

Report Date: 9/15/89
Job #: 1008
Lot #: 1053
P.O. #: 88-017-01
Invoice #: 89055
Sample Date: 8/10/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 South Basin (mg/L)
Ammonia-N	<0.02
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	4.88
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	1.92

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Report Date: 9/15/89
Job #: 1008
Lot #: 1053
P.O. #: 88-017-01
Invoice #: 89055
Sample Date: 8/10/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 South Outlet (mg/L)
Ammonia-N	< 0.02
Nitrate-N	0.08
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	< 0.02
Soluble Ortho Phosphate-P	< 0.02
Chlorophyll a (mg/M^3)	3.08
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	< 0.3

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Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State N.J. Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 10/12/89
Job #: 1008
Lot #: 1055
P.O. #: verbal
Invoice #: 89061
Sample Date: 8/24/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 South Tributary (mg/L)
Fecal Coliform (#col/100ml)	90
Total Coliform (#col/100ml)	9510
Total Suspended Solids	4
Ammonia-N	< 0.02
Nitrate-N	0.14
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	0.91
Soluble Ortho Phosphate-P	0.25

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To Attn. of: Dr. Steven Souza

Report Date: 10/12/89
Job #: 1008
Lot #: 1055
P.O. #: verbal
Invoice #: 89061
Sample Date: 8/24/89

REPORT OF ANALYSIS

	Cranberry Lake Station 2 West Tributary (mg/L)
Fecal Coliform (#col/100ml)	5
Total Coliform (#col/100ml)	4900
Total Suspended Solids	1.5
Ammonia-N	< 0.02
Nitrate-N	0.09
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	0.11
Soluble Ortho Phosphate-P	0.10

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Report Date: 10/12/89
Job #: 1008
Lot #: 1055
P.O. #: verbal
Invoice #: 89061
Sample Date: 8/24/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 Main Outlet (mg/L)
Ammonia-N	0.05
Nitrate-N	0.04
Total Kjeldahl Nitrogen	0.07
Total Phosphate-P	0.15
Soluble Ortho Phosphate-P	< 0.02
Chlorophyll a (mg/M^3)	8.28
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	5.73

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Report Date: 10/12/89
Job #: 1008
Lot #: 1055
P.O. #: verbal
Invoice #: 89061
Sample Date: 8/24/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4A North Basin Surface (mg/L)
Ammonia-N	< 0.02
Nitrate-N	< 0.01
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	0.07
Soluble Ortho Phosphate-P	0.02
Chlorophyll a (mg/M^3)	6.82
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	4.32

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Report Date: 10/12/89
Job #: 1008
Lot #: 1055
P.O. #: verbal
Invoice #: 89061
Sample Date: 8/24/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4B North Basin Bottom (mg/L)
Ammonia-N	< 0.02
Nitrate-N	0.04
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	0.15
Soluble Ortho Phosphate-P	0.08
Chlorophyll a (mg/M^3)	6.15
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	< 0.3

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Report Date: 10/12/89
Job #: 1008
Lot #: 1055
P.O. #: verbal
Invoice #: 89061
Sample Date: 8/24/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 South Basin (mg/L)
Ammonia-N	< 0.02
Nitrate-N	0.06
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	0.09
Soluble Ortho Phosphate-P	< 0.02
Chlorophyll a (mg/M^3)	2.92
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	2.81

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Report Date: 10/12/89
Job #: 1008
Lot #: 1055
P.O. #: verbal
Invoice #: 89061
Sample Date: 8/24/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 South Outlet (mg/L)
Ammonia-N	< 0.02
Nitrate-N	0.02
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	< 0.02
Soluble Ortho Phosphate-P	< 0.02
Chlorophyll a (mg/M^3)	3.16
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	1.35

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ECM
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Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State N.J. Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 10/20/89
Job #: 1008
Lot #: 1063
P.O. #: verbal
Invoice #: 89066
Sample Date: 9/14/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 South Tributary (mg/L)
Fecal Coliform (#col/100ml)	20
Total Coliform (#col/100ml)	1500
Total Suspended Solids	<1.3
Ammonia-N	<0.02
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.03
Soluble Ortho Phosphate-P	0.03

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Address 909 State Road
City Princeton State N.J. Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 10/20/89
Job #: 1008
Lot #: 1063
P.O. #: verbal
Invoice #: 89066
Sample Date: 9/14/89

REPORT OF ANALYSIS

Cranberry Lake

Station 2
West Tributary

Fecal Coliform (#col/100ml)	8
Total Coliform (#col/100ml)	700
Total Suspended Solids	< 1.3
Ammonia-N	< 0.02
Nitrate-N	< 0.01
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	0.43
Soluble Ortho Phosphate-P	0.06

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Report Date: 10/20/89
Job #: 1008
Lot #: 1063
P.O. #: verbal
Invoice #: 89066
Sample Date: 9/14/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 Main Outlet (mg/L)
Ammonia-N	0.07
Nitrate-N	0.03
Total Kjeldahl Nitrogen	0.03
Total Phosphate-P	0.09
Soluble Ortho Phosphate-P	0.04
Chlorophyll a (mg/M^3)	3.01
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	4.74

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Report Date: 10/20/89
Job #: 1008
Lot #: 1063
P.O. #: verbal
Invoice #: 89066
Sample Date: 9/14/89

REPORT OF ANALYSIS

Cranberry Lake

Station 4A
North Basin Surface
(mg/L)

Ammonia-N	< 0.02
Nitrate-N	< 0.01
Total Kjeldahl Nitrogen	< 0.02
Total Phosphate-P	0.16
Soluble Ortho Phosphate-P	0.02
Chlorophyll a (mg/M^3)	3.46
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	5.45

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Report Date: 10/20/89
Job #: 1008
Lot #: 1063
P.O. #: verbal
Invoice #: 89066
Sample Date: 9/14/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4B North Basin Bottom (mg/L)
Ammonia-N	<0.02
Nitrate-N	0.03
Total Kjeldahl Nitrogen	0.03
Total Phosphate-P	0.31
Soluble Ortho Phosphate-P	0.06
Chlorophyll a (mg/M^3)	17.9
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	27.1

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Report Date: 10/20/89
Job #: 1008
Lot #: 1063
P.O. #: verbal
Invoice #: 89066
Sample Date: 9/14/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 South Basin (mg/L)
Ammonia-N	<0.02
Nitrate-N	<0.01
Total Kjeldahl Nitrogen	<0.02
Total Phosphate-P	0.12
Soluble Ortho Phosphate-P	0.04
Chlorophyll a (mg/M^3)	1.56
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	4.45

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Report Date: 10/20/89
Job #: 1008
Lot #: 1063
P.O. #: verbal
Invoice #: 89066
Sample Date: 9/14/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 South Outlet (mg/L)
Ammonia-N	0.03
Nitrate-N	0.14
Total Kjeldahl Nitrogen	0.05
Total Phosphate-P	0.13
Soluble Ortho Phosphate-P	0.06
Chlorophyll a (mg/M^3)	6.73
Chlorophyll b (mg/M^3)	< 0.3
Chlorophyll c (mg/M^3)	< 0.3
Pheophytin (mg/M^3)	6.65

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ECM
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Company Coastal Environmental Services, Inc.
Address 2 Research Way
City Princeton State NJ Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 11/15/89
Job #: 1008
Lot #: 1067
P.O. #: verbal
Invoice #:
Sample Date: 9/28/89

REPORT OF ANALYSIS

	Cranberry Lake Station 1 South Tributary (mg/L)
Fecal Coliform (#col/100 ml)	54
Total Coliform (#col/100 ml)	600
Total Suspended Solids	1.0
Ammonia-N	<0.01
Nitrate-N	0.06
Total Kjeldahl Nitrogen	<0.01
Total Phosphate-P	< 0.02
Soluble Ortho Phosphate-P	< 0.02

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ECM
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Company Coastal Environmental Services, Inc.
Address 2 Research Way
City Princeton State NJ Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 11/15/89
Job #: 1008
Lot #: 1067
P.O. #: verbal
Invoice #:
Sample Date: 9/29/89

REPORT OF ANALYSIS

	Cranberry Lake Station 2 West Tributary (mg/L)
Fecal Coliform (#col/100 ml)	<2
Total Coliform (#col/100 ml)	250
Total Suspended Solids	2.5
Ammonia-N	<0.01
Nitrate-N	0.05
Total Kjeldahl Nitrogen	<0.01
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02

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Company Coastal Environmental Services, Inc.
Address 2 Research Way
City Princeton State NJ Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 11/15/89
Job #: 1008
Lot #: 1067
P.O. #: verbal
Invoice #:
Sample Date: 9/28/89

REPORT OF ANALYSIS

	Cranberry Lake Station 3 Main Outlet (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.06
Total Kjeldahl Nitrogen	0.05
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	8.14
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	6.27

ECM
environmental compliance monitoring

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P.O. #: verbal
Invoice #:
Sample Date: 9/28/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4A North Basin Surface (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.04
Total Kjeldahl Nitrogen	<0.01
Total Phosphate-P	<0.02
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	10.1
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	12.8

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ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 2 Research Way
City Princeton State NJ Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 11/15/89
Job #: 1008
Lot #: 1067
P.O. #: Verbal
Invoice #:
Sample Date: 9/28/89

REPORT OF ANALYSIS

	Cranberry Lake Station 4B North Basin Bottom (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.05
Total Kjeldahl Nitrogen	<0.01
Total Phosphate-P	0.11
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	6.47
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	10.2

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ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 2 Research Way
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Report Date: 11/15/89
Job #: 1008
Lot #: 1067
P.O. #: verbal
Invoice #:
Sample Date: 9/28/89

REPORT OF ANALYSIS

	Cranberry Lake Station 5 South Basin (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.01
Total Kjeldahl Nitrogen	0.02
Total Phosphate-P	0.22
Soluble Ortho Phosphate-P	<0.02
Chlorophyll a (mg/M^3)	3.98
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	5.33

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ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 2 Research Way
City Princeton State NJ Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 11/15/89
Job #: 1008
Lot #: 1067
P.O. #: verbal
Invoice #:
Sample Date: 9/28/89

REPORT OF ANALYSIS

	Cranberry Lake Station 6 South Outlet (mg/L)
Ammonia-N	<0.01
Nitrate-N	0.04
Total Kjeldahl Nitrogen	<0.01
Total Phosphate-P	0.11
Soluble Ortho Phosphate-P	0.02
Chlorophyll a (mg/M^3)	2.99
Chlorophyll b (mg/M^3)	<0.3
Chlorophyll c (mg/M^3)	<0.3
Pheophytin (mg/M^3)	6.62

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APPENDIX C
TRIBUTARIES - STORM DATA

ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State NJ Zip 08540
To Attn. of: Steve Souza

Report Date: 5/29/89
Job #: 1008
Lot #: 1035
P.O. #: 88-017-01
Invoice #: 89040
Sample Date: 5/2/89

REPORT OF ANALYSIS

	Cranberry Lake	
	Tote Road Station A (mg/L)	Lake Drive Station B (mg/L)
Ammonia-N	0.28	<0.01
Nitrate -N	2.03	0.60
Total Kjeldahl Nitrogen	0.40	0.06
Soluble Ortho Phosphate-P	0.07	<0.02
Total Phosphate-P	0.33	0.21
Total Suspended Solids	11	36

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ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State NJ Zip 08540
To Attn. of: Steve Souza

Report Date: 6/9/89
Job #: 1008
Lot #: 1039
P.O. #: 88-017-01
Invoice #: 89043
Sample Date: 5/16/89

REPORT OF ANALYSIS

	Cranberry Lake	
	Station 1 (mg/L)	Station 2 (mg/L)
Ammonia-N	<0.01	<0.01
Nitrate-N	0.14	0.06
Total Kjeldahl Nitrogen	0.24	<0.02
Soluble Ortho Phosphate-P	<0.02	<0.02
Total Phosphate-P	0.08	0.17
Total Suspended Solids	6	20

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ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State N.J. Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 11/15/89
Job #: 1008
Lot #: 1068
P.O. #: verbal
Invoice #: 89071
Sample Date: 10/2/89

REPORT OF ANALYSIS

	Cranberry Lake Station A Stormwater (mg/L)
Fecal Coliform (#col/100ml)	--
Total Coliform (#col/100ml)	--
Total Suspended Solids	4.0
Ammonia-N	<0.01
Nitrate-N	1.25
Total Kjeldahl Nitrogen	<0.01
Total Phosphate-P	0.21
Soluble Ortho Phosphate-P	0.1

PO Box 427 Neshanic Station, New Jersey 08853

ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 909 State Road
City Princeton State N.J. Zip 08540
To Attn. of: Dr. Steven Souza

Report Date: 11/15/89
Job #: 1008
Lot #: 1068
P.O. #: verbal
Invoice #: 89071
Sample Date: 10/2/89

REPORT OF ANALYSIS

	Cranberry Lake Station B Stormwater (mg/L)
Fecal Coliform (#col/100ml)	--
Total Coliform (#col/100ml)	--
Total Suspended Solids	9.3
Ammonia-N	<0.01
Nitrate-N	0.06
Total Kjeldahl Nitrogen	<0.01
Total Phosphate-P	0.43
Soluble Ortho Phosphate-P	<0.02

PO Box 427 Neshanic Station, New Jersey 08853

APPENDIX D
SEPTIC SNOOPER DATA

ECM
environmental compliance monitoring

Company: Coastal Environmental Services, Inc.
Address: 909 State Road
City: Princeton State: NJ Zip: 08540
To Attn. of: Steve Souza

Report Date: 6/26/89
Job #: 1008
Lot #: 1045
P.O. #: Verbal
Invoice #: 89047
Sample Date: 6/22/89

REPORT OF ANALYSIS

	Cranberry Lake				
	Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
Fecal Coliform (# Colonies/100 ml)	<2	<2	20	2	<2
Total Coliform (# Colonies/100 ml)	4250	82	350	48	1300
Fecal Streptococcus (# Colonies/100 ml)	2800	50	200	14	1000
Nitrate-N (mg/L)	<0.01	<0.01	<0.01	<0.01	0.02
Chloride (mg/L)	3.0	24	23	22	22

PO Box 427 Neshanic Station, New Jersey 08853

APPENDIX E
SEDIMENT QUALITY DATA

ECM
environmental compliance monitoring

Company Coastal Environmental Services, Inc.
Address 2 Research Way
City Princeton State N.J. Zip 08540
To Attn. of: Steve Souza

Report Date: 12/29/89
Job #: 1008
Lot #: 1079
P.O. #: Verbal
Invoice #: 89077
Sample Date: 10/26/89

REPORT OF ANALYSIS

	Cranberry Lake In Lake Sediment (mg/Kg Dry Wt.)
Cyanide	< 0.5
Oil & Grease	130
pH (units)	6.5
Chloride	7,860
Sulfate (Soluble)	< 100
Sulfide	1.7
Percent Solids	42.6
Arsenic	16.3
Cadmium	10.4
Chromium	3.0
Copper	21.6
Iron	7,420
Lead	93.3
Mercury	< 0.05
Nickel	25.2
Zinc	101
Ignitability	Non-Ignitable
Reactivity	Non-Reactive
Corrosivity	Non-Corrosive
Percent Sand	74
Percent Silt	26
Percent Clay	< 1
Total Phenols	0.72

ECM
environmental compliance monitoring

Company Coastal Environmental Services
Address 2 Research Way
City Princeton State N.J. Zip 08540
To Attn. of: Steve Souza

Report Date: 12/29/89
Job #: 1008
Lot #: 1079
P.O. #: Verbal
Invoice #: 89077
Sample Date: 10/26/89

REPORT OF ANALYSIS

	Cranberry Lake In Lake Sediment EP Toxicity Leachate (mg/L)
Arsenic	<0.005
Barium	<0.5
Cadmium	<0.01
Chromium	<0.01
Lead	<0.05
Mercury	<0.0005
Selenium	<0.005
Silver	<0.01

Lab Name : Bridgeport Environmental, Inc.
Case No : N/A

ORGANICS ANALYSIS DATA SHEET
(Page 2)

Sample Number
D5747

Cranberry Lake
In Lake Sediment

Base Neutral Semivolatile Compounds

Concentration: (Low) Medium (Circle One)
Date Extracted: 11/03/89
Date Analyzed: 11/08/89 16:04
Conc/Dil Factor: 30G:1ML
Percent Moisture: 57.1%

GPC Cleanup __ Yes ✓ No
Separatory Funnel Extraction __ Yes
Continuous Liquid-Liquid Extraction __ Yes

C.A.S. Number		ug/L or (ug/Kg) (Circle One)		C.A.S. Number		ug/L or (ug/Kg) (Circle One)	
111-44-4	bis(-2-Chloroethyl)Ether	780.	U	83-32-9	Acenaphthene	780.	U
541-73-1	1,3-Dichlorobenzene	780.	U	132-64-9	Dibenzofuran	780.	U
106-46-7	1,4-Dichlorobenzene	780.	U	121-14-2	2,4-Dinitrotoluene	780.	U
100-51-6	Benzyl Alcohol	780.	U	606-20-2	2,6-Dinitrotoluene	780.	U
95-50-1	1,2-Dichlorobenzene	780.	U	84-66-2	Diethylphthalate	780.	U
39638-32-9	bis(2-chloroisopropyl)Ether	780.	U	7005-72-3	4-Chlorophenyl-phenlyether	780.	U
621-64-7	N-Nitroso-Di-n-Propylamine	780.	U	86-73-7	Fluorene	780.	U
67-72-1	Hexachloroethane	780.	U	100-01-6	4-Nitroaniline	3900.	U
98-95-3	Nitrobenzene	780.	U	86-30-6	N-Nitrososdiphenylamine (1)	780.	U
78-59-1	Isophorone	780.	U	101-55-3	4-Bromophenyl-phenylether	780.	U
65-85-0	Benzoic Acid	3900.	U	118-74-1	Hexachlorobenzene	780.	U
111-91-1	bis(-2-Chloroethoxy)Methane	780.	U	85-01-8	Phenanthrene	640.	J
120-82-1	1,2,4-Trichlorobenzene	780.	U	120-12-7	Anthracene	110.	J
91-20-3	Naphthalene	780.	U	84-74-2	Di-n-Butylphthalate	780.	U
106-47-8	4-Chloroaniline	780.	U	206-44-0	Fluoranthene	560.	J
87-68-3	Hexachlorobutadiene	780.	U	129-00-0	Pyrene	860.	
91-57-6	2-Methylnaphthalene	780.	U	85-68-7	Butylbenzylphthalate	780.	U
77-47-4	Hexachlorocyclopentadiene	780.	U	91-94-1	3,3'-Dichlorobenzidine	1600.	U
91-58-7	2-Chloronaphthalene	780.	U	56-55-3	Benzo(a)Anthracene	780.	U
88-74-4	2-Nitroaniline	3900.	U	117-81-7	bis(2-Ethylhexyl)Phthalate	780.	U
131-11-3	Dimethyl Phthalate	780.	U	218-01-9	Chrysene	560.	J
208-96-8	Acenaphthylene	780.	U	117-84-0	Di-n-Octyl Phthalate	780.	U
99-09-2	3-Nitroaniline	3900.	U	205-99-2	Benzo(b)Fluoranthene	360.	J
193-39-5	Indeno(1,2,3-cd)Pyrene	220.	U	207-08-9	Benzo(k)Fluoranthene	***	
53-70-3	Dibenzo(a,h)Anthracene	780.	U	50-32-8	Benzo(a)Pyrene	330.	J
191-24-2	Benzo(g,h,i)Perylene	780.	U	92-87-5	Benzidine	1600.	U
62-53-3	Aniline	3900.	U				

(1)-Cannot be separated from diphenylamine
***-Cannot be separated from Benzo(b)Fluoranthene

Lab Name : BRIDGEPORT ENVIRONMENTAL INC
Case No : N/A

Sample Number
D5747

ORGANICS ANALYSIS DATA SHEET
(Page 3)

Cranberry Lake
In Lake Sediment

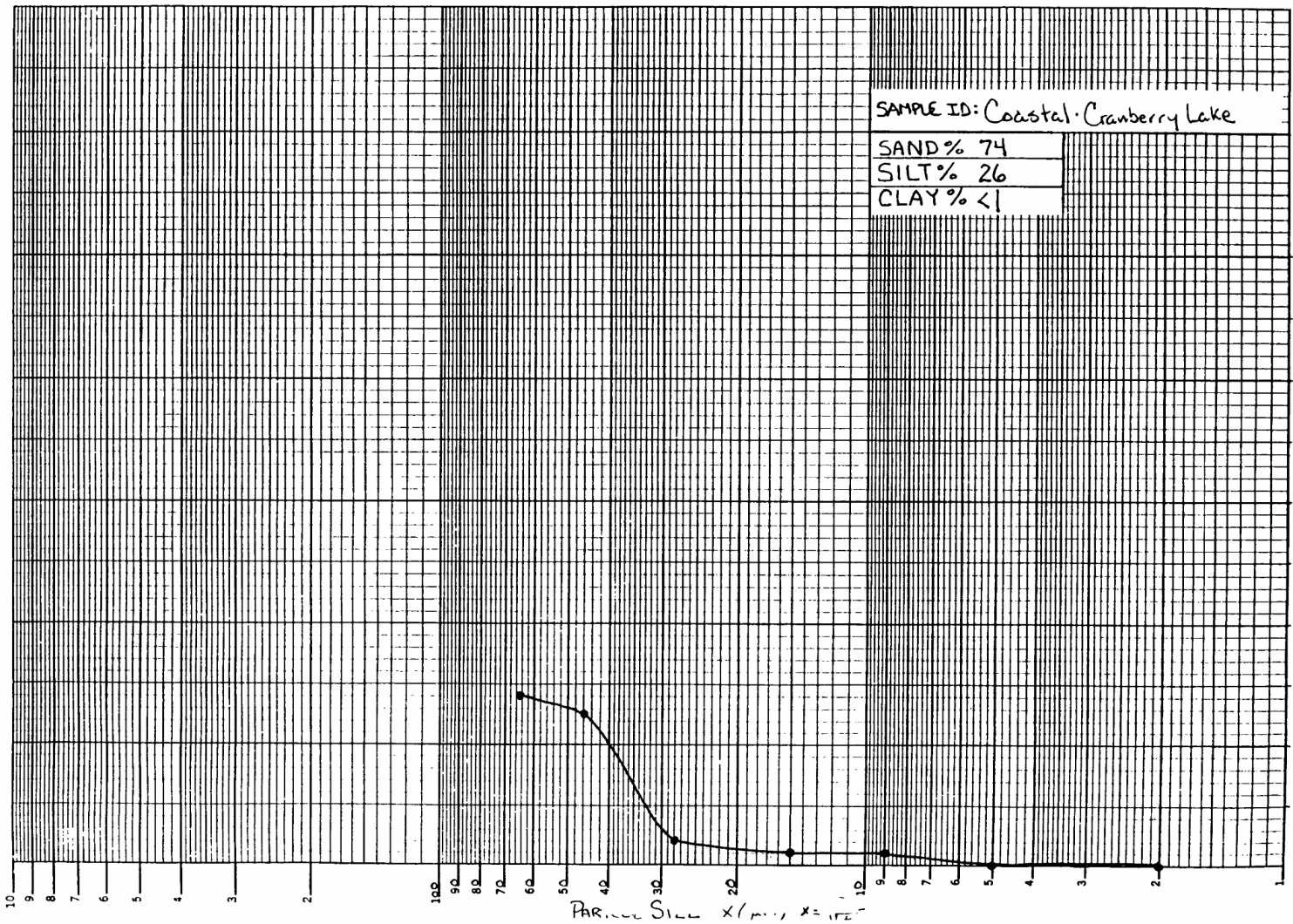
Pesticides/PCBs

Concentration: (Low) Medium (Circle One)
Date Extracted/Prepared: 11/06/89
Date Analyzed: 11/27/89
Conc/Dil Factor: 9.98g/10ml
Percent Moisture: 57.1%

GPC Cleanup __ Yes ✓ No
Separatory Funnel Extraction __ Yes
Continuous Liquid-Liquid Extraction __ Yes

C.A.S. Number		ug/L or (ug/Kg)	
319-84-6	Alpha-BHC.	100	U
319-87-7	Beta-BHC	100	U
319-86-8	Delta-BHC.	100	U
58-89-9	Gamma-BHC (Lindane). .	100	U
76-44-8	Heptachlor	100	U
309-00-2	Aldrin	100	U
1024-57-3	Heptachlor Epoxide . .	100	U
959-98-8	Endosulfan I	100	U
60-57-1	Dieldrin	100	U
72-55-9	4,4'-DDE	10	U
72-20-8	Endrin	10	U
33213-65-9	Endosulfan II.	10	U
72-54-8	4,4'-DDD	10	U
1031-07-8	Endosulfan Sulfate . .	10	U
50-29-3	4,4'-DDT	10	U
72-43-5	Methoxychlor	250	U
7421-93-4	Endrin Aldehyde. . . .	10	U
57-74-9	Chlordane.	5000	U
8001-35-2	Toxaphene.	500	U
12674-11-2	Arochlor-1016.	5000	U
11104-28-2	Arochlor-1221.	5000	U
11141-16-5	Arochlor-1232.	5000	U
53469-21-9	Arochlor-1242.	5000	U
12672-29-6	Arochlor-1248.	5000	U
11097-69-1	Arochlor-1254.	250	U
11096-82-5	Arochlor-1260.	250	U

Vi = Volume of extract injected (uL)
Vs = Volume of water extracted (mL)
Ws = Weight of sample extracted (g)
Vt = Volume of Total extract (uL)


SAMPLE ID: Coastal · Cranberry Lake
SAND % 74
SILT % 26
CLAY % <1

APPENDIX F
VOLUNTEER MONITORING DATA

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION: SW [illegible]

OBSERVER: [illegible]

MONTH: SEPT – DEC [illegible]

DATE	TIME	STAFF GAGE READING	REMARKS	DATE	TIME	STAFF GAGE READING	REMARKS
9-24	SUN	76cm	--PM				
9-27	5:30PM WED	73cm					
10-2	5:30PM MON	74cm.	RAIN TO [illegible]	[illegible]			
10-4	5:30PM WED	68 cm					
10-9	[illegible] SUN	66cm	LEAVES ARE TURNING A[illegible] SAW FLOCK OF ABOUT 12 GEESE.				
10-11	5:30PM WED	66cm					
10-15	1:30PM SUN	64cm	LEAVES ARE FALLING RAPIDLY NOW				
10-16	5PM WED	72cm	RAIN YESTERDAY AND TODAY OBSERVED APPROX FLOCK OF 24 GEESE				
10-22	8AM SUN	82cm	LEAVES [illegible]	FALLEN - DUE TO RAIN MOST OF THE [illegible]			
10-25	5PM WED	75cm					
10-29	7AM SUN	71cm	BACK ONE HOUR	ON CLOCK - READINGS DONE SUN AM AS OF LAST WEEK			
11-1	7PM WED	70cm					
11-5	7:30AM SUN	67cm					
11-8	5PM WED	66cm					
11-12	7AM SUN	66cm					
11-15	5:30PM WED	66cm					
11-19	7AM SUN	65cm	DUSTING OF SNOW ON THIS AM. SWAMPY AREA OF LAKE				
WHERE	[illegible] STREAM	ENTERS	HAD THIN LAYER OF ICE. MAIN LAKE UNFROZEN				
11-23	7AM THR	66cm	3" OF SNOW THIS MORNING.				
11-26	7:45AM SUN	66cm	OVERCAST WITH LIGHT RAIN				
11-29	6:30PM WED	66cm	MUCH COLDER 20°F				
12-3	9PM SUN	64cm	FROZEN AT THIS MARK				
12-6	6:30PM WED	65cm	STREAM FLOWING BUT FROZEN IN SPOTS.				
12-10	8AM SUN	64cm	FROZEN AT MARK				
12-13	5:30PM WED	62cm	FROZEN AT 64cm AND WAS ABLE TO BREAK ICE.				
TO GET THE READING							
12-17	7:30AM SUN	VERY	FROZEN AT 64cm				
12-20	7:30AM WED		FROZEN AT 63cm				
12-24	8:30AM SUN		FROZEN AT 63cm				
12-27	7PM WED	63cm	FROZEN				
12-31	6PM SUN	66cm	WATER FLOWING OVER THE ICE. DUE TO				
RAIN AND	WARMER	TEMPERATURES					

COASTAL

ISA 1,900

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION: SOUTH WESTERN FEEDER STREAM

OBSERVER: MARK RINGENARY

MONTH: JAN –

DATE	TIME	STAFF GAGE READING	REMARKS
1-3-90	8PM	63cm	FROZEN AT 69cm BROKE THROUGH 6cm ICE AWAY FROM STAFF TO GET SOME WATER THROUGH ICE.
1-7	8AM SUN	61cm	FROZEN AT 63cm
1-10	7PM WED	64cm	MOST SNOW WAS MELTED BUT NOW THERE IS ABOUT AN INCH OF WET SNOW COVER
1-14	8AM SUN	62cm	
1-17	6:15PM WED	65cm	MILD ABOUT 50°F TODAY STILL SNOW COVERING IN MANY AREAS
1-21	SUN 8AM	68 cm	
1-24	WED 6:30AM	70cm	
1-28	SUN 7:30AM	75 cm	STREAM UNFROZEN

COASTAL

Weaver House Cove Inlet - Staff Guage Readings

By: Mark Lacombe

Date	Reading	Time	Comments
5/25/89	26.5	3:30 PM	Rain Yesterday
5/26/89	24.0	4:00 PM	
5/27/89	22.5	4:30 PM	
5/28/89	20.0	5:30 PM	
5/29/89	18.5	4:30 PM	
5/30/89	18.5	3:30 PM	
5/31/89	18.5	3:45 PM	
6/1/89	16.0	4:00 PM	
6/2/89	14.5	3:30 PM	
6/5/89	10.0	4:30 PM	
6/6/89	14.0	4:00 PM	Showers
6/7/89	15.0	3:15 PM	Showers
6/8/89	20.0	3:15 PM	Rain
6/9/89	16.0	4:30 PM	
6/12/89	13.5	4:00 PM	
6/13/89	20.0	3:30 PM	Heavy Rain Last Nite
6/14/89	16.0	4:00 PM	Showers
6/15/89	18.5	4:30 PM	Showers
6/16/89	24.0	4:00 PM	Rain Last Nite
6/17/89	19.5	3:00 PM	
6/18/89	17.0	2:30 PM	
6/19/89	14.0	4:00 PM	
6/20/89	12.0	4:00 PM	
6/21/89	19.5	4:30 PM	Heavy T-Storms Last Nite
6/22/89	18.0	5:00 PM	
6/23/89	28.5	5:00 PM	Heavy T-Storms
6/26/89	21.5	3:30 PM	
6/27/89	20.0	4:00 PM	
6/28/89	21.5	3:30 PM	
6/29/89	17.0	4:30 PM	

Weaver House Cove Inlet - Staff Gauge Readings

By: Mark Lacombe

Date	Reading	Time	Comments
7/4/89	10.0	5:00 PM	
7/5/89	30.0	3:30 PM	Rain last nite & during day
7/6/89	18.0	3:45 PM	
7/7/89	12.5	5:30 PM	
7/9/89	12.0	4:15 PM	
7/10/89	11.0	4:00 PM	
7/11/89	10.0	3:45 PM	
7/13/89	8.0	3:30 PM	
7/14/89	7.5	3:30 PM	
7/16/89	8.0	4:30 PM	Showers
7/17/89	10.0	4:00 PM	
7/18/89	7.5	3:30 PM	
7/19/89	6.5	3:30 PM	
7/20/89	11.0	3:30 PM	
7/21/89	8.0	4:00 PM	
7/23/89	6.0	6:30 PM	
7/24/89	5.5	3:30 PM	
7/25/89	5.0	3:30 PM	
7/26/89	4.0	3:30 PM	
7/27/89	3.0	4:15 PM	
7/28/89	3.0	12:00 PM	

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION:
OBSERVER:
MONTH:

DATE	TIME	STAFF GAGE READING	REMARKS
7-12	WED	7:15PM	57cm
7-16	SUNDAY	NO READING	
7-17	MON	59cm	6:15PM
7-19	WED	5:30PM	55cm
7-23	SUN	7:30PM	52cm
7-26	WED	6PM	51.5cm — VERY HOT IN THE 90°F RANGE OF TEMPERATURE
7-29	SUN	6PM	50cm
8-2	WED	5:30PM	55cm
8-7	MON	5:30PM	59cm
8-9	WED	51cm	6PM
8-13		61cm	PAST 3 DAYS 7:30PM.
8-16	WED	62cm	6:15 PM
8-20	SUN	2PM	53.5 cm
8-23			PAST
		APPROXIMATELY AN	HOUR AGO NOW IT'S
		PARTLY SUNNY DAY	
8-27	SUN	5PM	47cm CLEAR + SUNNY YESTERDAY
		AND TODAY	
8-30	WED	47cm	
9-3	SUN	3PM	46cm
9-6	WED	45cm	6PM
9-11	MONDAY	44cm	6PM NO RAIN IN ABOUT ONE WEEK
9-13	WED	6PM	43.5cm STEADILY MOVING
		JUST LOOKS LIKE SMALL	PUDDLES IN PITS.
9-17	SUN	6PM	55cm THE STREAM APPEARS TO
		BE A STREAM AGAIN, THE	TIME. WATER FROM SHORE
		TO SHORE.	
9-20	WED	6PM	98cm HEAVY RAIN.

COASTAL

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION:

OBSERVER:

MONTH:

DATE	TIME	STAFF GAGE READING	REMARKS	DATE	TIME	STAFF GAGE READING	REMARKS
5-24	7PM	72cm					MIDNT
5-31		6PM	67cm				FEDIT
	80.0°F						
6-7	WED	6PM	74 cm C				124
6-11	SUN	4:30PM	64cm				
6-12		PM	64 cm				
RAIN							
6-17	SUN	6:30PM	68 cm				
6-21	WED	6PM	66cm H				
			DAY				
6-25	SUN	PM	71.5 cm				
HEAVY RAIN			SEVERAL				
6-28	WED	5:15PM	70 cm				
7-2	SUN	7:30PM	61 cm				90°F
7-5	WED	5:30PM	79cm				
	AND	TODAY					
7-9	SUN	8PM	61cm 90	°F SUNNY	TODAY		

COASTAL

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION: Allamuchy State Forest stream

OBSERVER: M. McGARRITY

MONTH:

DATE	TIME	STAFF GAGE READING	REMARKS	DATE	TIME	STAFF GAGE READING	REMARKS
5/27/89	2:35	71	rain yesterday				
6/6/89	5:10	64	some light rain today				

COASTAL ENVIRONMENTAL SERVICES, INC.

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION:

OBSERVER: TJP

MONTH:

DATE	TIME	STAFF GAGE READING	REMARKS
[illegible]	10:30	[illegible]	CL
[illegible]	1:00	[illegible]	CL
[illegible]	[illegible]	[illegible]	CL
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	CL
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
7/4	10:30	5	Cloudy
7/5	9:00	5	Cloudy
7/6	——	——	Cloudy
7/7	1:00	8	Cloudy
8/7	11:00	7-8	Cloudy
8/8	4:00	7	CL
8/9	——	——	CL
8/10			Cloudy
7/11	8:00pm	5	Clear
7/12	7:00pm	4	Cloudy
7/13	7:00pm	2	
[illegible]	8:00pm	1	Clear
[illegible]	8:00pm	0	Clear
[illegible]	8:00pm	0	rain
7/17	[illegible]	0-1	Clear
7/18	8:00	0-1	clear
[illegible]	[illegible]	0-1	Clear
[illegible]	6:30	2	rain
7/21	8:00	1-2	clear - windy
7/22	8:00	1	clear / hazy
7/23	8:00	1	clear
7/24	8:00	1	clear "
7/25	8:00	0-1	clear "
7/26	8:00	0	clear "
7/27	8:00	0	Clear "

DATE	TIME	STAFF GAGE READING	REMARKS
[illegible]	10:30	49	CL
[illegible]	1:00	49	CL
[illegible]	[illegible]	[illegible]	CL
[illegible]	11:00	48-49	CL
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
7/4	11:30	46-47	Cloudy
7/5	9:00	46-47	Cloudy
7/6	——	——	Cloudy
7/7	1:00	48-49	Cloudy
8-8	11:00	47-48	Cloudy
8-9	4:00	47-48	CL
8/9	——	——	CL
8/10			Cloudy
7/11	8:00pm	47-48	Clear
7/12	7:00pm	47	Cloudy
[illegible]	[illegible]	46	light rain
[illegible]	8:00	45	Clear
7/15	5:00	44	Clear
7/16	[illegible]	44	rain
7/17	[illegible]	45	Clear
7/15	[illegible]	45	[illegible]
[illegible]	[illegible]	45	[illegible]
[illegible]	[illegible]	46	[illegible]
7/21	8:00	46	
7/22	8:00	46	
7/23	8:00	45	
[illegible]	[illegible]	45	
[illegible]	8:30	45	
[illegible]	8:00	45	
[illegible]	[illegible]	44	

COASTAL

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION:
OBSERVER: TJP
MONTH:

DATE	TIME	STAFF GAGE READING	REMARKS
5/26	2:00	7-8	Cloudy
5/27	10:00	7-8	CLEAR
5/28	2:00	7-8	Ch W
5/29	11:00	6-7	Ch W
5/30	9:30	6 1/2	Cloudy
5/31	10:00	6 1/2	Ch
6/1	1000	6 1/2	Cloudy
6-2	1100	6	Ch
6-3	2:00	5-6	Ch
6/4	1100	5	Ch
6/5	3:30	5	Cloudy
6/6	1130	4-5	R
6/7	1000	4-5	CLOUDY
6/8	1100	7	R
6/9			R
6/10	12:30	8-9	Ch W
6/11	130	7-8	Ch W
6/12	10:30	6-7	CL
6/13	10:30	6-7	R
6/14	11:00	6-7	R
6/15	2:00	6-7	R
6/16	4:15	6-7	R
6/17	11:00	6-7	cloudy
6/18	10:00	6-7	Ch
6/19	2:00	7	Ch
6/20	2:00	7	Ch
6/21	1:00	7	Cloudy R
6/22	10:00	7	Clear
6/23	5:30	7-7	Cloudy R
6/24	2:00	7-10	" R
6/25	1:00	7-10	Ch
6/26	3:00	7	Ch

DATE	TIME	STAFF GAGE READING	REMARKS
5/26	2:00	50-51	Cloudy
5/27	10:00	50-51	CLEAR
5/28	2:00	50-51	Ch W
5/29	11:00	49-50	Ch W
5/30	9:30	49	cloudy
5/31	10:00	49	Ch
6/1	10:00	49	Cloudy
6-2	1100	48	Ch
6-3	200	47-48	Ch
6/4	1100	47-49	CL
6/5	330	47	CLOUDY
6/6	1130	47	R
6/7	10:00	47-48	CLOUDY
6/8	1100	50	R
6/9			R
6/10	12:30	52-53	Ch W
6/11	1:30	51-52	Ch W
6/12	10:30	49-50	Ch
	10:30	49-50	R
6/14	11:00	49	R
6/15	2:00	4950	R
6/16	4:25	49-50	R
6/17	11:00	51-52	Cloudy
6/18	10:00	[illegible]	Ch
6/19	2:00	49	Ch
6/20	3:00	49-49	Ch
6/21	1:00	48-49	[illegible]
6/22	10:00	48-49	[illegible]
6/23	5:30	[illegible]	[illegible]
6/24	2:00	51-52	[illegible]
6/25	1:00	51-52	Ch
6/26	3:00	50	Ch

COASTAL

Beaver dam immediately above station + a little way downstream

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION: feeder stream, Allaire Wildlife State Park

OBSERVER: M. McGARRITY

MONTH:

DATE	TIME	STAFF GAGE READING	REMARKS
3/25/89	4:05	76	some rain in past few days
3/28/89	2:35	71.5	v. warm today + yesterday
4/2/89	5:40	71	heavy rain Fri. + some Sat.
4/7/89	4:15	71	Prior 3 days: rain
4/14/89	5:50	68.5	light rain + past few days — today nicer
4/17/89	3:45	68.5	rainy Sat. + Sun. am
4/20/89	4:15	67	sunny + dry past few days
4/30/89	10:50am	64.5	light rain Sat. — dry the week before
5/5/89	8:45am	68.5	
5/9/89	9:20am	77	rainy past few days sunny thru a.m.
5/20/89	8:30am	78	sunny yesterday + today

DATE	TIME	STAFF GAGE READING	REMARKS

COASTAL

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION: SOUTH WOODLAND FLOW

OBSERVER: MARK RINGENARY

MONTH: APR - MAY

DATE	TIME	STAFF GAGE READING	REMARKS
4-1-89	330PM	21cm	OVERCAST
HEAVY	RAIN	3-31	
4-5	WED	545PM	70cm
& THUNDER STORMS.			
4-11	WED	615PM	69cm ½SUN ½ CLOUDY — NO RAIN -
4-17	MON	6PM	68.5cm CLEAR ±70°F DURING THE
DAY	NOW	OVER CAST	AND LIGHT SPRINKLE OF
RAIN			
4-19	WED	615PM	67cm SUNNY 65°F SOME RAIN
LAST EVENING 4-18→4-19			
4-26	WED	6PM	65cm CLEAR SKIES 70°F
5-2	WED	530AM	68cm PARTLY CLOUDY —
INTERMITTENT	SHOWERS		HEAVY RAIN 5-2-IN AM
5-10	WED	6PM	81cm HEAVY RAIN
5-12	FRI	815AM	78cm INTERMITTENT RAIN
[illegible]	FRI	5PM	82cm [illegible]
AND	[illegible]	[illegible]	[illegible]

DATE	TIME	STAFF GAGE READING	REMARKS
INTERMITTENT SHOWERS			

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION:

OBSERVER: T.J. Piscotty

MONTH:

readings at 2 dams

DATE	TIME	STAFF GAGE READING	REMARKS
2/23	12 Noon	50	CLEAR
2/25	12 "	49	CLEAR
2/27	12 "	49	SNOW SHWR
3/1	2 PM	48½	CLEAR
3/3	12 N	48½	"
3/4	12 N	48	CLOUDY
3/5	11:30	47½	MISTY
3/7	3:30	48	CLEAR
[illegible]	2:30	48	"
3/10	2:00	48	"
3/11	12:00	48½	"
3/13	2:30	47½	"
3/14	3:00	48	"
3/16	4:00	48½	"
3/17	4:00	49	Cloudy
3/19	2:00	48½	CLOUDY
3/20	2:30	48½	CLOUDY
3/21	12:00	49	CLOUDY
3/23	2:30	48½	CLEAR
3/24	2:30	49	RAIN SLIGHT
3/26	12:00	50	[illegible]
3/27	4:00	49½	CLEAR
3/29	1100	49	CLOUDY
3/31	1130	50½	" R
4/1	11:00	50	CLEAR
4/2	2:00	49	"
4/4	11:00	49½	cloudy R
4/6	12:00	50	clear
4/7	12:00	50	cloudy R W
4/8	3:00	50	CLEAR W
4/10	1:30	49½	CLEAR "
4/12	3:00	49½	" "

DATE	TIME	STAFF GAGE READING	REMARKS
3/25	12:00	9	CLEAR
3/27	4:00	9	CLEAR
3/29	11:00	8½	CLOUDY
3/31	1130	8½	" R
4/1	11:00	8½	CLEAR
4/2	2:00	7	"
4/4	11:00	7	cloudy R
4/6	12:00	7	clear
4/7	12:00	7	Cloudy R W
4/8	3:00	7	CLEAR W
4/10	[illegible]	[illegible]	CLEAR W
4/12	3:00	6½	" W

COASTAL

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION:

OBSERVER:

MONTH:

DATE	TIME	STAFF GAGE READING	REMARKS
4/14	3:00	49	CLEAR
4/15	11:00	48½	cloudy R
4/16	11:30	50	cloudy R
4/17	10:00	49½	CLEAR
4/18	11 00	49	" W
4/19	1:00	48½	" W
4/21	1130	48	" W
4/25	1:30	47.48	" W
4/28	4:30	46-47	" W
4/30	2:00	46-47	" W
5/2	11:00	49-50	" W
5/4	11:00		
5/6	3:00	54-55	cloudy W
5/8	10:00	53-54	" W
5/10	2:30	53-54	RAIN W
5/12	1:00	53-54	" W
5/13	4:00	53	cloudy F
5/15	12:30	51	" F
5/16			R
5/17	11:00	58	CLEAR
5/19	4:30	54	"
5/20	2:30	53-54	"
5/22	3:00	51-52	"
5/23	9:00	50-51	"
5/24	10:30	53	R
5/25	11:00	53-54	CLEAR

DATE	TIME	STAFF GAGE READING	REMARKS
4/14	3:00	6½	CLEAR
4/15	11:00	6	cloudy R
4/16	11.30	6½	cloudy R
4/17	10100	6½	CLEAR
4/18	1100	6½	" W
4/19	1:00	6½	" W
4/21	1130	6	" "
4/25	1:30	5	" W
4/28	430	5	" W
4/30	2:00	5	" W
5/2	11:00	8	" W
5/4	11:00		
5/6	3:00	10	cloudy W
5/8	10:00	8½	" W
5/10	2:30	9	RAIN W
5/12	1:00	9	" W
5/13	4:00	9	cloudy F
5/15	12:30	8	" F
5/16			R
5/17	11:00	11	CLEAR
5/19	4:30	9	"
5/20	2:30	8½	"
5/22	3:00	8	"
5/23	9:00	7½	"
5/24	10:30	9	R
5/25	11:00	8-9	clear

COASTAL

STREAM GAGING STATION RECORD FORM: CRANBERRY LAKE

STATION: Weaver House Cove Inlet

OBSERVER: Mark Lacombe

MONTH:

DATE	TIME	STAFF GAGE READING	REMARKS
2/27/89	3:00 PM	34	
2/28/89	3:30 PM	29	
2/25/89	4:00 PM	23.5	Lt. Snow
2/27/89	3:30 PM	25.5	
2/28/89	3:30 PM	24.0	
3/1/89	4:00 PM	22.6	
3/2/89	3:30 PM	21.5	
3/3/89	4:06 PM	21.0	
3/4/89	3:00 PM	21.0	
3/5/89	3:45 PM	23.0	Showers
3/6/89	4:30 PM	28.0	Rain/Snow
3/7/89	3:30 PM	27.0	
3/8/89	6:00 PM	21.0	
3/9/89	3:30 PM	20.5	
3/10/89	4:00 PM	21.5	Warm - Melting
3/11/89	2:45 PM	22.0	Warm - Melting
3/12/89	3:30 PM	22.5	Lt. Rain/Flurries
3/13/89	3:30 PM	22.0	
3/14/89	3:15 PM	24.0	Melting Snow
3/15/89	3:30 PM	31.5	Wash
3/16/89	3:30 PM	27.0	
3/17/89	3:15 PM	25.0	
3/18/89	3:00 PM	28.0	Showers
3/19/89	3:30 PM	26.0	
3/20/89	3:30 PM	24.0	
3/21/89	3:15 PM	34.5	Melting Snow
3/22/89	3:30 PM	30.0	
3/23/89	3:30 PM	27.5	
3/27/89	3:30 PM	23.0	
3/28/89	3:30 PM	22.0	
3/29/89	3:45 PM	22.0	
3/30/89	3:30 PM	21.5	Showers
3/31/89	4:00 PM	24.6	Showers
4/1/89	4:00 PM	24.0	
4/2/89	3:00 PM	22.5	
4/3/89	3:30 PM	23.6	Showers
4/4/89	3:30 PM	22.6	Showers
4/5/89	3:15 PM	21.5	
4/6/89	3:30 PM	26.0	Rain
4/7/89	4:15 PM	23.0	
4/8/89	3:15 PM	22.5	
4/9/89	4:30 PM	22.0	
4/10/89	3:30 PM	21.0	
4/11/89	3:30 PM	20.5	
4/12/89	3:45 PM	20.0	
4/13/89	3:15 PM	20.0	
4/14/89	3:30 PM	20.0	
4/15/89	3:45 PM	21.0	Showers
4/16/89	4:00 PM	24.5	Showers
4/17/89	4:00 PM	22.0	
4/18/89	3:30 PM	20.5	
4/19/89	3:30 PM	19.0	
4/20/89	3:15 PM	18.5	
4/21/89	3:30 PM	18.5	
4/22/89	3:15 PM	18.0	
4/23/89	3:00 PM	17.0	
4/24/89	3:30 PM	17.0	
4/25/89	3:30 PM	17.0	
4/26/89	3:15 PM	16.5	
4/27/89	3:30 PM	16.0	
4/28/89	3:15 PM	15.0	
4/29/89	3:00 PM	14.5	
4/30/89	3:45 PM	14.0	
5/1/89	3:30 PM	14.0	

COASTAL

Stream Gaging Station Record Form: Cranberry Lake

Station: Weaver House Cove Inlet
Observer: Mack Lacombe

Date	Time	Staff Gage Reading	Remarks
5/2/89	3:16 PM	41.0	RAIN
5/3/89	3:16 PM	24.5	
5/4/89	3:30 PM	21.5	
5/5/89	3:30 PM	24.5	SHOWERS
5/6/89	4:00 PM	45.0	HEAVY RAIN
5/7/89	3:15 PM	37.0	RAIN
5/8/89	3:30 PM	31.5	
5/9/89	3:15 PM	29.0	
5/10/89	3:30 PM	40.0	RAIN
5/11/89	3:30 PM	41.0	RAIN
5/14/89	4:00 PM	30.0	SHOWERS
5/15/89	4:00 PM	27.5	
5/16/89	3:15 PM	52.0	HEAVY RAIN
5/17/89	3:15 PM	50.0	AM RAIN
5/18/89	3:30 PM	35.0	
5/19/89	3:15 PM	29.5	
5/20/89	4:00 PM	26.0	
5/21/89	3:00 PM	26.0	
5/22/89	4:00 PM	24.0	
5/23/89	3:15 PM	23.0	
5/24/89	3:15 PM	36.5	RAIN

RAIN GAGE RECORD FORM: CRANBERRY LAKE

OBSERVER: Paul Zendzian

MONTH:

RAIN GAGE

DATE	TIME	RAIN GAGE READING	REMARKS
2/23	12 00 Noon	–	Gage Installed
24	1 PM	0	–
25	11 30 AM	0	–
26	12 00 Noon	–	will wait for SNOWing
27	9 00 AM	4	–
28	1: 30 AM	T	Flurrys
3/ 1	12:30 PM	0	–
2	12:30 PM	0	–
3	11:00 AM	0	–
4	11:30 AM	0	–
5	11:00 AM	T	Sun + starting to Rain
6	10:30 AM	18.6	Rain + Snow
7	12:00 Noon	10.2	Snow
8	12:00 Noon	0	
9	11:30 AM	0	
10	12:30 PM	0	
11	2: PM	0	
12	12:45 PM	0.6	
13	1 PM	0	
14	12: Noon	0	
15	11:45 AM	0	
16	1 PM	0	
17	11 AM	0	
18	11 30 AM	0	
19	12 45 PM	5.9	
20	11:45 AM	0	
21	11:00 AM	9.4	Snow + Rain
22	12:30 PM	0	
23	1 00 PM	0	
24	1:30 PM	10.9	
25	12 00 Noon	15.6	
26	12 Noon	T	
27	1 0 PM	0	
28	12 30 PM	0	
29	12 PM	0	
30	11:45 AM	2.4	
31	1 30 PM	11.8	
4/ 1	12:45 PM	8.1	
2	1 – PM	0	
3	1 30 PM	2.5	
4	12:45 PM	.5	
5	2 00 PM	3.0	
6	3:30 PM	14.6	
7	1 30 AM	3.2	
8	12 30	1.4	
9	11 30 PM	3.6	
10	Noon	0	
11	–	0	
12	–	0	
13	1:30 PM	3.6	
14	12:30 PM	13.8	2 days was out here
15	–	–	
16	–	0	
17	–	0	
18	–	0	
19	11 00 AM	1.4	
20	–	0	
21	–	0	
22	–	0	
23	–	0	
24	–	0	
25	–	0	
26	–	0	
27	–	0	

COASTAL
ENVIRONMENTAL SERVICES INC.

RAIN GAGE RECORD FORM: CRANBERRY LAKE

OBSERVER: Paul Zendzian

MONTH:

DATE	TIME	RAIN GAGE READING	REMARKS	DATE	TIME	RAIN GAGE READING	REMARKS
4-28	–	0					
4-29	–	0	gone for WK				
4-30	2 PM	1.8	2 Days				
5-1	–	0					
5-2	1 PM	29.6					
5-3	–	0					
5-4	–	0					
5-5	–	0					
5-6	11 AM	40.4					
5-7	–	0					
5-8		6.0					
5-9	–	0					
5-10	130 PM	21.1					
5-11	130 PM	13.8					
5-12	11 AM	.5					
5-13							
5-14		4.6	gone for WK Ends				
5-15							
5-16							
5-17							
5-18							
5-19							
5-20							
5-21							
5-22							
5-23							
5-24							
5-25							
5-26							
5-27							
5-28							
5-29							

COASTAL
ENVIRONMENTAL SERVICES INC.

RAIN GAGE RECORD FORM: CRANBERRY LAKE

OBSERVER: M. CARRUTH

MONTH:

DATE	TIME	RAIN GAGE READING	REMARKS
5-15	—	0	
5-16	12:30 PM	48.2	
5-17	11: AM	15.4	
5-18			
5-19			
5-20			
5-21			changed volunteers: Jan Zendzian to McCarthy
5-22			
5-23			
5-24			
5-25			
5-26			
5-27			
5-28			
5-29			
5-30			
5-31	7am.	0	
6-1	10:45am	4	
6-2	8am	0	
6-3	8am	0	
4	7:15am	0.6	
5	8am	0	
6	8am	0.8	
7	8:15 am	4.4	
8	8:10am	23.0	
9	7:40am	0.4	
10	7:30am	30.25	
11	8:30 am	0.4	
12	8:30am	11.4	
13	8:30	—	
14	8:40am	0	
15	8:40am	5.2	

DATE	TIME	RAIN GAGE READING	REMARKS
6/16/89	8:05am	9.2	
6/17/89	7:30am	17.3	
6/18/89	7:30am	0.5	
6/19	11	0	
6/20	11	0	
6/21	8 am	10.0	
6/22	8am	1.6	
6/23	8 am	17.7	
6/24		0	
6/25		0	
6/26		0	
6/27		0	
6/28	[illegible]	[illegible]	
6/29	11:30am	4.9	
6/30-7/4		0	
7/5	7:20am	6.8	
7/6	8:20am	32.2	
7/7	8:30am	0	
7/8	7:40am	25.5	
Vacation 7/15 — 7/21 cumulative reading on return			
7/22		17	
7/23	2pm.	1.4	
7/24	am	0	
7/25	am	0	
7/26	am	0	
7/27	am	0	
7/28	8am	.4	

COASTAL ENVIRONMENTAL SERVICES INC.

RAIN GAGE RECORD FORM: CRANBERRY LAKE

OBSERVER: M. McGARRITY

MONTH:

RAIN GAGE

DATE	TIME	RAIN GAGE READING	REMARKS
7/31	9:30	.7	
8/1	7:45	9.0	
8/2	8:30	0	
8/3	8:45	5.1	
8/4	8:30	0	
8/5	7:00am	7.8	
8/6	7am	6	
8/7	6am	5.4	
8/8	8am	4.2	
8/9	9:30am	0	
8/10	" "	4.2	
8/11	7:15am	21.6	Tues
8/12	8:30am	7.2	
8/~~14~~	9:30am	5.7	
8/~~15~~	7am	1.1	
8/16	8am	.5	
8/17	—	—	
8/18	—	—	
8/19	6:30am	.5	
8/20	8:30am	1.8	
8/21	—	0	
8/22	6am	.5	
8/23	—	0	
8/24	7:30am	17	
8/25	—	—	
8/26	—	—	
8/27	—	—	
8/28	—	—	
8/29	7:30am	1.7	
8/30	9am	.9	
8/31		0	
9/14			

RAIN GAGE

DATE	TIME	RAIN GAGE READING	REMARKS
9/15	6:30am	13	
9/16	8am	0	
9/17	8am	16	
9/18	8am	0	
9/19	9:15am	1.9	
9/20	7am	12.6	
9/21	7am	95.2	
9/22	7:10am	6.0	
9/23	7:30am	9.6	
9/24	8:30am	14.0	
9/~~25~~	7:15am	18.0	
9/27	7:45am	4.0	

COASTAL ENVIRONMENTAL SERVICES INC.

RAIN GAGE RECORD FORM: CRANBERRY LAKE

OBSERVER: M. M'GARRITY

MONTH:

DATE	TIME	RAIN GAGE READING	REMARKS
9/29	7am	0	
9/30	7am	0	
10/1	7am	0	
10/2	7am	7.8	
10/3	7am	9.0	
~~10/5~~			
10/4		} 0	
10/6			
10/7	8am	1.2	
10/9	8am	2.0	
10/10	7am	0	
10/11	7am	6.2	
10/12	}	0	
10/17			
10/18	7:15am	42.2	
10/19	7:30am	8.6	
10/20	6:30am	22.6	
10/21	7:45am	51.3	
10/22 to 10/31		0	
11/1	7:45am	9.4	
11/3	8am	2.0	
11/4 to 11/6		0	
11/7	10am	1.0	
11/8		0	
11/9	7:30am	3.3	
11/10	7am	10.6	
11/11	7:40am	1.7	
11/12	~~7~~	~~3~~	
11/13 to 11/14		0	
11/15	7am	3.2	

DATE	TIME	RAIN GAGE READING	REMARKS
11/16	—	0	
11/17	7:30am	9.0	
11/18 -		0	
11/20			
11/21	9am	1.6	
11/22	7	3.0	
11/24	}		
11/25	7	0	
11/26	}		
11/27	9:30am	1.2	
11/28	7:30am	3.2	
12/6	9am	2.2	cumulative for last week
12/7 - 12/11		0	
12/12	1pm	1.8	
12/13 - 12/15		0	
12/16	11am	7.6	snow
12/17 - 12/21		.9	snow
12/22 - 12/26		—	
12/27		.4	snow
12/28 - 12/29		—	
12/30	8:30am	7.0	snow
12/31		—	
1/1	8:30am	14.0	rain
1/9	11am	14.0	snow
1/10	9am	3.2	rain

COASTAL ENVIRONMENTAL SERVICES INC.

APPENDIX G
SURFACE WATER QUALITY CRITERIA

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance		Criteria	Classifications
1.	Bacterial quality (Counts/100 ml)	i. Bacterial Indicators shall not exceed, in all shellfish waters, the standard for approved shellfish waters as established by the National Shellfish Sanitation Program as set forth in its current manual of operations.	Shellfish Waters
		ii. Fecal Coliforms:	
		(1) Fecal coliform levels shall not exceed a geometric average of 50/100 ml.	Within 1500 feet of shoreline in SC waters.
		(2) Fecal coliform levels shall not exceed a geometric average of 200/100 ml nor should more than 10 percent of the total samples taken during any 30-day period exceed 400/100 ml.	FW2 , SE1, and SC 1500 feet to 3 miles from the shoreline.
		(3) Fecal coliform levels shall not exceed a geometric average of 770/100 ml.	SE2
		(4) Fecal coliform levels shall not exceed a geometric average of 1500/100ml.	SE3

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance	Criteria	Classifications
	iii. Enterococci:	
	(1) Enterococci levels shall not exceed a geometric mean of 33/100 ml, nor shall any single sample exceed 61/100 ml.	FW2
	(2) Enterococci levels shall not exceed a geometric mean of 35/100 ml, nor shall any single sample exceed 104/100 ml.	SE1 and SC
	iv. Samples shall be obtained at sufficient frequencies and at locations during periods which will permit valid interpretation of laboratory analyses. As a guideline and for the purpose of these regulations, a minimum of five samples as equally spaced over a 30-day period, as feasible, should be collected; however, the number of samples, frequencies and locations will be determined by the Department or other appropriate agency in any particular case.	All Classifications
2. Chloride (mg/l)	i. 250	FW2

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance		Criteria	Classifications
3.	Dissolved oxygen (mg/l)	i. Not less than 7.0 at any time.	FW2-TP
		ii. 24 hour average not less than 6.0. Not less than 5.0 at any time (see paragraph viii below).	FW2-TM
		iii. 24 hour average not less than 5.0, but not less than 4.0 at any time (see paragraph viii below).	FW2-NT (except as in iv below), SE1
		iv. Not less than 4.0 at any time.	Tidal portions of FW2-NT tributaries to the Delaware River, between Rancocas Creek and Big Timber Creek inclusive.
		v. Not less than 5.0 at any time.	SC
		vi. Not less than 4.0 at any time.	SE2
		vii. Not less than 3.0 at any time.	SE3
		viii. Supersatuarted dissolved oxygen values shall be expressed as their corresponding 100 percent saturation values for purposes of calculating 24 hour averages.	FW2-TM, FW2-NT, SE1

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance		Criteria	Classifications
4. Floating, colloidal, color and settleable solids; petroleum hydrocarbons and other oils and grease	i.	None noticeable in the water or deposited along the shore or on the aquatic substrata in quantities detrimental to the natural biota. None which would render the waters unsuitable for the designated uses.	All Classifications
	ii.	For "Petroleum Hydrocarbons" the goal is none detectable utilizing the Federal EPA Environmental Monitoring and Support Laboratory Method (Freon Extractable - Silica Gel Adsorption - Infrared Measurement); the present criteria, however, are those of paragraph i. above.	All Classifications
5. pH (Standard Units)	i.	6.5-8.5	FW2, All SE
	ii.	Natural pH conditions shall prevail.	SC
6. Phosphorus, Total (mg/l)	i.	Lakes: Phosphorus as total P shall not exceed 0.05 in any lake, pond or reservoir, or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed pursuant to N.J.A.C. 7:9-4.5(g)3.	FW2

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance		Criteria	Classifications
	ii.	Streams: Except as necessary to satisfy the more stringent criteria in paragraph i above or where site-specific criteria are developed pursuant to N.J.A.C 7:9-4.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.	FW2
7. Radioactivity	i.	Prevailing regulations adopted by the U.S. Environmental Protection Agency pursuant to Sections 1412, 1445, and 1450 of the Public Health Services Act, as amended by the Safe Drinking Water Act (PL 93-523)	All Classifications
8. Solids, Suspended (mg/l) (Non-filterable residue)	i.	25.0	FW2-TP, FW2-TM
	ii.	40.0	FW2-NT
	iii.	None which would render the waters unsuitable for the designated uses.	All SE, SC

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance		Criteria	Classifications
9. Solids, Total Dissolved (Filterable Residue) (mg/l)	i.	No increase in background which may adversely affect the survival, growth or propagation of the aquatic biota or would interfere with the designated or existing uses, or 500 mg/l, whichever is more stringent. (Increases up to 133 percent of background are deemed to be in compliance with the narrative criterion above. Increases above 133 percent of background may be granted where the discharger demonstrates, to the satisfaction of the Department, that the proposed increase will not adversely affect the aquatic biota.)	FW2
	ii.	None which would render the water unsuitable for the designated uses.	All SE
10. Sulfate (mg/l)	i	250	FW2
11. Taste and odor producing substances	i.	None offensive to humans or which would produce offensive taste or odors in water supplies and biota used for human consumption. None which would render the water unsuitable for the designated uses.	All Classifications
12. Temperature and Heat Dissipation Areas	i.	Thermal Alterations (Temperatures shall be measured outside of heat dissipation areas)	

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

tance	Criteria	Classifications
	(1) Streams	
	(i) No thermal alterations which would cause changes in ambient temperatures except where properly treated wastewater effluents are discharged. Where such discharges occur, temperatures shall not deviate more than 0.6°C (1°F) from ambient temperature.	FW2-TP
	(ii) No thermal alterations which would cause temperatures to exceed ambient by more than 1.1°C (2°F) at any time or which would cause temperatures in excess of 20°C (68°F).	FW2-TM
	(iii) No thermal deviations which would cause temperatures to deviate more than 2.8°C (5°F) at any time from ambient temperatures. No heat may be added which would cause temperatures to exceed 27.8°C (82°F) for small mouth bass or yellow perch waters, or 30°C (86°F) for other nontrout waters.	FW2-NT

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance	Criteria	Classifications
	(iv) No thermal alterations which would cause temperatures to deviate from ambient by more than 2.2°C (4°F), from September through May, nor more than 0.8°C (1.5°F) from June through August, nor cause temperatures to exceed 29.4°C (85°F).	All SE
	(2) Lakes, Ponds or Reservoirs	
	(i) No thermal alterations except where it can be shown to be beneficial to the designated and existing uses.	FW2-TM
	(ii) No thermal alterations of more than 1.7°C (3°F) in the epilimnion of lakes and other standing waters. No discharges of heated effluent into the hypolimnion nor pumping of water from the hypolimnion (for discharge back into the same water body) shall be permitted unless it is demonstrated, to the satisfaction of the Department, that such practices will be beneficial to the existing and designated uses.	FW2-NT

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

bstance	Criteria	Classifications
	(3) Coastal Waters - No direct heat additions within 1500 feet of the shoreline. No thermal alterations which would cause temperatures to deviate from ambient temperatures by more than 2.2°C (4°F) from September through May, nor more than 0.8°C (1.5°F) from June through August, nor which would cause temperatures to exceed 26.7°C (80°F).	SC
	ii. Heat Dissipation Areas	
	(1) Streams	FW2-TM, FW2-NT, All SE
	(i) Not more than one-quarter (1/4) of the cross section and/or volume of the water body at any time.	
	(ii) Not more than two-thirds (2/3) of the surface from shore to shore at any time.	

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

bstance		Criteria	Classifications
		(iii) These limits may be exceeded by special permission, on a case-by-case basis, when a discharger can demonstrate that a larger heat dissipation area meets the tests for a waiver under Section 316 of the Federal Clean Water Act.	
	(2)	Lakes, Ponds, Reservoirs, Bays or Coastal Waters: Heat dissipation areas will be developed on a case-by-case basis.	FW2-TM, FW2-NT, All SE, SC
. Toxic Substances (general)	i.	None, either alone or in combination with other substances, in such concentrations as to affect humans or be detrimental to the natural aquatic biota, produce undesirable aquatic life, or which would render the waters unsuitable for the designated uses.	All Classifications
	ii.	None which would cause standards for drinking water to be exceeded after appropriate treatment.	FW2

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance	Criteria	Classifications
	iii. Toxic substances shall not be present in concentrations that cause acute or chronic toxicity to aquatic biota, or bioaccumulate within an organism to concentrations that exert a toxic effect on that organism or render it unfit for consumption.	All Classifications
	iv. The concentrations of nonpersistent toxic substances in the State's waters shall not exceed one-twentieth (0.05) of the acute definitive LC50 or EC50 value, as determined by appropriate bioassays conducted in accordance with N.J.A.C. 7:18.	All Classifications
	v. The concentration of persistent toxic substances in the State's waters shall not exceed one-hundreth (0.01) of the acute definitive LC50 or EC50 value, as determined by appropriate bioassays conducted in accordance with N.J.A.C. 7:18.	All Classifications

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance		Criteria	Classifications
14.	Toxic Substances (ug/l):		
	NOTE: Criteria followed by an (a) represent aquatic protection based criteria. Criteria followed by an (h) represent criteria based upon human health information. Criteria follows by an (a*) or (h*) represent criteria developed after review of both human health information and aquatic protection data. The basis for the criterion adopted (human health or aquatic protection) is indicated by the letter preceding the (*).		
i.	Aldrin/Dieldrin	(1) 0.0019 (a)	All Classifications

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance		Criteria	Classifications
ii. Ammonia, un-ionized (24 hr. average)	(1)	20 (a)	FW2-TP, FW2-TM
	(2)	50 (a)	FW2-NT
	(3)	0.1 of acute definitive LC50 or EC50 (a)	All SE, SC
iii. Arsenic, Total	(1)	50 (h)	FW2
iv. Barium, Total	(1)	1000 (h)	FW2
v. Benzidine	(1)	0.1 (h*)	All Classifications
vi. Cadmium, Total	(1)	10 (h)	FW2
vii. Chlordane	(1)	0.0043(a)	FW2
	(2)	0.0040(a)	All SE, SC
viii. Chlorine Produced Oxidants (CPO)	(1)	24 hour average less than 11.0. Less than 19 at any time. (a)	FW2
	(2)	24 hour average less than 7.5. Less than 13 at any time. (a)	All SE, SC
ix. Chromium, Total	(1)	50(h)	FW2
x. DDT and Metabolites	(1)	0.0010(a)	All Classifications
xi. Endosulfan	(1)	0.056(a)	FW2
	(2)	0.0087(a)	All SE, SC
xii. Endrin	(1)	0.0023(a)	All Classifications

7:9-4.14 (c) Surface Water Quality Criteria for FW2,SE and SC Waters

(Expressed as maximum concentrations unless otherwise noted)

Substance		Criteria	Classifications
xiii. Heptachlor	(1)	0.0038(a)	FW2
	(2)	0.0036(a)	All, SE, SC
xiv. Lead, Total	(1)	50(h)	FW2
xv. Lindane	(1)	0.080(a)	FW2
	(2)	0.004(a)	All SE, SC
xvi. Mercury, Total	(1)	2(h)	FW2
xvii. Polychlorinated biphenyls (PCB's)	(1)	0.014(a)	FW2
	(2)	0.030(a)	All SE, SC
xviii. Selenium, Total	(1)	10(h)	FW2
xix. Silver, Total	(1)	50(h)	FW2
xx. Toxaphene	(1)	0.013(a)	FW2
	(2)	0.005(a)	All SE, SC
15. Turbidity (Nephelometric Turbidity Unit-NTU)	i.	Maximum 30-day average of 15 NTU, a maximum of 50 NTU at any time.	FW2, SE3
	ii.	Maximum 30-day average of 10 NTU, a maximum of 30 NTU at any time.	SE1, SE2
	iii.	Levels shall not exceed 10.0 NTU.	SC

I. General Information

1. Applicant: Township of Byram

Address: 10 Mansfield Drive

Contact Person & Phone #: Ronald F. Gatti 973-347-2500

2. Lake Name: Lake Lackawanna

County: Sussex County
(See site and area maps attachments #1, #2)

3. Please indicate type of lake and type of funding.

- [ ] Public lake/Grant
- [x] Private lake/Loan
- [ ] State-owned/Grant

4. Total Project Cost

State share (grant/loan): $21,900

Local share: 3,100

Total cost: $25,000

5. Project time frame (months): 7 months estimated
(project start date is subject to award date of grant or loan)

II. Priority Ranking Information

The following information must be provided to the Department so that applications can be prioritized for funding. If the spaces provided do not permit enough space for responses, please use additional sheets and attach to the application package.

1. In the space provided below please document any recreational activities the applicant's lake supports which are listed in N.J.A.C. 7:9-2.5(a)1. (*Lake use and recreational potential).* Please also describe recreational usage as it pertains to specific point totals.

SEE ATTACHED RESPONSE

2. In the space provided below, please list any cities, boroughs, towns or townships and any counties contiguous to the lake [N.J.A.C. 7:9-2.5(a)2]. Please also provide populations for each based on Federal 1990 Census Data.

SEE ATTACHED RESPONSE

3. In the space provided below, please detail local interest and involvement as defined in N.J.A.C. 7:9-2.5(a) 3. In order to justify points awarded for this category, please provide documentation of local involvement.

SEE ATTACHED RESPONSE

4. In the space provided below, indicate if the lake is located within a Center or an Environmentally Sensitive Area (Planning Area 4B, Planning Area 5 or the jurisdiction of Pinelands Protection Act) as designated by the State Development and Redevelopment Plan [N.J.A.C. 7:9-2.5(a) 4].

SEE ATTACHED RESPONSE

5. In the space below, please indicate if this lake restoration project will be coordinated with other pollution control or watershed activities specified in N.J.A.C. 7:9-2.5(a)5.

SEE ATTACHED RESPONSE

6. If this is a Phase II Application, please indicate below if the applicant has completed a Phase I Diagnostic-Feasibility Study [N.J.A.C. 7:9-2.5(a)6.]. If a Phase I Study has been completed please include a copy with this application.

NOT APPLICABLE

THE DEPARTMENT OF ENVIRONMENTAL PROTECTION

LAKE RESTORATION FUNDING - NJAC 7:9-2.5

PHASE I APPLICATION

II. PRIORITY RANKING INFORMATION

I. Lake Use and Recreational Potential

A. Wildlife Habitat

1. In addition to Lake Lackawanna being home to many swans, ducks, and geese, several less common or threatened birds, such as the great blue heron, are indigenous to Lake Lackawanna. (See attachment #3)

2. Turtles, beavers, muskrats, and otters

3. Fish include large mouth bass, pickerel, perch, crappies, catfish, & sunfish.

B. Fishing - Both summer and winter fishing are permitted with catch & release methods encouraged.

C. Swimming - One community beach is situated at the base of the lake. Due to its current shallow state, swimming is not feasible in approximately half of the lake.

D. Recreational boating - Although currently permitted, it is only feasible in approximately 1/3 of the lake due to the lake's eutrophication.

II. Lake Lackawanna is 109 acre in size with 352 homes within its immediate watershed. All contiguous areas of Lake Lackawanna are within the boundaries of the Township of Byram, who's population is under 10,000.

III. Byram Township interest and involvement.

A. A Lake Lackawanna Environmental Committee has been formed with dedicated, volunteer residents to work toward ensuring a viable future for the lake. (See attachment #4 for a list of LLEC members)

B. Byram Township officials and area environmental contractors have already established an excellent working relationship with this volunteer committee by working jointly on other related projects. (See attachment #5 for a list of LLEC Affiliates whom would be assisting in this project)

C. Byram township and its Environmental Commission are well-schooled in environmental issues as they are currently working on four other related projects:

1. A long-term lake management program at Cranberry Lake under a three-year EPA grant aimed at implementing strategies recommended in a DEP funded feasibility study;

2. A Cranberry Lake Septic Management Program initiated under a Sussex County state-funded grant project and implemented under a 1990 township ordinance;

3. A 1996-1997 riverway project funded through a DEP OES grant to protect a two-mile stretch of Lubber's Run immediately south of Lake Lackawanna.

4. A recently authorized grant to conduct a Sewer vs. Septic Management Study for Lake Lackawanna under the Watershed Management Public Education and Outreach Grant Program.

IV. Lubber's Run flows out of Lake Lackawanna and is a major tributary of the Musconetcong River. The Musconetcong River is located approximately 2 miles downstream from Lake Lackawanna and runs through historical Waterloo Village in Byram Township. The Musconetcong River is currently being considered as a "Wild and Scenic River" by the Planning Boards of Warren, Hunterdon, Morris, and Sussex Counties; the National Park Service; and the Musconetcong Watershed Association. Additionally, the Musconetcong and the 2-mile section of Lubber's Run which connects Lake Lackawanna with the Musconetcong River are currently the subject of "Riverway Projects". These projects are being funded by a grant from the N.J.D.E.P.'s Office of Environmental Services..

V. In 1997, Byram Township and Lake Lackawanna was authorized to conduct a "Sewer vs. Septic Management Study" under the Watershed Management Public Education and Outreach Grant Program. A key component of this project is to establish the environmental feasibility of either the Septic Management or Sewer Extension option for the long-term management of Lake Lackawanna's wastewater. LLEC has recently contracted with Thonet Associates to conduct this study, which is scheduled to be completed by year-end 1998. We feel this proposal will compliment this project as well as the Lubber's Run and Musconetcong River projects in helping to preserve the quality of these waterways. (See Attachment #6 - Recommendation from Musconetcong Watershed Association)

VI. Not applicable.

III. **PHASE I STUDY OBJECTIVES**

The Township of Byram and the Lake Lackawanna Environmental Committee is committed in protecting and enhancing its watershed area. We are concerned about the eutrophication of Lake Lackawanna and its future use by its residents for recreational purposes. We currently utilize chemical application of DEP permitted algaecides and herbicides to control aquatic weed and algae growth. However, these chemicals are absorbed and transferred from Phytoplankton, to Zooplankton, to the larger fish which are caught by fish eaters, such as Osprey, Great Blue Heron, and Humans. This proposed study would allow us to determine the problem(s), the cause(s) of those problems, and possible solutions to reduce or suppress the eutrophication process. This would have a positive impact on the water quality of the lake, rivers, and well water supplies, as well as the recreational enjoyment of the lake. Ultimately, we hope any remedial action could then result in a major reduction of the current chemical applications needed to control aquatic weed and algae growth. (See Attachment #7 - Current Chemical Treatment Plan)

There are many methods which could, singularly or collectively, address the lakes problem(s) and its cause(s). These may include dredging, septic management, sewer installation, installation of additional storm drains, repair of existing storm drains, a fertilizer ordinance, and shore erosion controls. However, before we can determine which of these method(s) would provide us the most benefit(s), an evaluation of the lake's current problem(s) and cause(s) of those problem(s) must be made. The following outlines the steps we propose be undertaken to make this determination:

Study Objectives # 1 & # 2

Task #1 - Conduct a water quality survey using a septic leachate study method. This would identify the sources and loadings of pollutants to the lake as described in the survey methodology outlined in attachment # 8 .

Time Frame

Diagnostic work to be completed during the 1998 summer season
(see attachment #9 - Aquatic Analysts, Inc.'s proposal.)

Funding

AAI Septic Leachate survey conducted along approimately 4 miles of shoreline, plus hot spot sampling and analysis.

Shoreline survey	=	$ 3,800
Lake Center sampling / analysis	=	$ 175
11 hot spot samples @ &175/each	=	$ 1,925
TASK #1 TOTAL	=	$5,900

Study Objective # 3

Task #2 - An investigation into the various methods of addressing Lake Lackawanna's problems through evaluation of the lake's characteristics. Core sampling of the lake bottom will evaluate the potential depth, volume, and bathymetry of Lake Lackawanna.

Time Frame
Core sampling work to be completed during 1998
(see attachment #10 - F.X. Brown proposal.)

Funding
F.X. Brown core sampling and analysis of core samples to analyze dredging option.
TASK #2 TOTAL = $16,000

Task #3 - An investigation into the various methods of addressing Lake Lackawanna's problems related to aging septic systems on small property lots. Thonet Associates will be working with the LLEC to conduct a previously approved "Sewer vs. Septic Management Study" to determine the feasibility of those options.

Time Frame
This study will be conducted simultaneously with this proposed project,
and completed by year-end 1998.

Funding
Project is funded by N.J. Watershed Management Public Education and Outreach Grant
TASK #3 TOTAL = $0

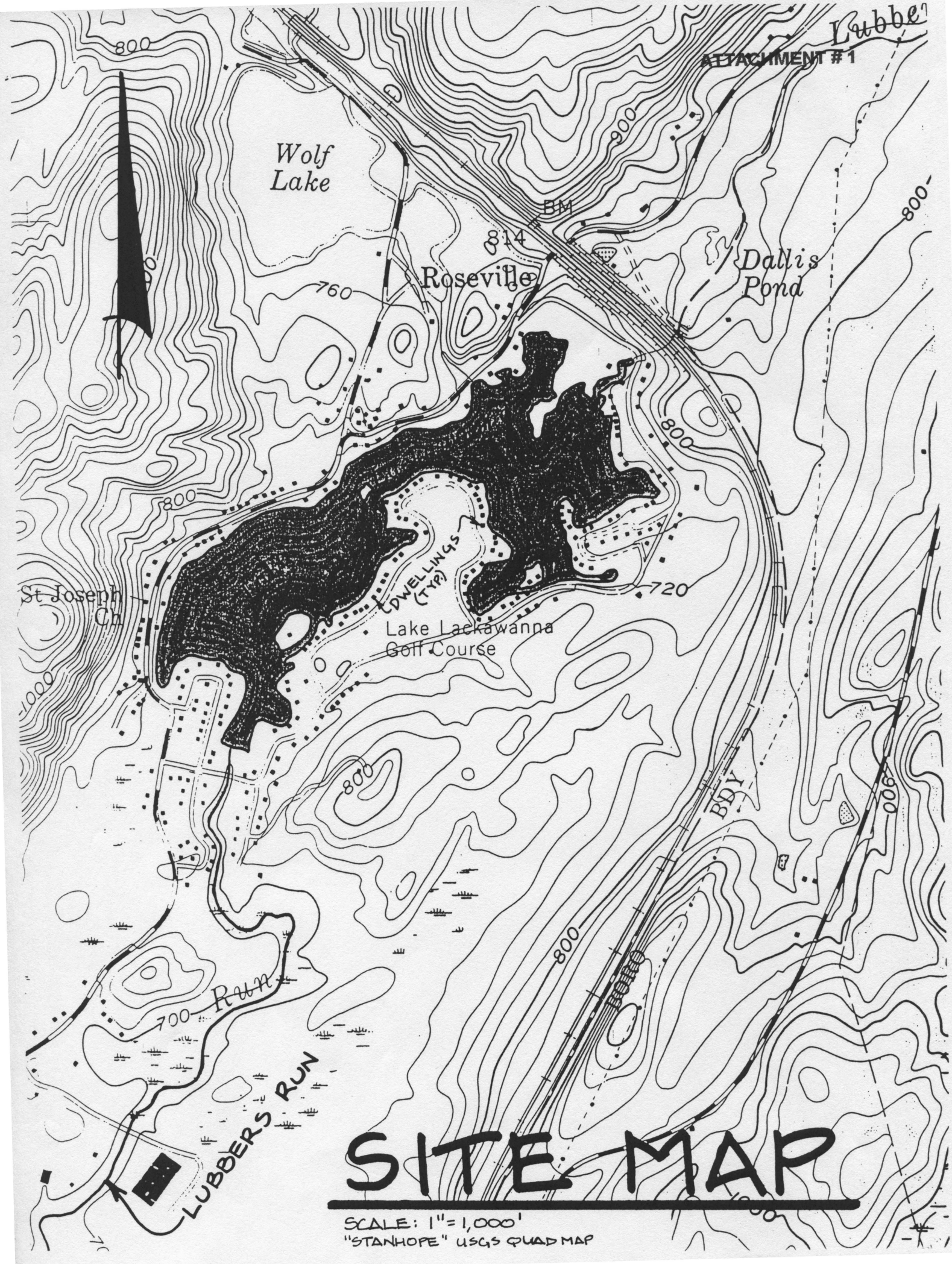
Task #4 - A final phase I report will be completed using priority ranking of the problem(s) identified to be affecting the lake and the cause(s) of those problem(s). This final report will also identify the various methods which would address these problem(s) and cause(s).

Time Frame
Provided all diagnostic work can be completed within the summer/fall seasons of 1998,
this final phase I report should be completed by year-end 1998.

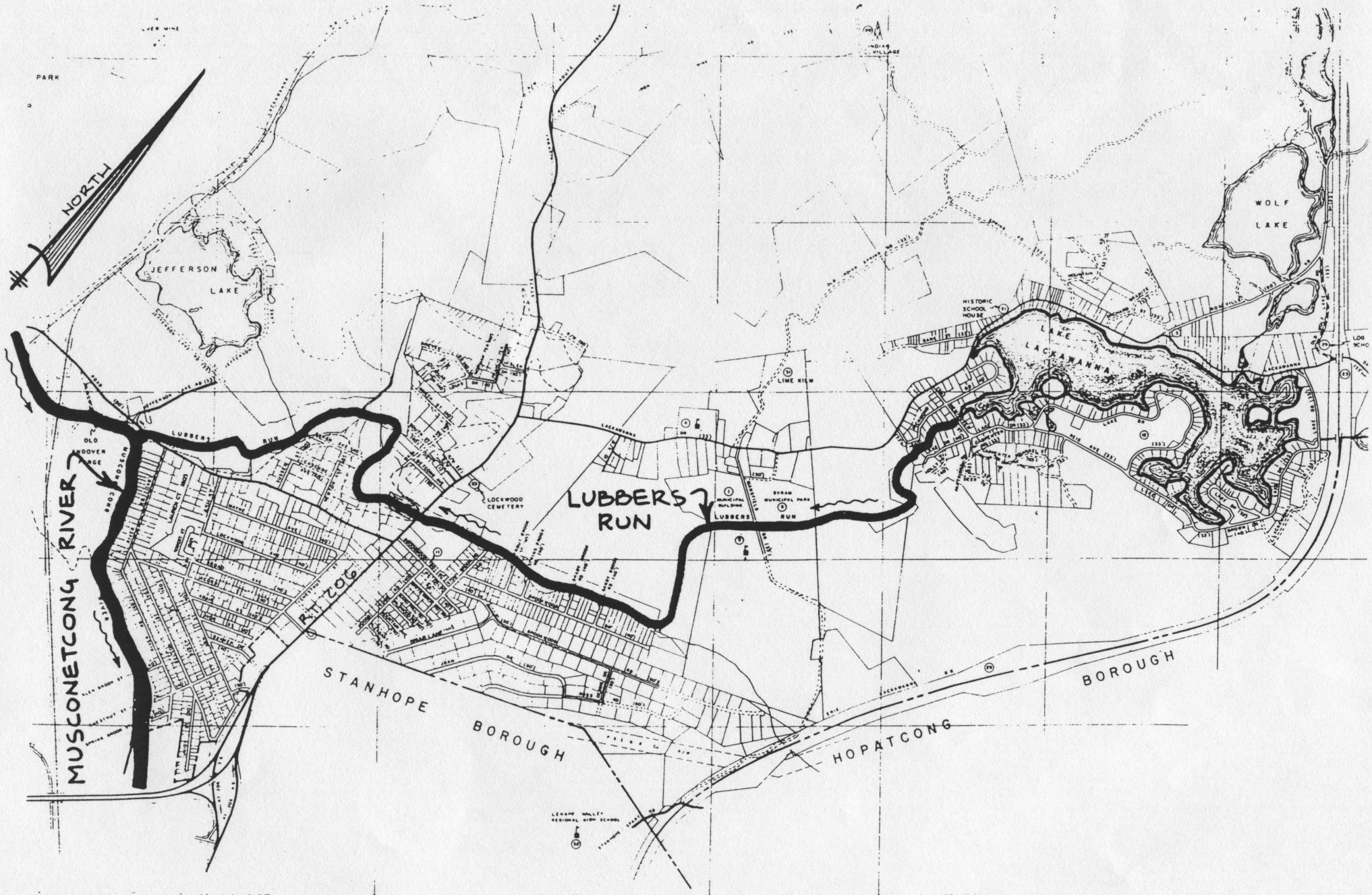
Funding
This portion of the project would be funded by Byram Township & LLEC.
TASK #4 TOTAL = $0

TOTAL FUNDING REQUIRED FOR THIS PROJECT = $ 21,900

Attachments


ATTACHMENT # 1
Wolf Lake
Roseville
814
BM
760
800
900
Dallis Pond
DWELLINGS (TYP.)
720
St Joseph Ch
Lake Lackawanna Golf Course
BDY
700
Run
LUBBERS RUN
SITE MAP
SCALE: 1"=1,000'
"STANHOPE" USGS QUAD MAP

ATTACHMENT # 2



AREA MAP

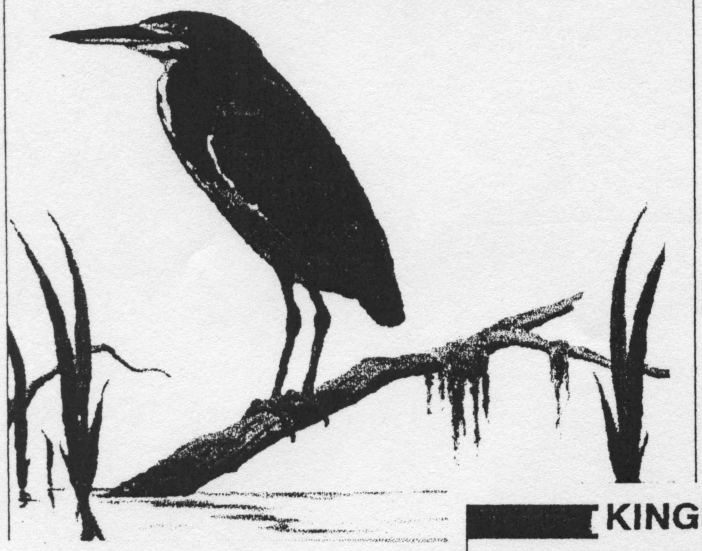
SCALE: 1" = 1,800' (APPROX)

LAKE LACKAWANNA

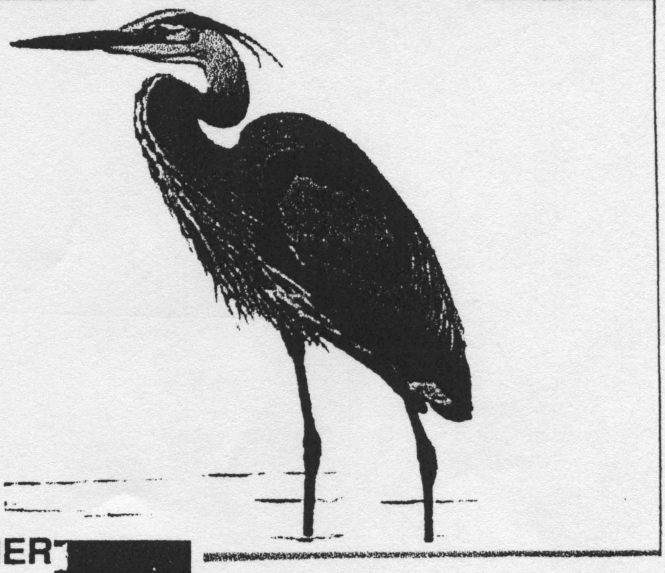
BYRAM TWP
SUSSEX CTY

FISH-EATING BIRDS COMMONLY SEEN ON LAKE LACKAWANNA

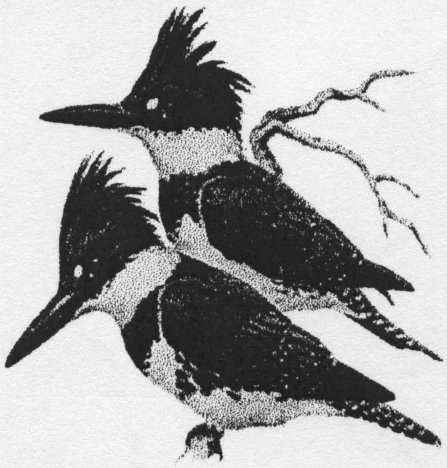
COMMON GREEN HERON



GREAT BLUE HERON



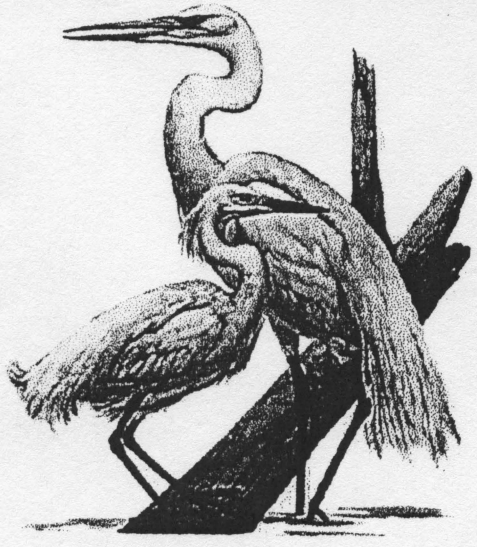
KINGFISHER



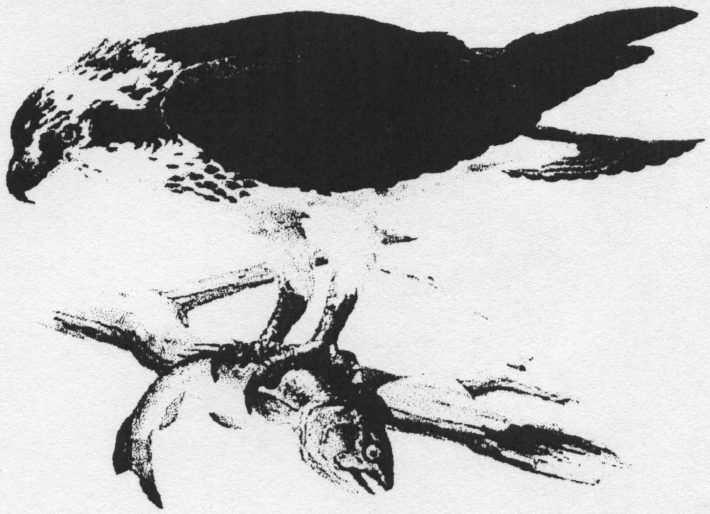
Lake Lackawanna is home to a variety of fish-eating birds. We feel it is our responsibility to improve the lake's condition to provide a healthy habitat.

The Great Blue Heron and the Osprey are currently "threatened" species in New Jersey.

GREAT EGRET



OSPREY



Members of the Lake Lackawanna Environmental Committee

David J. Shepherd **237 Lake Drive** **Byram Township** **Stanhope, NJ 07874** **(973) 347-6949** **(973) 347-5049 (FAX)**	Chairperson - Lake Lackawanna Environmental Committee. Lake-front property owner on Lake Lackawanna since 1994. Member of the Lake Lackawanna Investment Company Board of Directors. Member: Trout Unlimited (Motto: Conserve, Protect, & Restore) Member: NALMS (North American Lake Management Society Member: COLA (NJ Coalition of Lakes) Owner of Shepherd Security Systems since 1981 - sales, installation, and service of security systems.
Skot G. Koenig & **Donna Koenig** **2 Lake Drive** **Byram Township** **Stanhope, NJ 07874** **(973) 691-8761**	Lake Lackawanna residents since 1990. Member of the Lake Lackawanna Investment Company Board of Directors. Skot is Head Landscape Architect of Lapatka Assoc. since 1983. Responsible for site evaluation, feasibility studies, conceptual design, approval process for governmental agencies, and construction supervision. Registered Professional Planner in New Jersey; License No. LI05256. Certified Landscape Architect in New Jersey; License No. AS00229. Certified Landscape Architect in Pennsylvania; License No. AS00229.
Richard A. Volk & **Betsy Volk** **197 Lake Drive** **Byram Township** **Stanhope, NJ 07874** **(973) 347-7226**	Lake-front property owners on Lake Lackawanna since 1972. Stockholders & Richard has been Treasurer of Lake Lackawanna Investment Company's Board of Directors since 1976. Richard is a Self-Employed Certified Public Accountant since 1977, servicing individuals and small businesses. Supervisory Auditor and Technical Specialist for Defense Contract Audit Agency, 1966 - 1995. Responsible for auditing/supervising Department of Defense contractors. Director and Treasurer of Byram's Little League since 1995.
Edward A. Brzezinski **12 Lake Dr. West** **Byram Township** **Stanhope, NJ 07874** **(973) 691-2273**	Lubber's Run adjoining property owner. Member of the Lake Lackawanna Investment Company Board of Directors. N.J.A.C. 7:9-2.5 Application Coordinator 8 years as member of Township of Byram Zoning Board Self-Employed Business owner since 1983.
Gail R. Hoffman **46 Richmond Rd.** **Byram Township** **Stanhope, NJ 07874** **(973) 347-4128**	Lake-front property owner on Lake Lackawanna since 1983. Stockholder & Spouse of Vice President of the Lake Lackawanna Investment Company's Board of Directors. Loss Prevention Specialist and Industrial Hygiene Representative for CNA Insurance Companies since 1980. Responsible for evaluating commercial companies for insurability, including pollution insurance products.

Affiliates of the Lake Lackawanna Environmental Committee

Ronald F. Gatti **Township of Byram** **10 Mansfield Drive** **Stanhope, NJ 07874** **(973) 347-2500**	Township Manager of Byram since 1989. Has experience managing many State and Federal grant programs, with full compliance with all audit requirements. Township Manager's involvement will assure cooperation with volunteer activities and municipal policies.
Margaret McGarrity **Township of Byram** **10 Mansfield Drive** **Stanhope, NJ 07874** **(973) 347-2500**	Vice-Chairperson of Byram Township Environmental Commission. Member of the Environmental Commission for 10 years; chairperson for 7 years. Free-lance environmental writer currently working for the Association of New Jersey Environmental Commissions in Mendham.
Other Affiliates **Township of Byram** **(973) 347-2500**	Eric K. Snyder - Professional Planner of Byram Township Planning Board Gary Stevens - Superintendent of the Byram Township's Public Works Department
Larry Kovar and **Dr. Michael Sebetich** **Aquatic Analysts, Inc.** **9 Green Road** **Hawthorn, NJ 07507** **(973) 423-9407**	Established in 1984, AAI is an ecological consulting company, specializing in lake, pond and watershed management. AAI is the certified applicator hired by Lake Lackawanna for chemical control of aquatic weeds and algae since 1996. AAI would also be contracted to complete the septic leachate survey outlined in this proposal to assist in the identification of the problems affecting Lake Lackawanna.
John A. Thonet, PE **THONET ASSOCIATES** **76 South Orance Ave.** **So. Orange, NJ 07079** **(973) 762-5900**	Founded in 1980, Thonet is a consulting firm specializing in environmental planning and land development. They have been recently contracted by Byram & LLEC to conduct a "Septic Management vs. Sewer Extension" study for Lake Lackawanna area.
Lapatka Associates,Inc. **12 Route 17 North** **Suite 230** **Paramus, NJ 07652** **(973) 587-1600**	Civil engineering, landscape architecture, land surveying and planning. Projects have involved environmentally sensitive areas, wetlands, tidal and non-tidal floodplains, and stream encroachment. Responsibilities have included site evaluation, design, and securing approvals/permits from Municipal and County Boards, Soil Conservation Districts, Dept of Transportation, Department of Environmental Protection, etc.
Richard C. Cotton **Musconetcong** **Watershed Assn.** **(908) 537-2232**	President of Musconetcong Watershed Association P.O. Box 87 Washington, NJ 07882
Don Drake and **Fred Sulgik** **Sussex County** **(973) 579-0500**	Sussex County Department of Planning and Development County Administration Building Plotts Road, Newton, NJ

ATTACHMENT # 6

MUSCONETCONG WATERSHED ASSOCIATION

March 26, 1997

David J. Shepard
Lake Lackawanna Environmental Committee
P.O. Box 89
Stanhope, NJ 07843

Dear Mr. Shepard:

The Musconetcong Watershed Association commends and applauds your committee's efforts to remediate the non-point source pollution in Lake Lackawanna and Lubber's Run. As you are aware, Lubber's Run is a significant tributary to the Musconetcong River and the Association fully supports all efforts to enhance the water quality of the Musconetcong River and within the watershed.

As part of our charter and goals, the MWA has assisted other groups throughout the watershed to reduce pollutants and improve the water quality in their areas. As you proceed with your evaluation of alternatives for remediation we would be pleased to provide whatever assistance possible. Please keep us posted on your progress and how the MWA can help.

Very truly yours,

Richard C. Cotton, President
Musconetcong Watershed Association

RCC/lwr

Illustration of current chemical applications for control of aquatic weeds and algae.

I. Chemical control of Planktonic algae. To deliver timely treatments that will help prevent algal blooms, Aquatic Analysts, Inc. make site visits every two weeks during May to September to observe the lake and make recommendations on need for chemical treatments. Reward, Hydrothol-191 (liquid) and copper sulfate will be used to control the growth of algae.

II. Chemical Control Macrophytes. The aquatic herbides, Reward and Aquathol-K (liquid) will be used to control the growth of pondweed and milfoil during the season. The growth of water lilies will be controlled by the herbicide, Rodeo.

III. If filamentous algae persists after chemical treatment, Aquatic Analysts, Inc. will use a mechanical weed harvester to pick up and remove the algae. A chemical treatment for algae should be applied immediately following.

SEPTIC LEACHATE SURVEY

INTRODUCTION

The septic leachate detector (Endeco Septic Snooper) is used to help locate, indirectly, potential sources of excess nutrients (nitrogen and phosphorus), bacteria and other substances that tend to lower water quality or increase the rate of lake eutrophication. By detecting elevated electrical conductivity of the lake water and substances that fluoresce, the instruments alerts the operator to potential "hot spots" along the shoreline. Household wastes (graywater) and sewage wastes contain substances that increase electrical conductivity (e.g., chlorides in wastes products) or that fluoresce (e.g., urine breakdown products and detergents). Runoff from other cultural activities (e.g., road salt, plant nurseries, animal grazing) can also cause these two variables to increase near the shoreline. Detection by the instrument indicates a potential source of pollution, but does not identify the substances causing the elevated conductivity or fluorescence.

A water sample at the hot spot is taken for laboratory analysis of selected chemical and bacteriological variables. Results of the analyses can help characterize the potential problem. The analytical variables tested may include: specific conductivity, chloride, ammonia-N, nitrate-N, total phosphorus-P, pH, MBAS (surfactant), and various forms of bacteria. A water sample is also taken from the center of the lake as a control to compare with the shoreline hot spot samples. If one or more of the measured variables from a hot spot is substantially greater than the corresponding variables(s) from the control sample, then there is an indication of a potential source input from the shoreline property.

DATA ANALYSIS

Specific conductivity

A measure of the ability of the water to carry an electrical current, will increase when the concentration of dissolved ions increases in the water. Thus, the conductivity value depends on the total concentration of ionized substances dissolved in the water. In lakes, conductivity is most influenced by eight ions: calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, and chloride.

Chloride

Deicing salt used along roadways during winter causes the runoff of chloride into lakes from the watershed.

Ammonia-N (NH4-N)

A product of bacterial decomposition of organic matter. If a septic system leached into a lake, an elevated ammonia concentration might be detected as a result.

Nitrate-N (NO3-N)

A natural product of bacterial oxidation of ammonia in oxygenated waters. Therefore, high ammonia concentrations can often be correlated to high nitrate concentrations. However, another major source of inorganic nitrate-N is fertilizer.

Total phosphate-P (PO4-N)

A critical nutrient since it is commonly used as an indicator of pollution and lake eutrophication, and it is often limiting to growth of algae and vascular plants. Phosphate-P is analyzed because its major sources to lakes include land erosion, septic systems, fertilizers and detergents.

MBAS

An abbreviation for methylene-blue-active-substances, which are synthetic detergents that contain surfactants for cleaning. The MBAS test is used to detect the presence or absence of surfactants at the sampling sites.

Fecal coliform bacteria

Used to detect possible contamination from septic systems. Fecal coliform bacteria can come from feces of other warm-blooded animals as well as humans. Tests for fecal coliform bacteria are generally done to indicate the possible presence of pathogenic organisms (bacteria, viruses, protozoa). For public swimming beaches, 200 per 100 ml water is the mean allowable concentration. Recently, another group of bacteria, fecal streptococci, have been used to help characterize the source of fecal bacterial contamination. Fecal streptococci also are common to the intestines of humans and other animals, but the fecal streptococci that are discharged by humans are substantially different from the amounts discharged by other animals. Thus, the ratio of fecal coliform (FC) to fecal strep (FS) in a water sample might be used to determine whether the contamination is from humans or other animals. Typically the FC/FS ratio for humans is greater than 4.0, and for domestic animals is less than 1.0.

AAI

AQUATIC ANALYSTS, INC.

Lake Management • Environmental Impact • Certified Applicator

9 Glen Court • P.O. Box 660 • Hawthorne, NJ 07507-0660 • (201) 423-9407 • Fax (201) 423-2303

MICHAEL J. SEBETICH, Ph.D., President

LARRY KOVAR, B.S., Vice President

September 17, 1997

Gail Hoffman
46 Richmond Road
Stanhope, NJ 07874

Dear Ms. Hoffman:

We are pleased to submit this proposal for a septic leachate survey of

LAKE LACKAWANNA - 1998

SCOPE OF WORK

Aquatic Analysts, Inc. will conduct a septic leachate survey of Lake Lackawanna using a septic snooper (made by Endeco), an instrument that simultaneously measures and records (strip chart recorder) both relative electrical conductivity and fluorescence of the water. An experienced operator can detect hot spots of potential septic leachate. Water samples taken at the hot spots can be used to help confirm the presence of excessive nutrients or bacteria.

The entire shoreline of Lake Lackawanna will be surveyed in areas where houses are located. Water samples will be collected from a predetermined number of hot spots agreed upon by the representative. An additional sample will be taken at the center of the lake for comparison to hot spot samples. These samples will be taken to a certified laboratory for analysis of seven variables: nitrate, ammonia, phosphate, chloride, conductivity, pH, and fecal coliform bacteria.

The work will be conducted in 1998 as soon as practicable after receipt of signed contract. A written report will include all laboratory and field data, an analysis and interpretation of the data, and recommendations for management based on the results. The report will be submitted approximately one month following receipt of the laboratory results.

INSURANCE

AAI carries liability insurance and workers compensation, both of which will remain in effect throughout the term of this contract. Copies of insurance certificates are available on request.

COST AND PAYMENT

The cost for the services described in this proposal will be:

a. Total cost for entire shoreline (4 miles @ $950.00/mile). $3,800.00
b. Analysis of water samples $175.00/sample

Payment is requested as follows:

a. Retainer . . . . . .$$1,300.00
b. Balance due on receipt of written report.

AGREEMENT

If you agree to this proposal/contract, please sign below and return a copy along with the retainer.

Aquatic Analysts, Inc. _____
Michael J. Sebetich, President

Lake Lackawanna _____
Representative

Date of agreement _____

F. X. Browne, Inc.

Engineers • Planners • Scientists

December 23, 1996

Dave Shepherd
Lake Lackawanna Investment Company, Inc.
237 Lake Drive
Stanhope, NJ 07874

RE: Lake Lackawanna Lake Committee
Cost Estimate for Engineering Services

Dear Mr. Shepherd:

F. X. Browne, Inc. understands that a soil broker has expressed interest in obtaining the sediment which has accumulated on the bottom of Lake Lackawanna. The soil broker would finance the dredging of the lake in exchange for the sediment. You have indicated that the lake covers approximately 120 acres in Byram Township, is approximately 6 feet deep and contains approximately 2-6 feet of accumulated sediment. We understand the lake is contained by a dam, has several streams flowing into it, is nutrient-rich and has been treated in the past for nuisance weeds. Dredging the lake to remove the accumulated sediment would remove a source of nutrients and increase the volume of the lake.

The first step in determining whether the lake will be dredged or not is to ensure that the soil broker can use the accumulated sediment from Lake Lackawanna. This can be done by taking a small number of sediment samples throughout the lake, testing them for particle size and the NJDEP Soil Cleanup parameters, comparing the results to the NJDEP Soil Cleanup Standards, and presenting the results to the soils broker.

The other piece of information which is very important to obtain is the volume of accumulated sediment in the lake. Once the sediment volume is known, the soil broker can determine how much sediment he wants to dredge. NJDEP bases the number of sediment samples it requires to be collected and analyzed on the volume of sediment to be dredged. At this stage of the project, we suggest performing a preliminary bathymetric survey which will measure sediment depth at 68 locations throughout the lake. From this survey, an estimate of the sediment volume can be calculated. If dredging is to be performed, a more detailed bathymetric survey should be performed in order to design the dredging plans.

F. X. BROWNE, INC.

Mr. Dave Shepherd
December 23, 1996
Page -2-

F. X. Browne, Inc. is pleased to provide the following cost estimates for services to perform a preliminary bathymetric survey of Lake Lackawanna and to collect six (6) discrete sediment samples for physical and chemical analysis. The sediment samples will be analyzed at an NJDEP-Certified laboratory. The results of this work will allow the soil broker to determine the feasibility of this project and the volume of sediment to be dredged.

Task		Cost
1.	Perform a bathymetric survey to estimate the volume of accumulated sediment and prepare a sediment thickness plan	$4,400.00
2.	Collect six (6) discrete sediment samples, submit the samples to a laboratory for analysis, review and analyze the sediment data and submit the data to NJDEP	$1,500.00
F. X. Browne, Inc. Engineering		**$5,900.00**
Subcontracted Laboratory Analysis of Sediment Samples*		**$13,200.00**
Total Cost		**$19,100.00**

*Laboratory costs are estimates only and may change after receiving firm price quotes.

Due to the high laboratory costs, we recommend that you discuss the sediment sampling with the soil broker and determine which parameters he/she wants the sediment analyzed for.

Thank you for contacting us concerning this project and we hope that we may perform the above engineering services for you. If you have any questions or need additional information, please call me.

Sincerely,

F. X. BROWNE, INC.

Donna L. Raudenbush

By:
Donna L. Raudenbush

/dlr

INVESTIGATIONS AND MANAGEMENT OF NEW JERSEY'S FRESHWATER FISHERIES RESOURCES 2016

State of New Jersey
Division of Fish and Wildlife
Bureau of Freshwater Fisheries

NEW JERSEY DIVISION OF
Fish and Wildlife

INVESTIGATIONS AND MANAGEMENT OF NEW JERSEY'S FRESHWATER FISHERIES RESOURCES 2016

Including
Sport Fish Restoration Grant F-48-R

Job Performance Reports Segment 27
(November 1, 2015 – October 31, 2016)

and

Final Reports

March 2017

New Jersey Department of Environmental Protection
Division of Fish and Wildlife
Bureau of Freshwater Fisheries

This grant was paid for by fishing license sales and matching Dingell-Johnson/Wallop-Breaux funds available through the Federal Sportfish Restoration Act.

State of New Jersey

Chris Christie
Governor

Kim Guadagno
Lt. Governor

New Jersey
Department of Environmental Protection

Bob Martin
Commissioner

Rich Boornazian
Assistant Commissioner
Natural and Historic Resources

Division of Fish and Wildlife

Larry Herrighty
Director

Dave Golden
Acting Assistant Director, Operations

BUREAU OF FRESHWATER FISHERIES
Research and Management Unit

Lisa Barno
Chief

Shawn Crouse
Principal Fisheries Biologist

Pat Hamilton
Principal Fisheries Biologist

Christopher Smith
Principal Fisheries Biologist

Mark Boriek
Principal Fisheries Biologist

Ross Shramko
Senior Fisheries Biologist

Scott Collenburg
Assistant Fisheries Biologist

Eric Boehm
Assistant Fisheries Biologist

Charles Sedor
Technician II

With the assistance of:
Scott Catton, Kyle Civalier, Luke Diglio, Chris Grohgans, Christine Szpond, and Scott Ward

New Jersey's Freshwater Research and Management activities are funded entirely by New Jersey's licensed anglers. These activities benefit the state's 8 million residents by protecting and assessing New Jersey's vital freshwater resources.

Clean water for fish means clean water for us and generations to come

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D List of New Jersey Freshwater Fish Species
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F Opening Day Trout Angler Survey Report (2016) G
G Round Valley Reservoir Fisheries Management Plan

INTRODUCTION

Highlights for 2016

The Bureau of Freshwater Fisheries conducted total of 237 fisheries surveys at 138 waterbodies in 2016 to address a variety of recreational and resource management needs, including response to emerging fisheries issues. Fifty-six of the 138 waterbodies were streams and rivers, while 82 were ponds and lakes. Fisheries biologists captured, identified, and counted over 65,000 fish, represented by 76 species. Surveys were conducted to satisfy a wide variety of projects, such as the final year of a coolwater fisheries assessment at 12 lakes, focusing on Muskellunge, Northern Pike, Walleye, and Hybrid Striped Bass stocking programs. Warmwater fish populations were electrofished at 32 waterbodies so that staff can better manage their recreational fisheries, often with an emphasis on Largemouth Bass. Reproductive checks were also conducted at 49 ponds and lakes. Round Valley Reservoir was the focus of an intensive fisheries inventory and subsequent fisheries management plan. On the coldwater side, there was a continued effort to investigate current *Wild Trout Stream* regulations, leading to regulation changes in the management of these valuable resources. Other fisheries surveys were used to monitor populations, assess stocking programs, map the distribution of rare native fishes, document or control populations of invasive fishes/aquatic plants, among a variety of other functions. This report documents the ongoing fisheries management activities across New Jersey performed by the Division of Fish and Wildlife (NJDFW) and the status of its fisheries resources in 2016. This work is made possible by funding from the Sport Fish Restoration Federal Grant F-48-R and New Jersey's Hunter and Angler Fund.

2016 was especially difficult for the state's fisheries resources as below average precipitation levels resulted in record setting low stream flows that plagued the state's freshwater resources throughout the year. Impacts of extended dry weather patterns were further intensified by consecutive days of extreme temperatures during the summer. The Bureau continued to measure temperature through its ambient stream temperature monitoring network with 39 thermographs (instruments that continuously monitor temperature), deployed on 17 recreationally important trout streams and 14 small streams having reproducing trout populations. On July 25, 2016, an official Drought Watch was issued for most of northern New Jersey. Persistent dry weather patterns resulted in a Drought Warning being declared on October 21, 2016 for 14 counties within the Northeast, Northwest, Central, and Coastal North Water Supply Regions (Administrative Order 2016-10). A Drought Warning results in established minimum passing flow requirements to be reviewed and often reduced within affected areas. Drought conditions during the summer months are typically far more detrimental, than cooler seasons, due to reduced water temperatures, adequate oxygen, etc., in fact some flows were well beyond any flows that have been experienced in over 60 years. As a result, these extreme conditions have likely impacted aquatic biota in ways that we may or may not be able to measure.

This year marked the final year of the Coolwater Fisheries Assessment, which was initiated in 2013. This multi-year project will evaluate trophy coolwater fisheries for Muskellunge, Northern Pike, Walleye, and Hybrid Striped Bass. These fisheries are primarily maintained by annual stockings of fish reared at NJDFW's Hackettstown State Fish Hatchery. In 2016 surveys were conducted at 12 waterbodies including, Budd Lake, Canistear Reservoir, Carnegie Lake, Cranberry Lake, Deal Lake, Echo Lake, Greenwood Lake, Little Swartswood Lake, Manasquan Reservoir, Monksville Reservoir, Mountain Lake, and Pompton Lake using a variety of sampling

techniques to best capture the species of interest on each waterbody. The Bureau also conducted an online angler survey to obtain anglers opinions and experiences concerning their warmwater and coolwater fishing experiences in New Jersey.

The Bureau also conducted its three-year evaluation of streams regulated as the *Wild Trout Streams*. These 36 streams are not stocked with hatchery trout, but rather rely upon the wild, naturally reproducing trout populations inhabiting these streams to provide a recreational fishery. Electrofishing surveys were conducted on 46 sections of all 36 designated *Wild Trout Streams* in 2014, yielding 3,137 trout, with a mean of 68 trout per survey. Data collection efforts continued in 2015 with 47 additional surveys conducted on 38 streams and in 2016 with 5 additional surveys conducted at 3 streams. From January through June a team of Bureau biologists invested considerable time compiling, analyzing population data, and reviewing pertinent information including data analysis of nearly 100 stream surveys, literature review, public input (online survey and a two public meetings), and review of stocking histories. The Bureau will present recommendations to the Fish and Game Council in 2017 regarding this unique resource, which may lead to formal regulation changes into the state Fish Code.

Standardized stream electrofishing surveys contribute valuable data used for multiple projects and management functions, including the classification of New Jersey's surface waters within the Department's Surface Water Quality Standards N.J.A.C. 7:9B. This system is the regulatory cornerstone that helps protect critical watersheds. These assessments use important stream health indicators such as Brook, Brown, and Rainbow Trout to identify high water quality and critical habitat areas. Twenty-eight surveys confirmed existing stream classifications. Twelve surveys produced results that warrant changes to current classifications, six of which are upgrades to *Trout Production* and two to *Trout Maintenance*.

In 2013 the Bureau established an ambient stream temperature monitoring network on streams that has expanded to 39 thermographs (instruments that continuously monitor temperature), deployed on 17 recreationally important trout streams and 14 small streams having reproducing trout populations. Both water and air temperatures are recorded in wild Brook Trout streams as part of an Eastern Brook Trout Joint Venture initiative to assess climate change. The temperature data will be used to assess current habitat conditions, evaluate long term trends, determine if ambient water quality is consistent with surface water quality standards, and aid in the management of coldwater fisheries, including evaluation of stocking practices and fishing regulations. See page 36 for a summary and Appendix E for a full report.

An intensive fisheries inventory was conducted at Round Valley Reservoir, the second largest lake in New Jersey (2,350 acres), with a maximum depth of 160 feet. This popular waterbody has produced four current state record fish, for Lake Trout, Brown Trout, Smallmouth Bass, and American Eel. The reservoir is rather unique for New Jersey supporting a two tier fishery for both coldwater and warmwater fish populations. The reservoir has been stocked regularly with Rainbow and Brown Trout and is managed as a *Trophy Trout Lake* and supports an abundant, reproducing Lake Trout population. By definition, this Oligotrophic lake has very low nutrient levels and adequate oxygen throughout almost all of its depth. The abundant predator population consists of slow growing Lake Trout, stocked trout, and reproducing bass, but relatively few forage species and densities. Both Lake Trout and Largemouth Bass populations, despite being

slow growing and unbalanced, have the potential of producing a state records. The complete fisheries management plan can be found in Appendix G.

Largemouth Bass are the most popular and widely distributed of the state's game species. New Jersey has over 400 impoundments open to the general public for fishing and thousands more in private ownership scattered throughout the state. These lentic environments offer excellent fishing opportunities for a variety of species such as bass, sunfish, crappie, and pickerel. These species naturally reproduce in these waterways and often do not require active stocking to sustain their populations. In addition to Round Valley Reservoir, the Bureau of Freshwater Fisheries conducted electrofishing surveys at 32 lakes and ponds throughout the state to assess the status of their warmwater fisheries. Crews also collected fish with a 20 ft. seine to assess the reproductive success of warmwater species at 49 lakes and ponds. These data are used to determine if supplemental stockings are necessary.

Significant progress was made for a second year in the assessment and protection of our state's native fishes. A formal review process led by the NJDFW's Endangered and Nongame Species Program was conducted in 2014 and 2015 to determine the status of our native freshwater fishes, known as the Delphi Technique. This is a systematic method for reaching consensus among experts by incorporating all available data and disseminating those data among all participants. Results were presented to and approved by the Endangered and Nongame Species Advisory Committee. Next steps include the formal listing of state Endangered and Threatened species (along with Special Concern designation), as well as identifying species that are considered to be stable and secure. Proposed Endangered Species include Bridle Shiner, Ironcolor Shiner, and Shortnose Sturgeon and the Slimy Sculpin as a Threatened Species. The designation of Species of Special Concern will be given to American Brook Lamprey, Brook Trout, Blackbanded Sunfish, Comely Shiner, Mud Sunfish, Northern Hog Sucker, and Shield Darter.

The Bureau of Freshwater Fisheries participated in the ten-year revision of the State Wildlife Action Plan (SWAP). The SWAP is a strategic and cost-effective mechanism to preserve the state's wildlife resources for the future. Recovery of species that have reached threatened or endangered status is typically more-costly than preventative actions that keep species populations from reaching such declines. Proactive management actions identified in the SWAP are intended to keep species from becoming federally (and state) threatened and endangered. NJDFW is currently updating the New Jersey's Wildlife Action Plan as required by Congress to continue to receive federal wildlife grants. More importantly, New Jersey's update will serve as a blueprint for conserving our wildlife heritage. The plan will identify priority actions addressing known threats facing our targeted species and habitats that we, as a conservation community, can implement in the next ten years.

In addition to these highlights, this report describes a host of other field work and educational activities conducted by the Bureau of Freshwater Fisheries. The efforts of full-time Bureau personnel are complemented by a dedicated and talented seasonal staff, who provide incredible insight, enthusiasm, and the labor which is vital to raising fish, conducting fisheries surveys statewide, and performing countless tasks that help maintain and enhance New Jersey's freshwater fisheries resources. The Bureau's work is made possibly by both the dedicated monies of the Hunter and Anglers Fund and the Sport Fish Restoration Program.

Bureau of Freshwater Fisheries

The mission of the Bureau of Freshwater Fisheries (BFF) is to protect and manage the state's freshwater fish resources to maximize their long-term biological, recreational, and economic value for all New Jerseyans. Our goals are:

1) To maintain New Jersey's rich variety of freshwater fish species at stable, healthy levels and enhance the many habitats on which they depend;

2) To educate New Jersey residents on the values and needs of our freshwater fish resources and to foster a positive human/wildlife co-existence;

3) To maximize the recreational and commercial use of New Jersey's freshwater fishes for both present and future generations.

In 2014 freshwater fish culture and maintenance operations (Fish Culture Unit) were removed from the Bureau of Freshwater Fisheries. This is the first time since the early days of NJDFW that fish culture operations were separated from the protection and management of the state's fisheries resources. The reorganization resulted in only research and management operations remaining within the Bureau of Freshwater Fisheries.

The Bureau of Freshwater Fisheries has personnel in two regionally placed offices: Lebanon Field Office (Hunterdon) and the Central Regional Office (Monmouth). The Bureau oversees the management and protection of the state's over 27,000 miles of streams and over 400 public lakes. The biologists also carry out a number of freshwater projects each year.

The Bureau conducts fishery surveys, classifies the state's waterways, provides technical input on a variety of watershed and habitat based issues, facilitates habitat restoration projects, serves as liaisons to a variety of sportsmen groups, and provides information to the general public in a variety of forums concerning the status of the state's fishery resources. The Bureau of Freshwater Fisheries also administers permits for fish stocking, water lowering, commercial baitfish, and scientific collecting to further provide for the effective management and protection of the state's aquatic resources.

The Bureau of Freshwater Fisheries works closely with NJDFW's fish pathologist, Dr. Jan Lovy, within the Office of Fish and Wildlife Health and Forensics. The fish pathology laboratory is located at the Pequest Trout Hatchery outside Oxford, NJ, and close to the Hackettstown State Fish Hatchery. Dr. Lovy conducts disease monitoring and research in wild and hatchery-raised fish populations throughout the state. For disease diagnostics staff works with the NJ Animal Health Diagnostic Laboratory (NJ AHDL). The AHDL is a state-of-the-art facility equipped with molecular biology suites, a virology laboratory with cell culture facilities maintaining fish cell lines, and modern bacterial diagnostic equipment. The AHDL also provides diagnostic services in fish health for private fish hatcheries.

The Bureau currently has seven fisheries biologists on staff. The primary delineation of responsibilities is based on regional watershed management areas. The state currently is divided into seven regional watershed management areas (Figure 1). In addition to regional responsibilities assigned to biologists, each has a specific area of expertise and oversees related research and management programs:

Eric Boehm – Assistant Fisheries Biologist
Fisheries Management in the Lower Atlantic Coastal Region (Sloop Creek to Dennis Creek watersheds) and Warmwater Fish Management

Mark Boriek – Principal Fisheries Biologist
Fisheries Management in the Lower Passaic & Upper Atlantic Region (Lower Passaic, Saddle, Hackensack, Pascack & Elizabeth to Toms River watersheds), Water Lowering Permit Coordinator, and Anadromous Fishes Management

Scott Collenburg – Assistant Fisheries Biologist
Fisheries Management in the Upper Passaic Region (Pompton, Pequannock, Wanaque, Ramapo, Upper Passaic, Whippany, & Rockaway River watersheds), Coolwater Fisheries Assessment, Stream Temperature Monitoring, and Wild Trout Stream Team

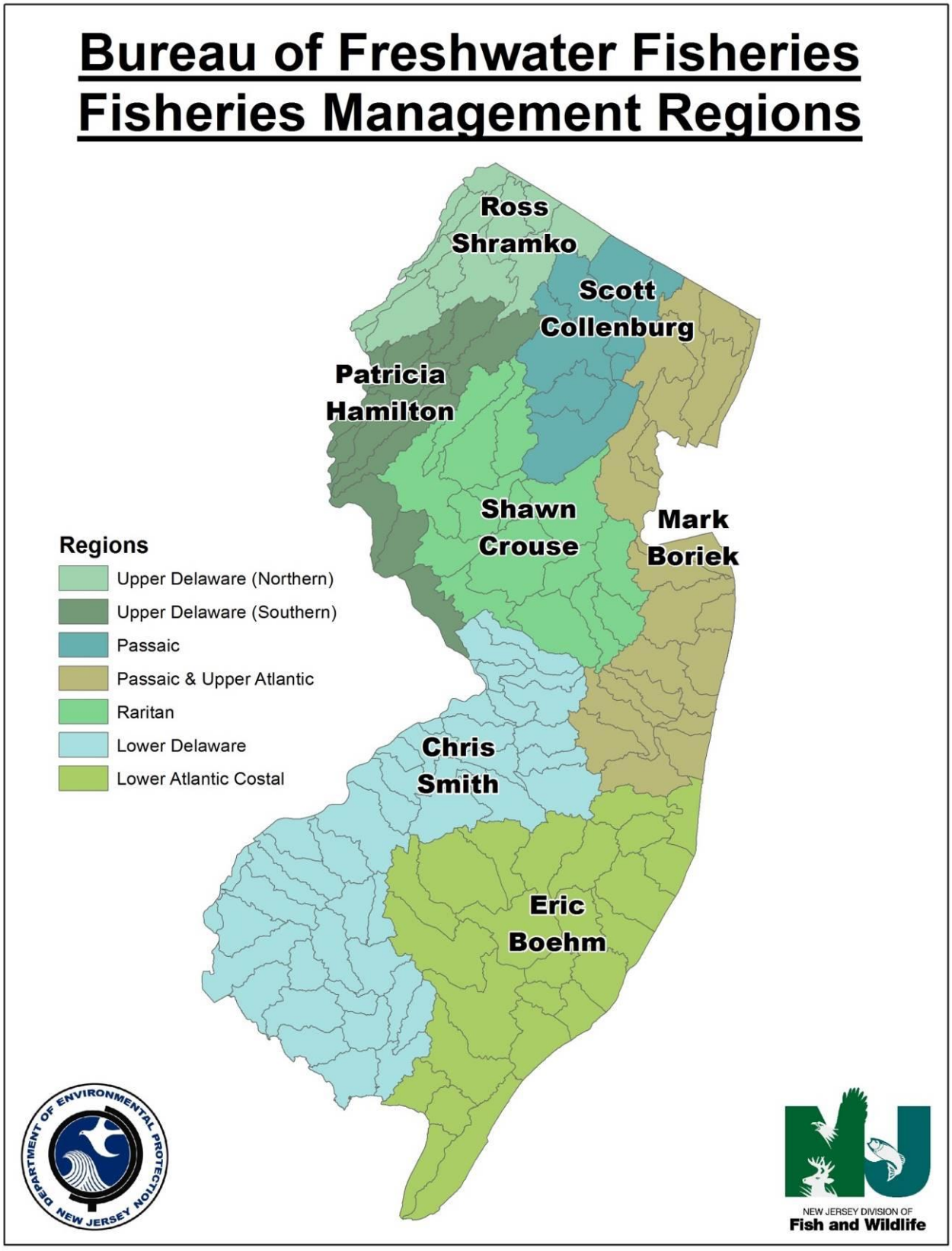
Shawn Crouse – Principal Fisheries Biologist
Fisheries Management in the Raritan Region (Raritan River Watershed), Native Fishes Management, State Wildlife Action Plan, and Annual Report Coordinator

Pat Hamilton – Principal Fisheries Biologist
Fisheries Management in the Upper Delaware (South) Region (Delawanna Creek to Lockatong Creek watersheds), Coldwater Fishes Management, Wild Trout Stream Team, and Federal Grant Coordinator

Ross Shramko – Senior Fisheries Biologist
Fisheries Management in the Upper Delaware (North) & Wallkill Region (Shimmers Brook to Paulins Kill and Wallkill River watersheds), Trout Stocking Coordinator, GIS, Database Management, and Wild Trout Stream Team

Chris Smith – Principal Fisheries Biologist
Fisheries Management in the Lower Delaware Region (Assunpink Creek to Maurice River watersheds), Warmwater Fisheries Management and Invasive Species Management

Figure 1. NJDFW, Bureau of Freshwater Fisheries – 2016 Fisheries Management Regions.



Funding

NJDFW's Bureau of Freshwater Fisheries is funded entirely by New Jersey sportsmen, through the sale of fishing licenses and through a Federal excise tax on the manufacturing of hunting and fishing related equipment. This "user-pays" system has made great strides in financing the management of New Jersey's fish and wildlife resources, not only to the benefit of licensed hunters and anglers but to every one of the state's over 8 million residents. Wildlife associated recreation also generates $2.2 billion dollars into the state's economy each year, with an estimated 300,000 freshwater anglers generating $138 million dollars alone. The two funding sources are described below and after each activity described later in this report the funding source is indicated as either Hunter and Angler Fund or Federal Grant F-48-R (with Project Number I, II, or III specified).

Hunter and Angler Fund - Licenses, Stamps, and Permits

The sale of freshwater fishing licenses and trout stamps generates over $3.5 million dollars to NJDFW each year. Of this, 1 million is allocated to the Bureau of Freshwater Fisheries to support the state's freshwater research and management efforts. The remaining funds are used to fund other activities within NJDFW such as Fish Culture operations, Information and Education, Lands Management, and Law Enforcement, as well as Administrative staff.

Sport Fish Restoration Program

Federal excise tax money is distributed through the Sport Fish Restoration Fund administered by the United States Fish and Wildlife Service (USFWS). The Sport Fish Restoration Program, established by an amendment to the Dingell-Johnson Act of 1950, provides funding for the management, conservation and restoration of fishery resources. The Sport Fish Restoration Program (SFRP) is funded by revenues collected by the manufacturers of fishing rods, reels, creels, and lures, who pay an excise tax on these items to the U.S. Treasury. The program is a cost-reimbursement program, where the state covers the full amount of the approved project then applies for reimbursement for up to 75% of project expenses.

The SFRP provides funding to the Bureau of Freshwater Fisheries annually for fisheries research and management activities through Grant F-48-R, *Investigations and Management of New Jersey's Freshwater Fisheries Resources*. For the one-year grant cycle, November 1, 2015 – October 31, 2016, the USFWS approved a total award of $256,668, 75% of which ($192,501) is federal funds and matched 25% with Hunter and Angler funds ($64,167).

Grant F-48-R is comprised of three projects that focus on (1) assessing and managing fisheries, (2) restoring fisheries and their aquatic habitats, and (3) managing the recreational use of fisheries. The grant's three projects, project objectives, and activities conducted under each project during 2016 are listed below.

Federal Grant F-48-R

Project I: Assessment of the Biological Integrity of Inland Fisheries

Objective: To assess the biological integrity New Jersey's aquatic resources through the collection of physical, chemical, and biological data and use this information to develop, implement, and evaluate management and stocking strategies to improve and enhance sport fishing.

Activities:
1. Anadromous Fisheries Assessment
2. Coolwater Fisheries Assessment
3. Database Management – *FishTrack*
4. Inventory of *Trout Production* Streams
5. Lake Inventory – Round Valley Fisheries Management Plan
6. Lake Trout Population Assessment
7. Special Regulation Trout Area Assessment
8. Stream and Lake Assessments for Surface Water Classification
9. Temperature Monitoring – Streams
10. Wild Brook Trout Assessment
11. Wild Trout Stream Regulations – Assessment and Development

Project II: Protection and Restoration of Inland Fisheries and Aquatic Habitats

Objective: To protect, maintain, and restore healthy fisheries and their aquatic habitats in New Jersey's inland waters.

Activities:
1. Aquatic Invasive Fishes and Plants Management
2. Conservation and Restoration of Fish Habitat
3. Wild Fish Population Health Assessment

Project III: Management of Recreational Fisheries Users

Objective: To obtain and use pertinent information on freshwater angler attitudes, preferences, participation, and resource utilization to protect, manage, and enhance sport fisheries.

Activities:
1. Opening Day Trout Angler Survey
2. Trout Angler Logbook Program
3. Wild Trout Angler Survey

The Bureau of Freshwater Fisheries conducted 285 surveys throughout the state in 2016. The map below demonstrates the survey quantity, geographic distribution, and type (Figure 2). 237 surveys were conducted at 138 waterbodies in which fish were collected, most of which include the determination of basic water quality parameters such as dissolved oxygen, temperature, pH, etc. An additional 19 locations were water quality surveys only. A complete list of field locations surveyed in 2016 is found in Table 1, following the map. Surveys were conducted under two funding sources, either Hunter and Angler Fund or Federal Grant F-48-R.

Figure 2. Field sites sampled in 2016 by NJDFW, Bureau of Freshwater Fisheries.

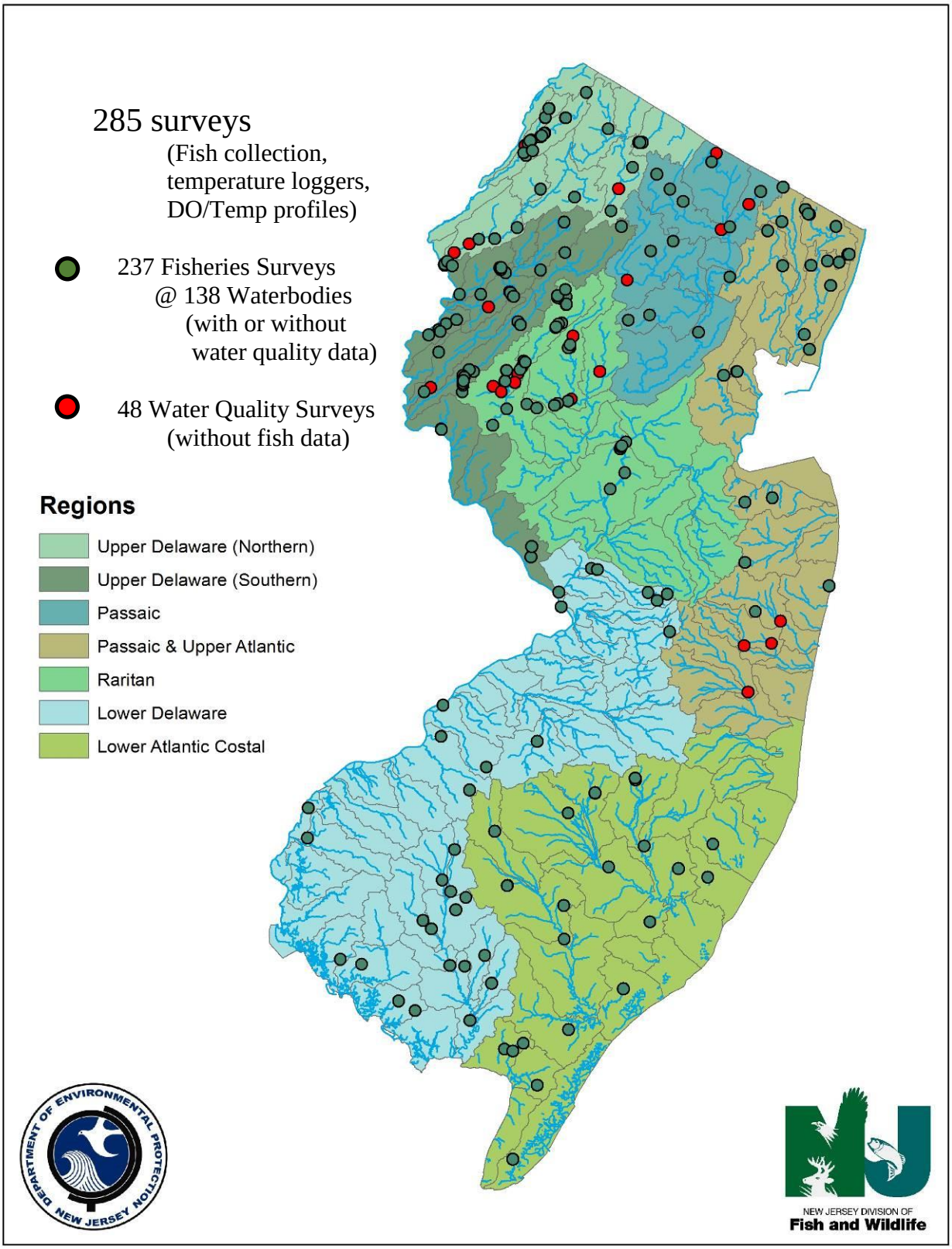


TABLE 1. 2016 field sampling locations

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										**Hunter & Angler Fund**						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Upper Delaware (North) & Wallkill Region (Shramko) (Shimmers Brook to Paulins Kill and Wallkill River watersheds)																	
Beerskill Creek	▲	▲	▲	■										▲		✓	36,47,51,128,A1
Big Flat Brook – old police barracks b/w Route 206 & Route 560	▲	▲	▲		●									▲		✓	23,47,51,131,143,A2
Big Flat Brook – below Route 560 – Pol. Bar. (1200m)			▲		●												23,47,143
Big Flat Brook – downstream of Route 560	▲	▲	▲		●									▲		✓	23,47,51,131,143,A3
Big Flat Brook – upstream of Blewitt Tract	▲	▲	▲	■	●									▲		✓	23,36,47,51,131,143,A4,E
Big Flat Brook (trib.) (Lake Ashroe)	▲	▲	▲							●				▲		✓	30,47,51,127,A5
Black Creek (trib.) (McAfee) – Route 517	▲	▲	▲							●				▲		✓	30,47,51,131,A6
Black Creek (trib.) (McAfee) – unnamed golf course access road	▲	▲	●											▲		✓	47,51,131,A7
Black Creek (trib.) (McAfee) – Golf Course Water Treat. Area			●											▲			47,A8
Columbia Lake	▲			●					●		▲	▲				NA	68,99,134
Flat Brook – Three Bridges	▲		▲		●									▲		✓	47,128,143,A9
Flat Brook – Roy Bridge				■												NA	36,E
Forked Brook	▲	▲	▲	■										▲		✓	36,47,51,128,A10
Frelinghuysen Forest Preserve Pond													●	▲		NA	82
Hyper Humus Ponds													▲	●		NA	83,105
Lake Neepaulin													●	▲		NA	85

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										**Hunter & Angler Fund**						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Upper Delaware (North) & Wallkill Region (Shramko) (Shimmers Bk to Paulins Kill and Wallkill River watersheds) (cont.)																	
Little Flat Brook – Layton-Hainsville Road	▲	▲	▲							●				▲		✓	30,47,51,131,A11
Little Flat Brook – Layton-Hainsville Road														●			105
Little Flat Brook – near confluence with Big Flat Bk	▲	▲	▲							●				▲		✓	30,47,51,131,A12
Little Swartswood Lake						●							●	▲		NA	60,85,F
Mud Pond Outlet Stream			▲							●				▲			47,A13
Paulins Kill – Route 94			▲						●					▲			47,99,A14
Paulins Kill – Lambert Road			▲						●					▲			47,99,A15
Paulins Kill – Vail Road and Sipley Road				■												NA	36,99,E
Paulins Kill – Paulinskill Viaduct				■												NA	36,99,E
Paulins Kill – below Columbia Lake Dam			▲	■					●					▲		NA	36,47,99,E
Paulins Kill – Route 46			▲						●					▲			47,99,A16
Sawmill Pond														●		NA	90,105
Shawanni Creek - Strubble (Dimon) Road	▲	▲	●											▲		✓	47,51,131,A17
Shawanni Creek - Mountain Road	▲	▲	▲							●				▲		✓	30,47,51,131,A18
Sparta Glen Brook	▲	▲	▲							●				▲		✓	47,51,55,131,A19
Tillman Brook	▲	▲	▲							●				▲		✓	30,47,51,128,A20
Wallkill River				■												NA	36,E

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										Hunter & Angler Fund						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Upper Delaware (South) Region (Hamilton) (Delawanna Creek to Lockatong Creek watersheds)																	
Allamuchy Pond	▲			●									●	▲		NA	79,134
Barkers Mill Brook – Barkers Mill Road	▲	▲	●											▲		✓	47,51,128,A21
Barkers Mill Brook – Townsburg Road	▲	▲	●											▲		✓	47,51,128,A22
Barkers Mill Brook – Cemetery Road	▲	▲	●											▲		✓	47,51,128,A23
Barkers Mill Brook – Cemetery Road, near Pequest confluence	▲	▲	●											▲		✓	47,51,128,A24
Beaver Brook (trib.) (E. of Manunka Chunk)	▲		●											▲		✓	47,127,A25
Buckhorn Creek – Route 519	▲	●	▲											▲		✓	47,51,128,A26
Buckhorn Creek – Roxbury Station Road	▲	●	▲											▲		✓	47,51,128,A27
Buckhorn Creek (trib.) (Hutchinson)			●														49
Buckhorn Creek (trib.) (Roxburg)	▲	▲	●											▲		✓	47,51,126,A28
Buckhorn Creek (trib.) (Summerfield)	▲	●	▲											▲		✓	47,51,126,A29
Cranberry Lake						●										NA	58,F
Delaware Lake	▲			●							▲	●	●	▲			69,82,134
Hakihokake Creek – Bridge Street, downstream of bridge	▲	▲	▲							●				▲		✓	47,51,55,128,A30
Hakihokake Creek – Bridge Street, behind library	▲	▲	▲							●				▲		✓	47,51,55,128,A31
Jacobs Creek – Pennington-Titusville Road			▲							●				▲		✓	47,119,A32
Jacobs Creek – Bear Tavern Road (Route 579)			▲							●				▲		✓	47,119,A33

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										**Hunter & Angler Fund**						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Upper Delaware (South) Region (Hamilton) (Delawanna Creek to Lockatong Creek watersheds) (continued)																	
Merrill Creek Reservoir															●		34,145
Mountain Lake	▲			●		●					●	▲	●	▲			62,74,87,134,135,F
Musconetcong River (trib.) (NW of Stephensburg)	●	▲	▲											▲		✓	47,51,126,A34
Musconetcong River (trib.) (S of Asbury)	●	▲	▲											▲		✓	47,51,126,A35
Musconetcong River (trib.) (W of Asbury)			▲							●				▲			47,A36
Pequest River				■													36,143,E
Pequest River (trib.) (SE of Shiloh)			●														47
Pohatcong Creek – Ravine Road				■												NA	36,E
Pohatcong Creek – Municipal Drive			▲											▲	●		47
Saffin Pond	▲			●									●	▲			89,134
Stephensburg Brook	▲	▲	▲	■										▲		✓	36, 47,51,128,A37
Trout Brook (Hope) (trib.) (Shiloh)	▲		●											▲		✓	47,A38
Twin Lakes	▲			●									●	▲			91,134
West Portal Creek			▲					●		●				▲			47,56,121

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										Hunter & Angler Fund						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Upper Passaic Region (Collenburg) (Pompton, Pequannock, Wanaque, Ramapo, Upper Passaic, Whippany, & Rockaway River watersheds)																	
Ames Lake													●	▲		NA	79
Canistear Reservoir						●					▲	▲				NA	57,67,F
Echo Lake Reservoir						●										NA	59,F
Green Turtle Pond											●	▲	●	▲		NA	71,83,135
Greenwood Lake						●					▲	▲				NA	60,71,120,F
Monksville Reservoir						●					▲					NA	61,F
Pequannock River				■												NA	36,143,E
Pompton Lake						●										NA	62,F
Ramapo River				■												NA	36,E
Rockaway River				■												NA	36,E
Scarlet Oak Pond													●	▲		NA	90
Split Rock Reservoir											●	▲				NA	77
Wanaque River				■												NA	36,E
Whippany River (trib.) (Brookside)	▲	●	▲											▲		✓	47,51,129,A39
Whippany River (trib.) (W. of Watnong Brook)	●		▲											▲		✓	47,126,A40

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										Hunter & Angler Fund						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Lower Passaic & Upper Atlantic Region (Boriek) (Lower Passaic, Saddle, Hackensack, Pascack & Elizabeth to Toms River watersheds)																	
Bear Brook (Park Ridge) – Brae Road	●		▲											▲		✓	47,126,A41
Bear Brook (Park Ridge) – Laurel Hill Rd. & Arrowhead Rd.	●		▲											▲		✓	47,126,A42
Bear Brook (Park Ridge) – Glendale Road	●		▲											▲		✓	47,126,A43
Coopers Park Pond													●	▲		NA	81
Cresskill Brook – Duck Pond Road	▲	▲	▲							●				▲		✓	47,51,54,132,A44
Cresskill Brook – Deerhill Road	▲	▲	▲							●				▲		✓	47,51,54,129,A45
Deal Lake						●										NA	59,F
Durant Park Pond													●	▲		NA	82
Elizabeth River, W/Br			▲											▲	●		47,148
Haworth Park Pond													●	▲		NA	83
Jersey City Reservoir #3											●	▲				NA	72
Lefferts Lake													●	▲		NA	85
Manasquan Reservoir						●						●				NA	61,73,F
Manasquan River				■												NA	36,E

TABLE 1. 2016 field sampling locations

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										**Hunter & Angler Fund**						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Lower Passaic & Upper Atlantic Region (Boriek) (Lower Passaic, Saddle, Hackensack, Pascack & Elizabeth to Toms River watersheds) (continued)																	
Metedeconk River, N/Br				■												NA	36,E
Metedeconk River, S/Br				■												NA	36,E
NJ American Water Pond														▲	●	NA	148
Passaic River – Florham Park			▲			●										NA	47,63,F
Passaic River – Fairfield			▲			●										NA	47,63,F
Passaic River – Elmwood Park			▲			●										NA	47,63,112,F
Pondside Park Lake													●	▲		NA	88
Roosevelt Commons Park Pond													●	▲		NA	88
Shallcross Pond (aka Black Brook Park Pond)														▲	●	NA	148
Silver Creek Pond													●	▲		NA	90
Thielke Arboretum Park Pond													●	▲		NA	91
Toms River				■												NA	36,143,E
Van Saun Park Pond													●	▲		NA	91
Veterans Park Pond													●	▲		NA	92
Whites Pond													●	▲		NA	92,109
Zabriske Pond													●	▲		NA	92

TABLE 1. 2016 field sampling locations

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										**Hunter & Angler Fund**						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Raritan Region (Crouse) (Raritan River watershed)																	
Black Brook	▲	▲	▲	■										▲		✓	36,47,51,132,A46
Black River – Below Kay's Pond				■												NA	36,E
Black River – Hacklebarney State Park				■												NA	36,E
Black River – River Rd below Fiddlers Elbow				■												NA	36,E
Budd Lake						●										NA	57,117,F
Carnegie Lake						●										NA	58,113,118,F
Hickory Run – Hickory Run Road	▲	▲	▲	■										▲		✓	36, 47,51,129,A47
Hickory Run – High Bridge – Califon Road	▲	▲	●											▲	●	✓	47,51,129,A48
Millstone River – Griggstown Causeway			▲											▲	●	✓	47,94,A49
Millstone River – Blackwells Mills Dam			▲											▲	●	✓	47,94,109,A50
Millstone River – above Weston Causeway Dam											▲	▲			●	NA	94
Millstone River – below Weston Causeway Dam											▲	▲		▲	●	NA	94
Millstone River – near Raritan confluence											▲	▲			●	NA	94
Raritan River, N/Br – off Peapack Road				■												NA	36,E
Raritan River, S/Br – Claremont - old stocking pt.	▲	▲	▲		●									▲		✓	29,47, 51,129,143,A51
Raritan River, S/Br – Claremont - fiber optic cross.	▲	▲	▲	■	●									▲		✓	29,36,47,51,129,143,A52,E
Raritan River, S/Br – KLG - boulder field	▲	▲	▲		●									▲		✓	27,47,51,121,126,143,A53
Raritan River, S/Br – KLG - below trestle	▲	▲	▲	■	●									▲		✓	27,36,47, 51,126,143,A54,E

TABLE 1. 2016 field sampling locations

NEW JERSEY DIVISION OF
Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										Hunter & Angler Fund						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Raritan Region (Crouse) (Raritan River watershed) (continued)																	
Raritan River, S/Br – Below Lake Solitude				■												NA	36,E
Raritan River, S/Br – Hamden Road														▲	●	NA	NA
Raritan River, S/Br (trib) (Drakestown)	▲	▲	▲	■										▲		✓	36,47,51,127,A55
Raritan River, S/Br (trib) (SW of Budd Lake)	▲	▲	▲	■										▲		✓	36,47,51,127,A56
Rinehart Brook	▲	▲	▲	■										▲		✓	36,47,51,129,A57
Rockaway Creek	▲													●		✓	47,105,129,A58
Rockaway Creek S/Br – off Railroad Ave.	▲													●		✓	47,105,132,A59
Rockaway Creek S/Br – Route 22	▲													●		✓	47,105,132,A60
Rocky Run	▲	▲	▲	■										▲		✓	36,47,51,129,A61
Round Valley Fathead Pond														▲	●	NA	NA
Round Valley Reservoir	▲			●						●	▲	▲	▲	▲		NA	32,64,89,114,134,146,H
Stony Brook (Morris-Washington)	▲	▲	▲	■										▲		✓	36,47, 1,129,A62
Spruce Run Reservoir	▲			●												NA	134
Sun Valley Brook – Stedwick Road	▲	▲	●	■										▲		✓	36,47,51,132,A63
Sun Valley Brook – Wolfe Road	▲	▲	●	■										▲		✓	36,47,51,132,A64
Sun Valley Brook – confluence with Raritan S/Br	▲	▲	●	■										▲		✓	36,47,51,132,A65
Trout Brook (Hacklebarney)	▲	▲	▲	■										▲		✓	36,47,51,129,A66
Turkey Brook	▲	▲	▲	■										▲		✓	36,47,51,129,A67
Willhoughby Brook	▲	▲	▲	■										▲		✓	36,47,51,129,A68

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										Hunter & Angler Fund						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Lower Delaware Region (Smith) (Assunpink Creek to Maurice River watersheds)																	
Assunpink Creek			▲											●		✓	47,105,A69
Assunpink Lake								●			▲	●				NA	66,115,117,150
Burnt Mill Pond											●	▲				NA	67
Burnt Mills Branch			▲											●			47,105,A70
Cedar Lake (Cedarville, Cumberland Co.)											●	▲	●	▲		NA	67,80
Davis Mill Pond												●				NA	68
Delaware River - Route 1 to PSE&G Mercer							●				▲					NA	70,109
Delaware River - Pennsauken Creek to Petty Island							●				▲					NA	70
DOD Lake							●					▲				NA	70,109,150
Game Creek							●					▲				NA	71,109
Iona Lake													▲	●		NA	84,105
Lake Audry												●				NA	72
Masons Run (trib.) (Pine Hill)	▲	▲	●											▲		✓	47,51,132,A71
Menatico Sand Pond											▲	●	▲	●		NA	73,86,105
Mercer Lake											▲	●				NA	73,112
Newton Lake							●					▲				NA	75,109
Parvin Lake												●				NA	75

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										**Hunter & Angler Fund**						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Lower Delaware Region (Smith) (Assunpink Creek to Maurice River watersheds) (continued)																	
Prospertown Lake											●	▲			▲	NA	76
Rainbow Lake												●				NA	76
Rancocas Creek SW/Br			▲											●		✓	47,105,A72
Rising Sun Lake												●				NA	76
Scotland Run	▲		▲											●		✓	47,105,130,A73
Shaws Mill Pond											▲	●	▲	●		NA	77,90,105
Silver Lake (Camden)							●									NA	109
Stone Tavern Lake												●				NA	77
Union Lake												●				NA	77
Wheaton Glass Pond											●	▲				NA	78
Wilson Lake											●	▲	●	▲		NA	78,92,105

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										Hunter & Angler Fund						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Lower Atlantic Coastal (Boehm) (Sloop Creek to Dennis Creek watersheds)																	
Atsion Lake													▲	●		NA	80,106
Cedar Lake (WMA)													▲	●		NA	80,106
Chatsworth Lake													▲	●		NA	80,106
Clint Mill Pond													▲	●		NA	81,106
Cresse Lane Pond (Cape May WMA)													●	▲		NA	68,81
Cumberland Pond													▲	●		NA	81,107
East Creek Pond													▲	●		NA	82,106
Harrisville Lake													▲	●		NA	83,106
Lake Absegami													▲	●		NA	84,106
Lake Lenape													▲	●		NA	84,106
Lake Nummy													▲	●		NA	85,106
Makepeace Lake													▲	●		NA	86,106
Marsh Lake Branch			▲											●		✓	47,106,A74
Mill Pond (Atlantic)													▲	●		NA	86,106
Morses Mill Stream			▲											●		✓	47,106,A75

TABLE 1. 2016 field sampling locations (continued)

NEW JERSEY DIVISION OF Fish and Wildlife

Bureau of Freshwater Fisheries
2016 Field Sampling Activities

- ● Funding source or reason of data collection
- ▲ Data are applicable to additional projects
- ■ Continuous Temperature Monitoring

	Federal Grant F-48-R (Project I or II)										Hunter & Angler Fund						
	Classification (I)	Wild Trout Stream Reg. (I)	Brook Trout Assess. (I)	Temp. / DO Monitor. (I)	Special Reg. Trout As. (I)	Coolwater Assess. (I)	Invasive Species (II)	Fish Health (II)	Anadromous (I)	Miscellaneous	Warmwater Assessment	Black Bass Assessment	Reproduction Checks	Native Fishes	Miscellaneous	RBA Stream Sampling Protocol Applied*	Results Page #
Lower Atlantic Coastal (Boehm) (Sloop Creek to Dennis Creek watersheds) (continued)																	
Mullica River							●							▲		NA	109
New Brooklyn Lake														●		NA	87,106
Pickle Factory Pond													▲	●		NA	87,106
Pohatcong Lake													▲	●		NA	88,106,135
Ponder Lodge Lake											●	▲				NA	75
Skit Branch			▲											●		✓	47,106,A76
Stafford Forge Impoundment #1													▲	●		NA	90,106
Tuckahoe Lake													▲	●		NA	91,106,135
Wading River, W/Br			▲										▲	●		✓	47,106,A77

** The Bureau of Freshwater Fisheries strives to use established sampling protocols for all field sampling efforts. However, certain sampling objective adherence to established sampling protocols would be prohibitive to accomplishing project goals. In these instances, non-standardized surveys are performed and are identified in appropriate areas within this document.*

COLDWATER FISHERIES

Catch & Release Trout Regulation Assessment

Catch & Release fishing regulations were implemented in 2014 on sections of two trout-stocked streams – the Flat Brook/ Big Flat Brook and the Ken Lockwood Gorge on the S/Br. Raritan River. Both support reproducing trout populations. Electrofishing surveys have been conducted on these streams to provide data for evaluating the effect of the regulation change on these trout fisheries.

Flat Brook/Big Flat Brook- Four sites per year on the Flat Brook/Big Flat Brook *Catch and Release (C&R)* regulation section were electrofished in 2012, 2013, 2014, 2015, and 2016. Although this stream reach is trout-stocked in the spring and fall, and naturally reproducing trout occurs within this section, few trout were encountered during these surveys (see table below). The "Three Bridges" site yielded significantly more trout in both the 2015 survey and the 2016 survey (counting the observed trout in 2016 - see footnote in table). After five years of study it is clear that stocked trout are not holding throughout the *C&R* regulation area in good numbers. Some trout appear to be utilizing deep, non-wadeable, very difficult to survey, pools in this stream, as evidenced by the 2014 informal (non-standardized) electrofishing survey that was conducted in a large, deep pool (see footnote in table), while other trout may be migrating out of the *C&R* regulation area outright. (Shramko)

To help biologists understand if and when trout maybe migrating out of the areas conducive to sampling, six additional surveys were conducted in 2016. These six additional surveys were very different than the typical standardized 150m surveys conducted previously. In an attempt to sample a larger area, these surveys covered a total of 1,200 nearly contiguous meters, with only a few pools throughout the 1,200m that were too deep to sample with backpack electrofishing units. In these deeper pools, visual observations of the trout were counted. Only stocked trout were collected and counted while wild trout and other species were observed and noted only if they were rare or never encountered in the Flat Brook system. The 1,200m survey section encompassed 3 of the 150m standardize surveys previously sampled. These 150m surveys conducted in July / August each year from 2012 through 2015 were very consistent and found on average 11 stocked trout per 100m. The consistency of this data suggests that 11 trout/100m is an average summertime density for these locations (See Table below).

Electrofishing locations along the Big Flat Brook and Flat Brook from 2012 – 2016.

Year	Water Temp	Total Trout	Brook Trout		Brown Trout		Rainbow Trout	
			Wild	Stocked	Wild	Stocked	Wild	Stocked
Big Flat (between Rt. 206 & Rt. 560 bridges)								
2012	19.9°C (67.8°F)	3				2		1
2013	17.1°C (62.8°F)	8	2			1		5
2014	17.6°C (63.7°F)	3	3					
Big Flat (Old Police Barracks) (page A2)								
2015	18.6°C (65.5°F)	6	3					3
2016	19.3°C (66.7°F)	3	2					1**
Big Flat (Station 2 – upstream from Blewitt Tract)								
2012	20.8°C (69.4°F)	3	3					
2013	18.6°C (65.5°F)	7	5			1		1
2014	17.6°C (63.7°F)	8	5		3			
Big Flat (between Rt. 560 & "Warner's Hole") (page A3)								
2015	17.1°C (62.8°F)	10						10
2016	20.4°C (68.7°F)	8						8
Big Flat (Station 1 – upstream from Blewitt Tract) (page A4)								
2012	19.1°C (66.3°F)	8	7					1
2013								
2014	17.5°C (63.5°F)	2			2			
2015	19.3°C (66.7°F)	3	1					2
2016	19.5°C (67.1°F)	2	1					1
Flat Brook (above Roy Bridge - just downstream of rifle range pool)*								
2012	18.8°C (65.8°F)	6	1		1	2		2
2013	16.3°C (61.3°F)	4	1		1			2
2014	17.3°C (63.1°F)	2			1			1
Flat Brook (Three Bridges WMA) (page A9)								
2015	18.7°C (65.7°F)	48	1					47
2016	18.6°C (65.5°F)	8	1					7***

* In addition to this site, the "rifle range pool" was electrofished. Due to the large size of the pool (wide, long, and deep) not all the trout were captured, however, a total of 15 trout (14 Rainbow Trout and 1 Brook Trout) were netted. They ranged in size from 11.3 – 15.7 inches and all appeared to be of hatchery origin (stocked). The brook has many pools similar to this one that hold trout but are difficult to effectively sample.

** 8-10 stocked rainbow trout were seen but located in a pool too deep to effectively sample and escaped capture.

*** 35 to 50 stocked rainbow trout were seen, but not captured due to a deep hole that this year could not be sampled. This deeper location was able to be sampled in 2015 and accounts for the difference in trout captured from 2015 to 2016 found in the table.

The C*atch and Release* regulation area on the Big Flatbrook / Flatbrook receives a preseason stocking and seven successive weekly stockings during the spring trout program. The 1,200m survey section of the *C&R* regulation area receives about 2,500 trout per season (approximately 312 trout/week). The first 1,200m survey occurred on May 16, 2016, three days after the fifth week of the spring trout stocking program. Since the first 1,200m survey was three days after the fifth in-season stocking (plus the pre-season stocking) for a total of six stocking events, the area was stocked with around 1,875 trout since mid-March. If all of the trout remained in this study area, the area would be holding approximately 156 trout/100m at the time of the initial survey, however only 13 trout/100m were documented. A single pass backpack electrofishing survey is not expected to capture all fish in an area nor are all stocked trout expected to remain in the *C&R* section since March, but the 13 trout/100m survey results is extremely and alarmingly lower than what is expected.

The second 1,200m survey occurred one week later on May 23, three days after the week six trout stocking of an additional 300 trout. Interestingly, the overall trout density increased to 21 trout/100m. This is still an extremely low number of trout compared to what would be expected to find if trout did not move out of the area at all (182 trout/100m after 7 stocking events). This slight increase in trout density found may be attributed to the additional stocking and/or the low flow conditions, potentially inhibiting fish movement.

The third 1,200m survey occurred on May 31, one week later than the previous survey and again three days after the stocking of an additional 300 trout (week seven). Stream flows increased due to rainfall between the previous survey and this survey allowing for a higher freedom of fish movement. Interestingly, the density of trout found decreased to 13 trout/100m, which is in line with first survey and similar to the 11 trout/100m density found from 2012 to 2015 average summertime levels. This density is again far lower than expected after eight stocking events totaling approximately 2,500 trout (208 trout/100 m density).

The data from the three surveys indicate that stocked trout are moving out of the 1,200m sample area in less than three days post-stocking. Three additional surveys were conducted in June, August, and October. Overall trout density in the 1,200m survey area continued to decrease in 2016 as the summer months took hold. This is not surprising due to low stream flows and high stream temperatures in the Flat Brook in the summer of 2016. Both conditions are not favorable for trout survival. See the table on the following page for a breakdown of the data collected on the six 1,200m surveys along with other relevant survey data collected in the area. Additional information is compiled in Appendix A (pages A2-A4 and A9).

It is possible that some trout are residing in deep pools outside of the 1,200m study area, but it is also possible that the trout are swimming even greater distances and leaving the *C&R* regulation area outright and possibly the Flat Brook system entirely. To answer this question, beginning in the spring of 2017, a trout telemetry study will be initiated to identify when fish are moving, where the fish are moving to and possibly shed light on why the fish are moving. The information gained could help explain why historically, the Big Flat Brook / Flat Brook reputation of a great trout fishery remains unsubstantiated by survey /creel data collected by the Division of Fish and Wildlife. (Hunter and Angler Fund)

Flat Brook Catch & Release Regulation Area Electrofishing Surveys 2012 – 2016.

	Survey site 1 (trout/100m)	End of site 1 to Rt. 560 (trout/100m)	Rt. 560 to beginning survey site 2 (trout/100m)	Survey site 2 (trout/100m)	Old Police Barracks site (trout/100m)	Total area (trout/100m)
7/30/12 45 days after last stocking	-----	-----	-----	9	-----	**-----**
8/29/13 45 days after last stocking	-----	-----	-----	11	-----	**-----**
7/30/14 45 days after last stocking	-----	-----	-----	9	-----	**-----**
7/14/15 45 days after last stocking	13	-----	-----	-----	12	**-----**
5/16/16 3 days after stocking	14	8	15	10	13	**13**
5/23/16 3 days after stocking	32	10	21	23	24	**21**
5/31/16 3 days after stocking	15	2	12	5	39	**13**
6/22/16 25 days after last stocking	7	1	12	9	21	**10**
7/19/16 52 days after last stocking	5	-----	-----	-----	-----	**-----**
8/2/16 66 days after last stocking	-----	-----	-----	-----	7	**-----**
8/18/16 82 days after last stocking	5	1	9	5	10	**6**
10/4/16 129 days after last stocking	1	0	1	0	5	**1**

* Shaded areas indicate days in which the 1,200-meter surveys were conducted. Unshaded areas indicate independent 150-meter surveys.

** Only results for stocked trout are included in the table above.

South Branch of the Raritan River- Known for its great scenery and fish habitat, the 2.5-mile section of the South Branch of the Raritan River known as the Ken Lockwood Gorge is very popular among anglers looking for *Catch and Release* (and artificial lures only) opportunities. Wild Brown Trout are the foundation of the fishery in this section of river, with numbers that seem to greatly fluctuate. Brook Trout (soon to be listed state Special Concern) are rarely encountered, with never more than a few individuals. This section is stocked by NJDFW in both the spring and fall, and periodically privately stocked. Prior to 2014, this section was regulated as a Year Round Trout Conservation Area (TCA) (1 trout per day greater than 15 inches). The *Catch and Release* (*C&R*) regulations went into effect in 2014. The popularity of the Ken Lockwood Gorge has warranted NJDFW to monitor the fish assemblage in this area very closely over the years, with electrofishing surveys conducted at 2 established locations during the summers of 2006, 2007, 2013, 2015, and 2016. (Federal Grant F-48-R, Project I) (Crouse)

Bureau of Freshwater Fisheries Electrofishing Survey conducted in the Ken Lockwood Gorge Wildlife Management Area during the summer of 2006.

Routine survey locations are referred to as "the boulder field" in the upper section and "below the trestle" towards the middle of the Ken Lockwood Gorge. A summary of results is found in the table below and Appendix A (pages A53-A54). Surveys conducted since 2006 at the boulder field will be discussed first. The total number of all trout species encountered during electrofishing surveys have generally increased (49, 73, 70, 168, 150). Brown Trout were the most abundant trout species during the first three surveys, consisting of almost exclusively wild fish. Their numbers were trending upward (41, 44, 55) until the last two years in which 28 and

38 were caught respectively. When broken down by species, the greatest difference noted is in regards to Rainbow Trout, which have increased (6, 11, 13, 139, 111).

The second of two survey locations is located below the railroad trestle in the middle of the KLG. Results from this location are similar to the boulder field site previously discussed. Over the last five sampling events since 2006, the total number of trout encountered during electrofishing surveys have fluctuated (47, 53, 143, 245, 83). Brown Trout were the most abundant species during the first three surveys, consisting almost exclusively of wild fish. Their numbers were trending upward (43, 29, 97) until the last two years in which 24 and 14 were caught. As with the boulder field site, when broken down by species, the greatest difference noted is in regards to Rainbow Trout, which have generally increased (3, 12, 37, 221, 68) over previous years.

This large number of stocked Rainbow Trout warrants concern, as wild trout numbers have declined. In regards to angler harvest of trout less than 15 inches, the previous *Year Round Trout Conservation Area* (*TCA*) regulations (1 trout per day greater than 15 inches) is no different than the *C&R* regulations, since under both regulations these trout must be released. The number of trout over 9 inches has generally increased at the boulder field (25, 43, 40, 149, 120) and below the trestle (29, 39, 109, 231, 74), which meets a management objective of increasing the average trout size. Unfortunately, the number of trout greater than 15 inches (*TCA* size limit) has not significantly increased since the new regulation went into effect.

Electrofishing locations within the Ken Lockwood Gorge from 2006 – 2016.

Year	Water Temp	Total Trout	Brook Trout		Brown Trout		Rainbow Trout	
			Wild	Stocked	Wild	Stocked	Wild	Stocked
Boulder Field (page A53)								
2006*	13.7°C (56.7°F)	49	2		41		6	
2007*	18.9°C (66.0°F)	73	18		44		11	
2013	19.8°C (67.6°F)	70		2	54	1	2	11
2015	25.0°C (77.0°F)	168	1		26	2	2	137
2016	20.6°C (69.1°F)	156	1		38		4	113
Below Trestle (page A54)								
2006*	13.7°C (56.7°F)	47	1		43		3	
2007*	18.9°C (66.0°F)	53	12		29		12	
2013**	18.4°C (65.1°F)	144 **		9	84	13		37
2015	22.8°C (73.0°F)	245	1		17	7		221
2016	19.6°C (67.3°F)	83	0	0	14	1		68

* Wild and stocked trout were not adequately differentiated during the 2006 and 2007 surveys.
** One wild Tiger Trout (Brook Trout X Brown Trout) was collected at this site.

In recent years, anglers have caught (and released) several stocked trout (as opposed to wild trout) with external lesions, in addition to several more collected by NJDFW staff, that were confirmed to have Furunculosis, a disease caused by the bacterium *Aeromonas salmonicida*. Stressful conditions persist in this section of the South Branch of the Raritan River during summer months and are exacerbated during drought conditions recently experienced. A high density of stocked trout (as seen in 2015 and 2016) does not help the situation. Concern for the sustainability (balance of wild trout to stocked trout and the possibility for disease outbreak) for this important fishery requires routine surveillance and management action.

Year Round Trout Conservation Area Assessment

South Branch of the Raritan River- The Claremont Stretch, a 1.1-mile section of the Raritan River South Branch, was surveyed to assess the fish assemblage and the current *Year Round Trout Conservation Area* (1 trout greater than 15 inches / day and artificial lures only) regulations. This specially regulated area is less popular than many others, likely due to several factors, including proximity to parking areas and a lack of trout stocking. Ironically, the Claremont Stretch typically holds more trout than any other location. This year, two sites that are routinely monitored every few years (ie. 1998, 2001, 2006, 2007, 2013, 2016) were surveyed. The two locations are referred to as "the old stocking point" (upper end) and the "fiber optic crossing" (lower end). The most noteworthy finding is that the once abundant Brook Trout population (soon to be listed state Special Concern) seems to be declining. (Federal Grant F-48-R, Project I) (Crouse)

Data from the old stocking point indicates the total number of Brook Trout during the two most recent surveys in 2013 (n=6) and 2016 (n=7) are substantially less than the average of the four last surveys conducted from 1998 through 2007 (n=31). The total number of Brown Trout has also declined in 2016 from its previous average of 118 down to 44. Slimy Sculpin (soon to be listed state Threatened) numbers (n=39) are within the range of the previous five surveys (14-72). White Suckers are a tolerant species and generalist feeder, and were extremely abundant (n=746), indicating a stressed system.

Data from the fiber optic crossing is similar, as the total number of Brook Trout during the two most recent surveys in 2013 (n=18) and 2016 (n=19) are substantially less than the average of the four last surveys conducted from 1998 through 2007 (n=49). The total number of Brown Trout has also declined in 2016 from its previous average of 90 to 13. Slimy Sculpin (soon to be listed state Threatened) numbers (n=108) are within the range of the previous five surveys (21-220). As with the previous survey location, White Suckers were abundant.

Claremont Stretch fiber optic crossing.

Water temperature was also elevated at both locations (23.4℃ and 20.3℃). River conditions since fall of 2015 have been stressful, as rainfall and subsequent flows have been very low. The decline in the fishery may also be due to a change in habitat. As the number and depth of pools have decreased at various locations in the upper section of this river as sand and other fine particles have increased in abundance. Recent habitat assessments indicate increasing percentages of sand and silt in the channel than those previously observed. The decline of this trout fishery is of concern and is believed to be related to habitat degradation, and subsequently exacerbated by drought conditions. Due to the presence of two species soon to be designated state Special Concern (Brook Trout and American Brook Lamprey) and another species soon to be listed as state Threatened (Slimy Sculpin) populations and habitats within the Claremont stretch should continue to be monitored. A summary of results is found in Appendix A (pages A51 - A52)

Inventory of Trout Production Streams

Waters used by trout for spawning and nursery areas are classified as *Trout Production* under the state's Surface Water Quality Standards. New Jersey has nearly 200 *Trout Production* streams and most of these are small tributaries and headwaters of larger rivers in the northern part of the state. Wild, naturally reproducing trout are important indicators of healthy ecosystems, requiring superior water quality and pristine habitat. Despite the protection that state regulatory programs afford *Trout Production* waters, ongoing changes in land use have impacted these coldwater fisheries populations. In particular, wild Brook Trout, New Jersey's only native trout species, have declined dramatically over the last century due to land use changes which have affected the quality of their habitat. Documenting the status of wild Brook Trout in New Jersey is important as this species will soon be designated state Special Concern.

Trout Production streams are monitored periodically to assess the status of their naturally reproducing trout populations (once every 20 years, or more frequently if wild Brook Trout were present or if regulated as a *Wild Trout Stream*). Surveys are conducted using established protocols which include electrofishing a 150 m reach, physicochemical measurements, and the EPA Rapid Bioassessment for habitat (with regional modifications) (Barbour et al. 1999) (Appendices C and D). The data collected through these surveys are evaluated to determine if population changes have occurred and are used in the development management strategies and fishing regulations to protect this fragile resource. The data are also used by the Eastern Brook Trout Joint Venture (a National Fish Habitat Partnership) as part of a range wide effort to conserve and manage Brook Trout in the eastern U.S. (Federal Grant F-48-R, Project I)

In 2016 a total of six surveys were conducted on five *Trout Production* streams in the Upper Delaware/Wallkill watershed at (or near) locations that had been surveyed in the past (see table below). These surveys can be summarized as follows:

- All five streams had wild trout, though one of two surveys conducted on the Little Flat Brook did not yield wild trout.
- 2 small tributary streams in the Flat Brook drainage, Tillman Brook and Big Flat Brook (trib.) (Lake Ashroe), continued to support populations of wild Brook Trout.
- Wild Brook Trout were documented for the first time in the Little Flat Brook near its confluence with the Big Flat Brook.
- Wild Brook Trout were not found in surveys conducted on Shawanni Creek and Black Creek (trib.) (McAfee), despite having been present in previous surveys conducted at the same locations in 2005. Only wild Brown Trout were detected in these two streams in 2016.

Results of six electrofishing surveys conducted on five streams in New Jersey during 2016 as part of a monitoring program for streams classified as *Trout Production*. An "*" following the species name indicates that only older than young-of-the-year trout were found and these were considered wild (not stocked) based upon a visual assessment of fin wear.

	2016			Prior to 2016	
Stream (County) and location	Survey date	Reproducing trout species	Results page #	Survey date	Reproducing trout species
Upper Delaware (North) & Wallkill watersheds					
Big Flat Brook (trib.) (Lk Ashroe) (Sussex) Brook Road bridge	7/1/16	Brook	A5	7/28/05	Brook
Black Creek (trib.) (McAfee) (Sussex) Rt. 517 bridge	8/26/16	Brown*	A6	7/26/05 7/29/70	Brook & Brown* Brook & Brown
Little Flat Brook (Sussex) Layton-Hainesville Road	8/9/16	Brook	A11	8/18/88 9/12/69	none none
Little Flat Brook (Sussex) Near confluence w Big Flat Brook	8/9/16	none	A12	8/18/88	Brown
Shawanni Creek (Sussex) Mountain Road bridge	7/29/16	Brown*	A18	8/19/05 8/11/70	Brook* Brook & Brown*
Tillman Brook (Sussex) Tillman Road	7/29/16	Brook	A20	8/19/05	Brook

Lake Trout Population Assessment

Lake Trout (*Salvelinus namaycush*) fisheries exist in two waterbodies within New Jersey, Round Valley Reservoir and Merrill Creek Reservoir. Although stocked for years, the Lake Trout populations in these two reservoirs are now entirely supported by natural reproduction and are no longer stocked by NJDFW's Hackettstown State Fish Hatchery. Surplus Lake Trout were periodically stocked into Monksville Reservoir from 2004 - 2012, however it did not develop into a significant fishery. As a result, Lake Trout are no longer stocked in NJ.

Round Valley Reservoir- The Lake Trout population in Round Valley Reservoir is closely monitored by NJDFW to evaluate the status of this trophy trout fishery. Lake Trout reared at the Hackettstown State Fish Hatchery were stocked in this deep reservoir (maximum depth 160 feet) from 1977 until 1995. In 1985, evidence that natural reproduction was occurring within the reservoir was documented. By 1995 it was determined that the population was capable of maintaining itself by natural reproduction, thus stocking was discontinued. Gill net surveys are conducted every fall, when mature Lake Trout seek out suitable spawning habitat along the boulders lining the reservoir's dams. Eight experimental gill nets, each net with varying mesh size openings, are used to capture a range of Lake Trout from juveniles to sub-adults. These nets are set at consistent locations in approximately 70 – 100 ft. of water. Eight additional large-mesh gill nets (6" stretch mesh) are set near the reservoir's north and south dams to capture mature Lake Trout as they begin congregating to spawn over the rocky substrate in approximately 50 ft. of water. Length and weight data are collected to assess physical condition of the fish using relative weight analysis. In addition, sex, fin clips, and sexual development information are also recorded. (Federal Grant F-48-R, Project I) (Crouse)

In 2016, large-mesh gill nets set overnight and retrieved on 11/15/16 and 11/16/16, resulted in the capture of 96 Lake Trout ranging from sub-adults to adults. Combined with 61 juveniles to sub-adults captured with experimental gill nets on 10/25/16 and 10/26/16, the 157 Lake Trout is average for surveys conducted since 2006. The majority of the Lake Trout (153 of 157) were less than 24 inches. The number of Lake Trout encountered during our monitoring program over 25 inches has steadily declined since 1996. During the mid-1990's more than 40 individual fish over 25 inches were documented. That number has decreased to single digits in recent years (see figure below).

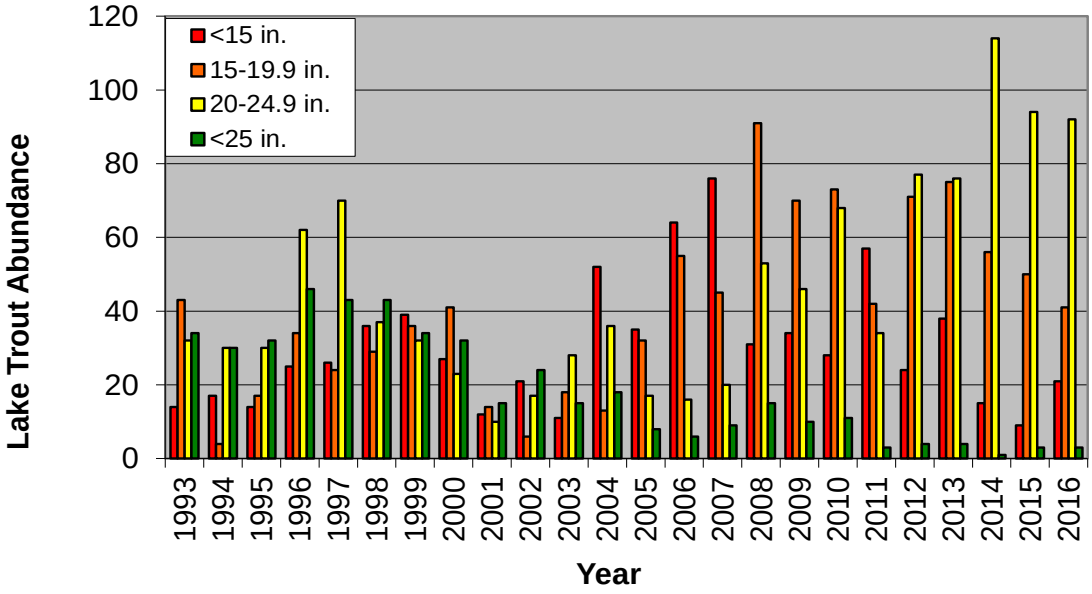
The largest Lake Trout collected during the 2016 RVR gill net surveys was this 21.2-lb. male

Unfortunately, the trend of decreasing numbers of large Lake Trout is resulting in a less-desirable trophy Lake Trout fishery. 2014 was the first year no Lake Trout over 30 inches or over ten pounds were caught, however two large Lake Trout were caught in both 2015 and 2016. The largest in 2016 was a male measuring 38.0 in. and weighing 21.2 lbs. (see photo above). Two additional noteworthy fish included a female measuring 30.7 in. and 11.9 lbs. and a male at 29.6 in. and 9.9 lbs.

In 2008 and then again in 2012, the regulations were modified to increase harvest, aiming to reduce competition and facilitate better condition and faster growth. This management strategy seems to have worked, as the number of Lake Trout from 15 to 20 inches has declined, while those from 20 to 25 inches have increased (see figure below). NJDFW plans to continue to encourage the harvest of Lake Trout from 15 to 24 inches with the intention of

achieving a more desirable trophy fishery. Despite few individuals reaching trophy proportions, the Lake Trout population is doing well. Data will be analyzed and compared to Lake Trout data collected in previous years.

Number of Lake Trout captured (by size) during annual gill net surveys at Round Valley Reservoir since 1993.



Round Valley Reservoir Salmonid Diet Study – In order to better understand the composition of trout diets in Round Valley Reservoir, NJDFW utilizes several methods of obtaining dietary data, including the examination of moribund Lake Trout captured during gill net monitoring and Round Valley Trout Association collection of trout stomachs from monthly tournaments. The primary purpose was to determine if the contribution of baitfish (primarily Alewives and Golden Shiners) in the diet of Rainbow, Brown, and Lake Trout. Interesting observations this year include the partially digested Rainbow Trout (12.8 inches) submitted from an angler who caught a 35-inch, 18.1-pound Lake Trout (see photo above). Another interesting observation is an increasing number of Lake Trout with a variety of small sunfish species in their stomachs, as compared to previous years. In fact, twelve trout had greater than 10 sunfish, with the most abundant coming from a 19-inch Lake Trout with 162 sunfish in its stomach (see photo to left). The data are used, in conjunction with other measures, to determine the status of the forage in the reservoir.

Merrill Creek Reservoir- Merrill Creek Reservoir is a 650-acre privately-owned reservoir located in Harmony Twp., Warren County that is open to public fishing. Following construction and filling in 1988, a variety of fish species have been stocked in this deep-water reservoir (200 ft deep) by NJDFW to establish and maintain desirable sport fisheries for Smallmouth Bass as well as Rainbow, Brown, and Lake Trout. The reservoir's fishery is managed by the Merrill Creek Owners Group in cooperation with Fish and Wildlife. This team meets annually to review and discuss fisheries data collected by the owner and their consultant, and to make management decisions. In recent years, Lake Trout have been the primary management focus and the owner's consultant annually monitors the Lake Trout population in the fall using gill nets. When the gill net survey data indicated that Lake Trout were naturally reproducing in the reservoir, stocking of this species was discontinued in 2013. (Federal Grant F-48-R, Project I) (Hamilton)

In 2016, to supplement fisheries data collected by the owners' fisheries consultant, the Bureau of Freshwater Fisheries deployed four experimental gill nets overnight (11/9/16 through 11/10/16) to target small Lake Trout. A total of 25 fish were captured, representing 3 species (Lake Trout, Yellow Perch, and Alewife). Only 18 Lake Trout were captured, compared to 20 in 2015 and 27 in 2014. The Lake Trout captured in the 2016 survey ranged in size from 202 – 629 mm (8.9 – 24.8 in). The largest laker weighed 4.8 kg (10.7 lbs). Four larger Lake Trout, size range 447 – 629 mm (17.6 – 24.8 in) were fin clipped which indicates that they were stocked (hatchery origin). The remaining 12 lakers captured, size range 202 – 620 mm (8.0 - 24.8 in) were not fin-clipped and these are generally considered to be the product of natural reproduction.

10.7 lb. Lake Trout from Merrill Creek Reservoir held by Charlie Dix of Normandeau Associates (2015)

Landlocked Salmon

Only a handful of deep lakes in New Jersey have suitable year round habitat for coldwater fish like trout and salmon. Landlocked Salmon (lake dwelling form of Atlantic Salmon *Salmo salar*) prefer water temperatures less than 21°C (70°F) and dissolved oxygen levels greater than 5 mg/L, but can withstand warmer, less oxygenated water conditions for short periods. Although not native to New Jersey, Landlocked Salmon were stocked in several NJ waters over a half-century ago, and the historical state record for Landlocked Salmon is an 8-pound fish caught from Lake Aeroflex in 1951.

In 2006, Fish and Wildlife began stocking Landlocked Salmon into two north Jersey lakes, Lake Wawayanda and Lake Aeroflex (Sussex), to provide anglers with an opportunity to fish for this unique coldwater sport fish close to home. The salmon stocked are surplus fish provided by Massachusetts Division of Fisheries and Wildlife in exchange for surplus Northern Pike from the Hackettstown State Fish Hatchery.

From 2006-2013, spring yearling salmon at about 200 mm (8 in) were stocked each May in lakes Wawayanda and Aeroflex immediately upon their arrival from Massachusetts. In 2013 the Hackettstown State Fish Hatchery began retaining some of salmon for 4-11 months and growing them to a much larger size (300-500 mm or 12-20 inches) before stocking. In 2014 Tilcon Lake (Morris) was added to the salmon stocking program. Our ability to stock salmon at a larger size has been making a big difference in both angler interest and angling success.

Tilcon Lake salmon stocking yields immediate results

No assessment activity was reported on this project for 2016. (Hunter and Angler Fund)

Stream Temperature Monitoring

In 2013 the Bureau established an ambient stream temperature monitoring network on streams having trout fisheries that are recreationally important or of conservation interest. The temperature data collected will be used to assess current temperature conditions, evaluate long term trends, determine if ambient water quality is consistent with NJDEP's Surface Water Quality Standards, and aid in the management of coldwater (trout) fisheries inhabiting these streams. Integral to the establishment of this monitoring network was the development of a quality assurance plan that complied with NJDEP's regulations concerning the certification of laboratories and environmental measurements under N.J.A.C. 7:18-1 et seq. A Quality Assurance Project Plan (QAPP) for Ambient Stream Water and Air Temperature Monitoring was prepared and subsequently approved by NJDEP's Office of Quality Assurance in July 2013. This certification is renewed annually. (Federal Grant F-48-R, Project I) (Collenburg)

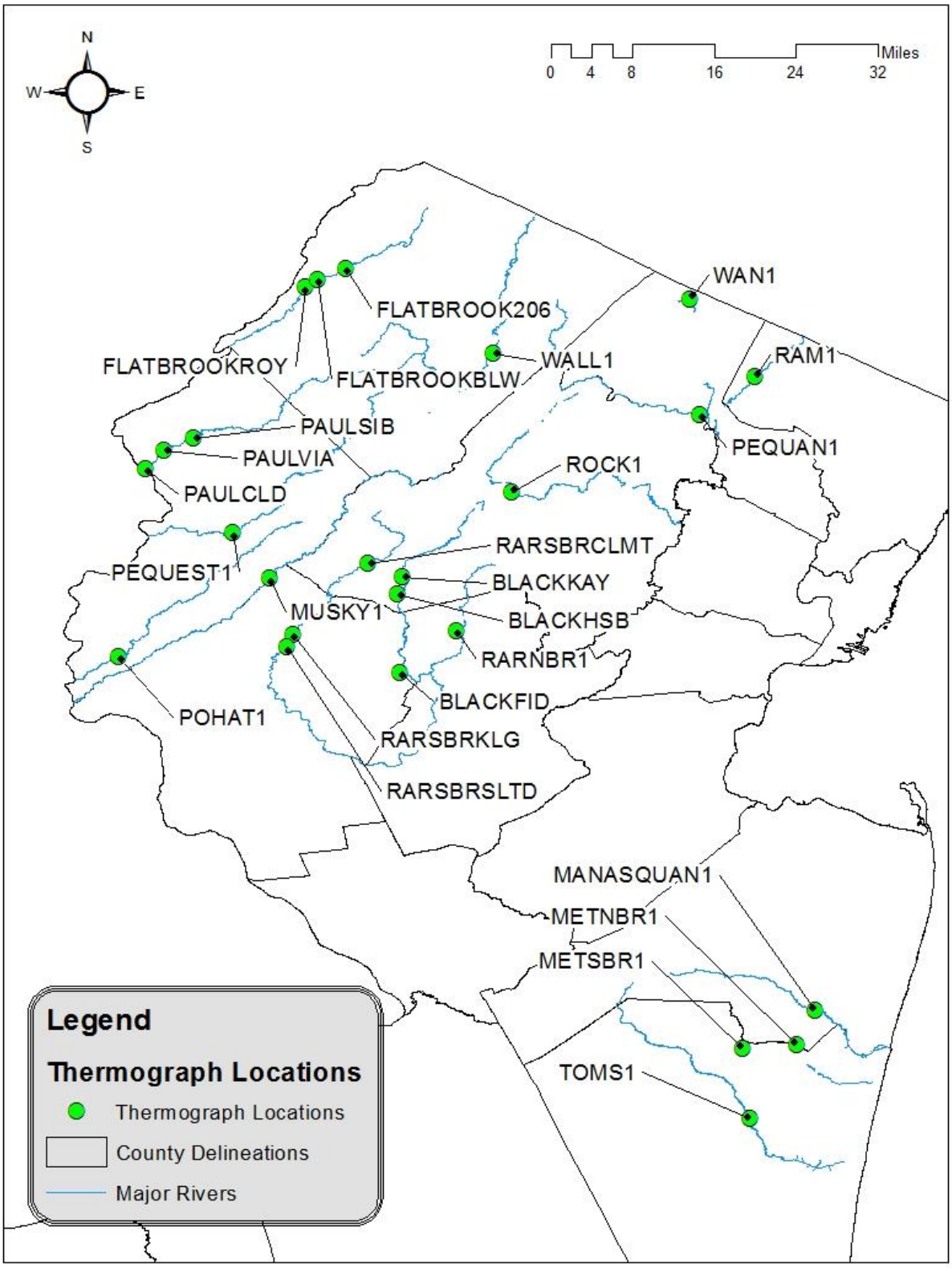
The Black River in Hacklebarney State Park

In 2016 water temperature was monitored at 39 sites (see table and figure below). Twenty-five of the sites were located on 17 recreationally important, major trout-stocked streams. Seventeen sites were located on stream sections classified as FW2-*Trout Production* (TP), nineteen were on stream sections classified as FW2-*Trout Maintenance* (TM), and three were on stream sections classified FW2-*Non-Trout* (NT). Five sites were located on small streams having populations of wild Brook Trout, as part of the Eastern Brook Trout Joint Venture initiative to assess climate change (using paired water/air thermographs). A total of 44 thermographs (Onset Hobo Pro v2) were deployed to record temperature at 30 minute intervals year round. The thermographs were calibrated and regularly checked to maintain the validity of the temperature data. The following results are only inclusive of the twenty-five stream temperature monitoring sites located on 17 recreationally important trout-stocked. For full report, see Appendix E.

2016 NJDFW stream temperature monitoring network on recreationally important trout-stocked streams.

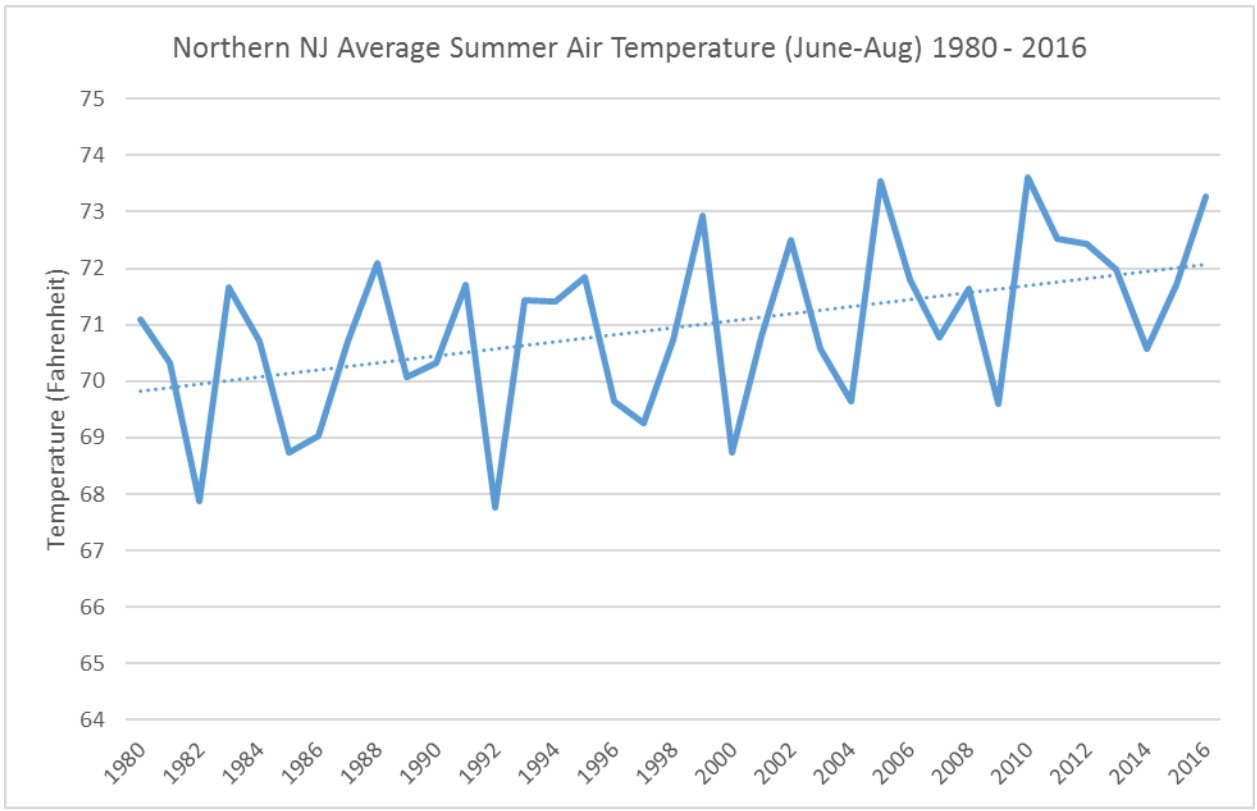
Stream	Site ID	Surface Water Classification	Monitoring Type
Black River	BLACKHSB	Trout Maintenance	water
Black River	BLACKKAY	Trout Maintenance	water
Black River	BLACKFID	Non-Trout	water
Big Flat Brook	FLATBROOK206	Trout Production	water
Big Flat Brook	FLATBROOKBLW	Trout Production	water
Flat Brook	FLATBROOKROY	Trout Maintenance	water
Manasquan River	MANASQUAN1	Trout Maintenance	water
Metedeconk River, N/Br	METNBR1	Trout Maintenance	water
Metedeconk River, S/Br.	METSBR1	Non-Trout	water
Musconetcong River *	MUSKY1	Trout Maintenance	water
Paulinskill	PAULCLD	Trout Maintenance	water
Paulinskill	PAULVIA	Trout Maintenance	water
Paulinskill	PAULSIB	Trout Maintenance	water
Pequannock River	PEQUAN1	Trout Maintenance	water
Pequest River	PEQUEST1	Trout Maintenance	water
Pohatcong Creek	POHAT1	Trout Maintenance	water
Ramapo River	RAM1	Non-Trout	water
Raritan River, N/Br.	RARNBR1	Trout Maintenance	water
Raritan River, S/Br.	RARSBRKLG	Trout Maintenance	water
Raritan River, S/Br.	RARSBRCLMT	Trout Production	water
Raritan River, S/Br.	RARSBRSLTD	Trout Maintenance	water
Rockaway River	ROCK1	Trout Maintenance	water
Toms River	TOMS1	Trout Maintenance	water
Wallkill River	WALL1	Trout Maintenance	water
Wanaque River	WAN1	Trout Maintenance	water

* Thermograph lost. Location will be monitored in 2017.



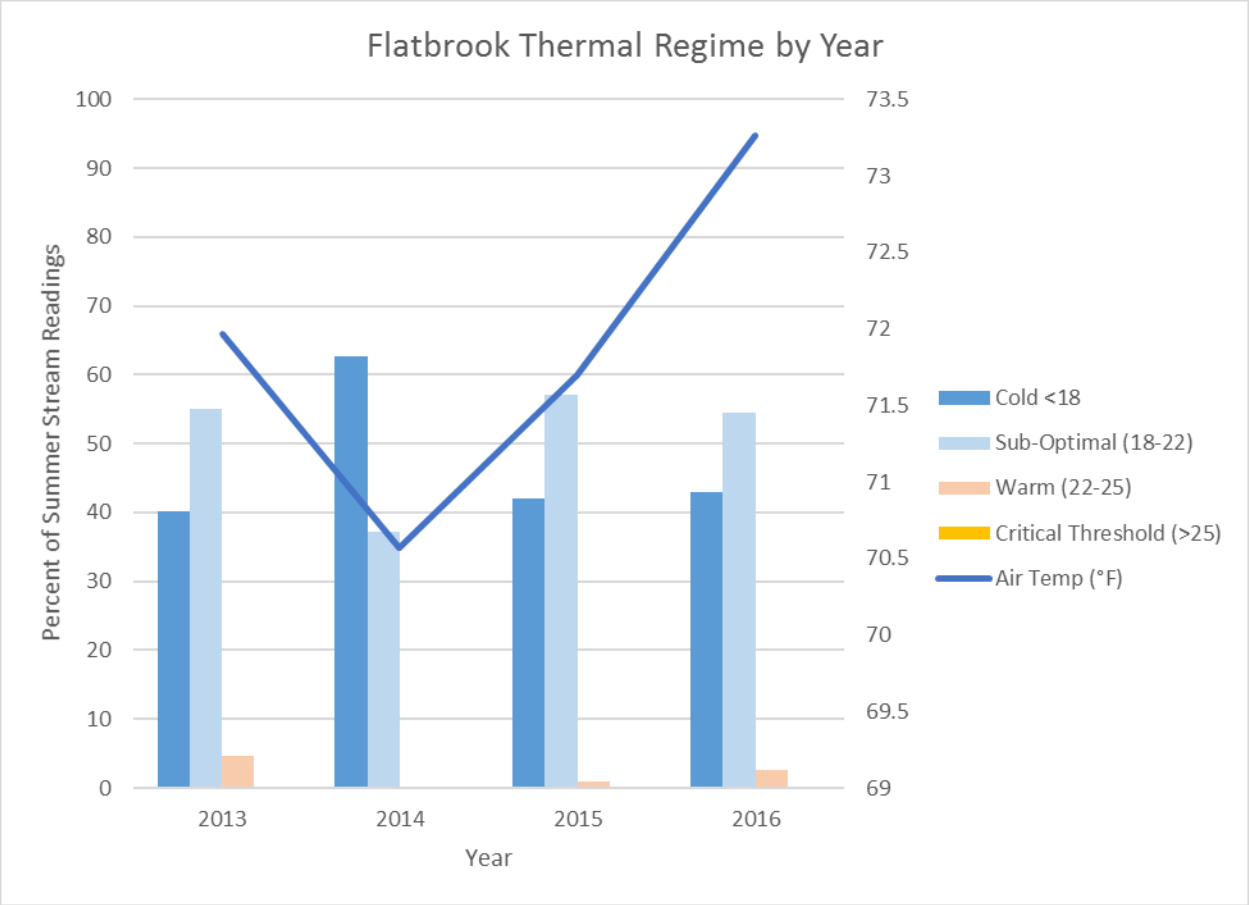
Locations of continuous stream temperature logger sites maintained by NJDFW in 2016 on recreationally important trout-stocked streams.

The stream temperature data collected in 2016 indicates that many of the streams stocked with trout experienced summer water temperatures that were stressful for trout. This is not surprising of recent trends that are indicating unusual summertime warmth in New Jersey statewide, which may be attributed to predicted climate change patterns. Broccoli et al. (2013) found that six of the ten warmest summers on record have occurred since 2005 (including data up to 2012). Looking specifically at Northern New Jersey (location of most of the state's trout stream sections), 2016 has been another warm summer and consistent with the long-term upward trend that is expected to continue in the decades to come as greenhouse gas concentrations continue to increase (see figure below).



Average summer (June 1 - August 31) air temperature in Northern New Jersey from 1980 to 2016.

Summer temperatures are critical for trout survival and a continuing warming trend can threaten the future of the NJDFW's trout stocking program if stream sections continue to warm and continually shorten the length of time the trout can survive in any section. As 2016 has been the warmest summer since the temperature monitoring program has initiated, the sensitivity of these stream sections to climate influencing factors such as air temperature was made more apparent. The Big Flatbrook site located on Route 206 in Sussex County consistently has the coldest stream temperatures compared to other sites across the state. This year was no different and it maintained relatively cold stream temperatures despite the warm summer (see figure below).



Flat Brook's thermal regime from 2013-2016 compared to average summer air temperature data for northern New Jersey.

A stream's structure helps exert internal control over stream temperature through its channel, the riparian zone, and the alluvial aquifer. The great thermal buffering capability of the Big Flat Brook is obvious when it did not exhibit extreme shifts in its thermal regime despite the warm summer of 2016 (see figure above). However, not all streams have the buffering capabilities that the Flat Brook seems to inherently hold. For example, the Pohatcong Creek, in cooler years (2014), has much more "cold" temperatures than in warmer years (2016), where it has shown how sensitive it can be when a warm summer occurs with much more readings in the "warm" and "critical threshold" categories (see figure below).

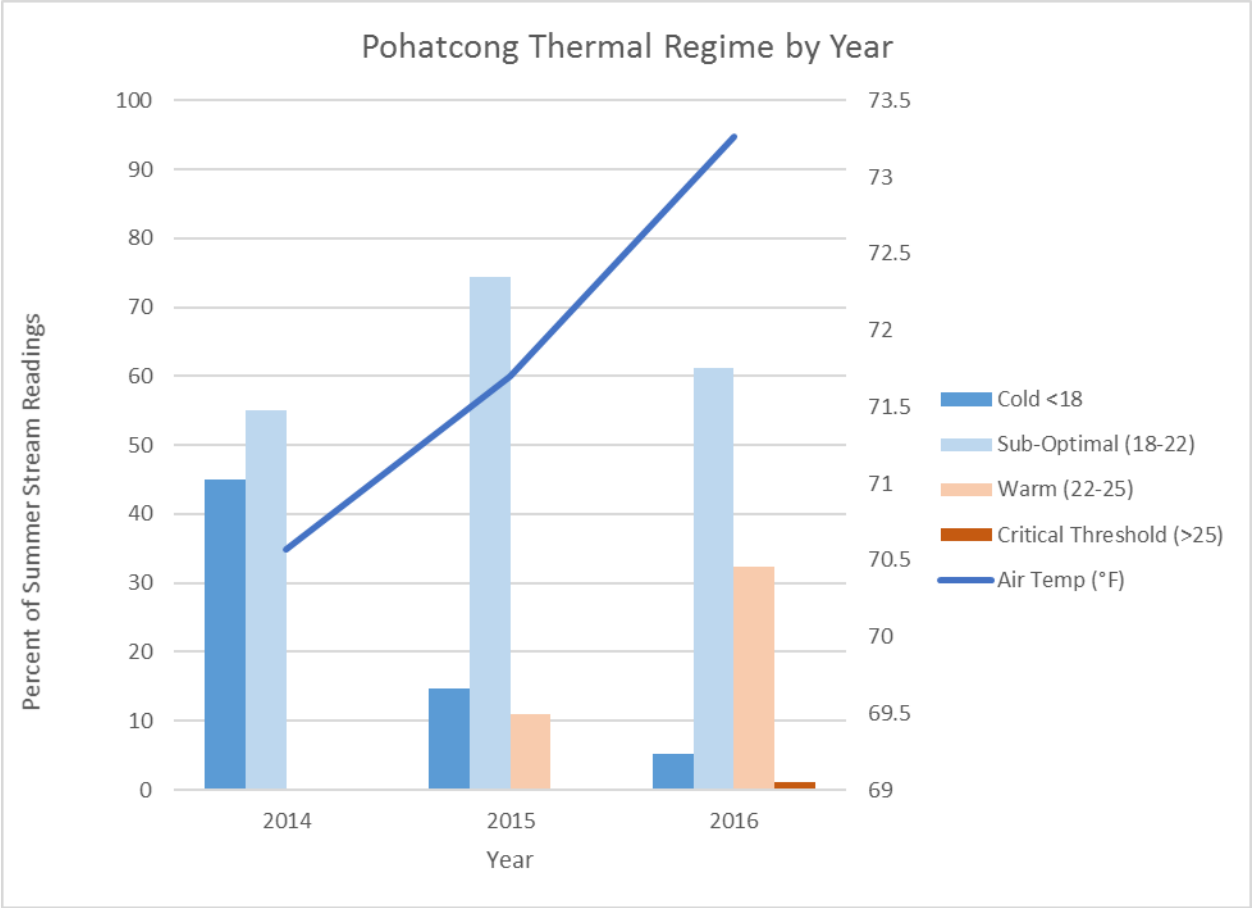


Figure. Pohatcong Creek's thermal regime from 2014-2016 compared to average summer air temperature data for northern New Jersey.

This is a large concern as already marginal habitat becomes even less hospitable for the game fish that are stocked here for recreational anglers to enjoy. One of the concerns of rising stream temperatures for the Division's trout stocking program is that the trout will simply not reside close to their stocking points. This is not so much of an issue around the opening day of trout season, which occurs during the first or second Saturday in April, but when temperatures start to warm up as the summer begins or even later into the trout stocking season, sections of streams that typically had the ability to hold trout, will no longer be hospitable. Currently, anglers report catching stocked trout on the Pequannock River, South Branch of the Raritan River, and the Pohatcong Creek late into the summer and holdover trout are common. As temperatures continue to climb, there will be fewer habitats to occupy, competition for limited space may increase, and stocked trout may find refuge elsewhere.

Temperature Monitoring on Trout Production Streams

Due to continued human impacts, we know that unprotected habitats that are currently marginal for fish survival, in both space and time, will continue to degrade in temperature, flows, and other stream characteristics, and will exceed biological tolerances of sensitive species such as trout. Whether the causative factors of these abiotic responses are induced from climatic forces or from a localized disturbance, the necessity to monitor these changes closely is driven by their tendency to be subtle and virtually invisible unless monitored closely. Background data from stream temperature monitoring established in 2013 by NJDFW and fisheries surveys done in close proximity to temperature monitoring sites resulted in the following observations:

- Streams experiencing the coldest temperatures during trout egg incubation (i.e. Flat Brook) have low wild trout recruitment.
  Note: Emergence times are delayed by cold winter stream temperatures, which may have led to low survival of wild trout (less time/slow growth, more subjected to redd scour from spring flows)
- *Trout Production* streams with higher Growing Degree Days (GDD) had better recruitment (slightly warmer streams).

These observations suggested the next steps to determine the limiting factors of recruitment of trout in New Jersey and if metrics could be developed for use in the monitoring of stream temperatures and in management of *Trout Production* streams.

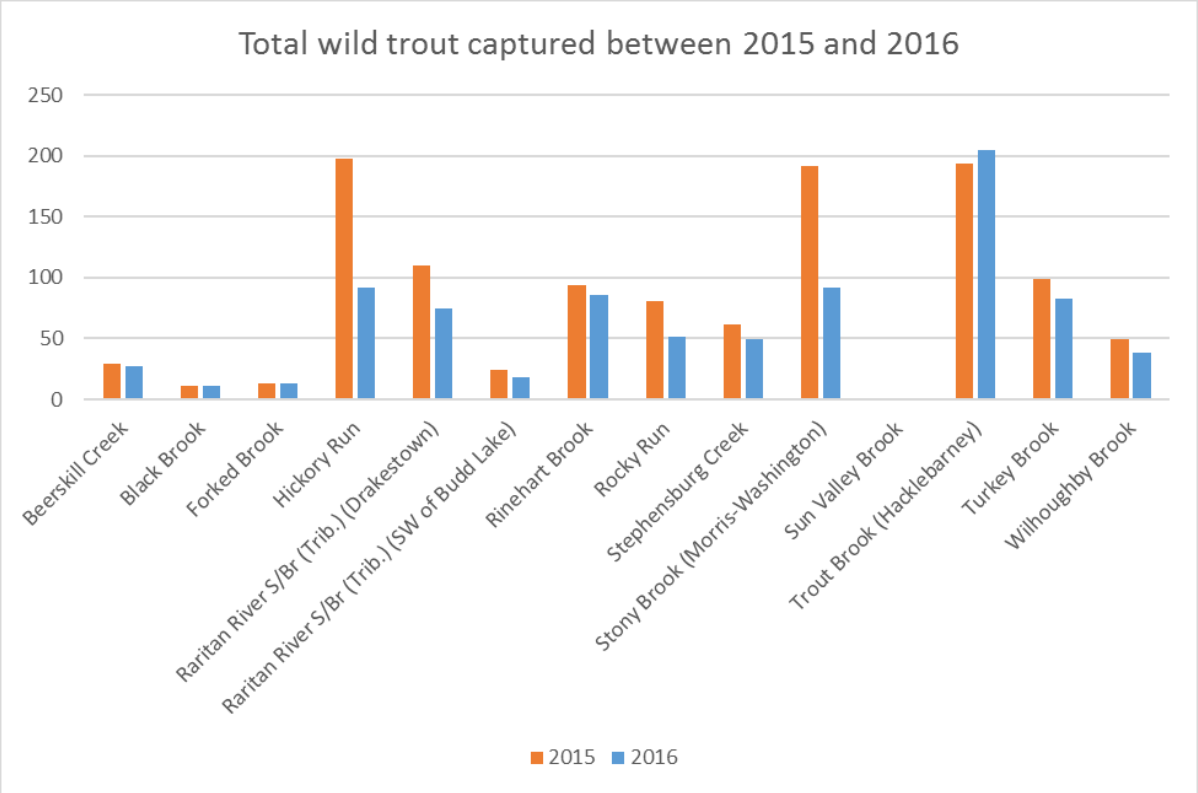
2015 marked the beginning of a three-year study to collect year-round continuous stream temperature data on wild *Trout Production* streams and assess their naturally reproducing trout populations. This study was initiated because excessively cold fall and winter temperatures (approaching 0°C) limit wild trout recruitment via late emergence and slow growth. The study was designed and fourteen *Trout Production* streams were picked, based on location (i.e. watershed, proximity to our office) and on population structure (struggling or well established trout populations) to help investigate this. On these streams, three years of year-round stream temperature monitoring and electrofishing surveys in these same locations will be conducted. The ultimate goals of the study are multi-faceted: (1) to develop a year to year analysis of how stream temperature is influencing New Jersey's wild trout populations, (2) submit data to NJDEP to determine if any streams qualify as part of 303(d) list, and (3) to develop metrics based on GDD, an understanding of emergence times, critical summer time temperatures, fall/winter/spring temperatures, and/or aerobic scope curves that can guide us in determining what streams are the best candidates for possible translocations.

Starting in the spring of 2015, 14 Trout Production streams were selected and stream temperature monitoring devices were placed. The fourteen streams include: Beerskill Creek, Black Brook, Forked Brook, Hickory Run, Raritan River S/Br. (Trib.)(Drakestown), Raritan River S/Br. (Trib.)(SW of Budd Lake), Rinehart Brook, Rocky Run, Stephensburg Brook, Stony Brook (Morris-Washington), Sun Valley Brook, Trout Brook (Hacklebarney), Turkey Brook, and Willoughby Brook. Subsequently, in the summer of 2015 and 2016, backpack stream electrofishing surveys were conducted on these streams following EPA bioassessment

protocols to determine abundance and sizes of wild trout present. A full report will be provided at the end of the study period.

The year 2016 was warm for this region. Summer air temperatures taken from Rutgers University NJ state climatologist dataset (nClimDiv) depict this, and since 1895, this was the warmest month of August recorded. This trend is expected to continue in the decades to come as greenhouse gas concentrations continue to increase. Not only did warm temperatures test the resilience of wild trout streams this summer, low flows and drought conditions presented themselves as well. As habitat becomes limited by lack of water and stream temperatures influenced by climatic forcing increase, the poikilothermic ectotherm trout either adjusts and finds thermal refuge or is limited within the space they are contained and struggle against sub-optimal conditions. The effect that conditions this summer and fall have on the recruitment and survivability of these populations will be evaluated. Data collected on fourteen streams in 2015 and 2016 have shown that total population abundance has decreased in 10 out of 14 streams, 3 showed no change, and one showed an increase (see figure below).

Total number of trout captured from stream temperature study sites between 2015 and 2016.



Trout Stocking Allocations

NJDFW's Bureau of Freshwater Fisheries annually determines which waterbodies and how many trout per waterbody to be stocked statewide. The allocation methodology uses a combination of biological, physical, and social factors to equitably allocate trout over a 10-week period in the spring, 2-week period in the fall, and 1-week period in the winter. A computerized database containing variables for each stream, lake, and pond is used in conjunction with a formula to calculate individual weekly allotments of trout. The database is annually reviewed and updated by biologists. (Hunter and Angler Fund) (Shramko)

Beginning in the spring of 2015 and continued into 2016, all of the fish stocked from the Pequest Trout Hatchery were Rainbow Trout only. In 2014, the Pequest Trout Hatchery had a serious Furunculosis outbreak occur that affected mostly Brook Trout and Brown Trout. Rainbow Trout in the hatchery showed a higher resistance to this Furunculosis outbreak. In an attempt to rid the hatchery of the Furunculosis bacterium, it was decided to raise only the more disease resistant Rainbow Trout out of the Pequest Hatchery for at least the next couple of years.

There were no changes to the Trout Formula methodology used to determine 2016 spring trout allocations. A spring baseline of 570,000 trout continues to be used to determine individual weekly allocations. Significant allocation changes for individual waterbodies are listed below.

Waterbodies dropped from Trout Stocking Program:

Hamilton Fire Pond (Monmouth Co.) Hamilton Fire Pond is a privately owned pond in Monmouth County. The property owners allowed fishing in the pond for years, but have decided to not allow fishing. Therefore, Hamilton Fire Pond has been dropped from the 2016 Trout Stocking Program.

Trout Brook (Hackettstown – Warren Co.) Trout Brook in Hackettstown, Warren County has had very low angler interest and usage for several years. In 2012, the opening day angler count did not record any anglers fishing it at all. Due to low angler usage, Trout Brook in Hackettstown, Warren County has been dropped from the Trout Stocking Program

Stream Mileage Updates:

Stocking locations for streams and rivers are ever changing. For example, when ownership of the land along a trout stocked stream changes, stocking locations may be gained or lost from the trout stocking program. This can affect the total stream stocking mileage used to determine trout allocations, and may result in more or less trout stocked in a particular stream. In addition to the adding or dropping of stocking locations, general stream mile database corrections occur due to continued communication with the Land Management Staff and the use of GIS mapping to assess stream mileage of trout stocked sections.

Little Flat Brook (Sussex Co) The Little Flat Brook trout stocking stream mileage was reduced from 3.7 miles to 2.7 miles due to the loss of a two stocking locations and recalculation of the total stream mileage based upon the remaining stocking locations. This 1-mile reduction results in a decrease of 850 fish in 2016.

Pohatcong Creek (above rt. 31) (Warren Co) The Pohatcong Creek (above Rt. 31) trout stocking stream mileage was reduced from 2.0 miles to 1.75 miles due to the loss of a stocking location and recalculation of the total stream mileage based upon the remaining stocking locations. This 0.25-mile reduction results in a decrease of 110 fish in 2016.

A summary of trout stocked from NJDFW's Pequest Trout Hatchery during 2016, by season and species, is found in the table below.

Spring 2016 Trout Stocking Summary				
Species	Type	Avg. Length	Lbs.	# Fish
Rainbow Trout	Production	11.3"	308,637	605,030
	Broodstock	15.5" & 22.2"	14,592	6,425
		Totals	**323,229**	**611,455**
Fall 2016 Trout Stocking Summary				
Species	Type	Avg. Length	Lbs.	# Fish
Rainbow Trout	Production	14.7"	30,125	20,770
	Broodstock	20.1"	3,060	765
		Totals	**33,185**	**21,535**
Winter 2016 Trout Stocked Lakes Program Summary				
Species	Type	Avg. Length	Lbs.	# Fish
Rainbow Trout	Production	14.6"	7,262	5,100
		Totals	**7,262**	**5,100**

In addition to the above stocking changes, there were also changes to the Fall and Winter Trout Stocking Programs this year. In 2016, the NJDFW expanded the fall trout fishing opportunities to a few more waterbodies. Stocking of the following six waterbodies were moved up several weeks from the Winter Program and are now be part of the Fall Trout Stocking Program: **Hook's Creek Lake, Lower Echo Park Pond, Mill Pond, Speedwell Lake, Verona Park Lake, and Woodcliff Lake**. As part of the Winter Program, these waterbodies were stocked in late November and most years it would only be a few weeks before ice would form on the surface of these lakes. For ice fisherman this is a perfect scenario as it would not be too long before the ice is thick enough to safely access the waterbody. Unfortunately, the owners of these six waterbodies do not allow ice fishing. This creates a problem as the fish are only accessible to anglers for a short time before the ice forms on the lakes. By incorporating these lakes into the fall stocking program, anglers now have several more weeks of additional angling opportunities on these waters.

A stocking allocation formula was also developed for the Fall and Winter Stocking Programs. This allocation formula uses metrics such as size of waterbody, length of stocked area in a stream, waterbody ownership, angler accessibility, angler interest, human population density of surrounding area, and ice fishing opportunities. All of these metrics are the same metrics that are used in the spring trout stocking program with the addition of the ice fishing metric. This change in allocation protocol resulted in minor individual waterbody allocations changes

Wild Brook Trout Assessment

Anthropogenic landscape changes and past management practices have negatively impacted New Jersey's freshwater resources, particularly Brook Trout, the state's only native trout species. Of the three species of trout that reproduce in New Jersey streams, Brook Trout are the least tolerant of habitat degradation. Habitat alteration and stream fragmentation, diminished water quality, and competition with non-native trout (Brown and Rainbow Trout) have contributed to the decline of wild Brook Trout in New Jersey. Wild populations of Brook Trout now persist in less than half their original range in New Jersey and this species will soon be designated state Special Concern.

NJDFW actively participates in the Eastern Brook Trout Joint Venture (EBTJV), a unique partnership initiated in 2004 under the National Fish Habitat Initiative (*www.fishhabitat.org*). EBTJV is a geographically focused, locally driven, and scientifically based effort to protect, restore, and enhance aquatic habitat throughout the range of the eastern Brook Trout. The Venture has produced a range-wide population assessment of wild Brook Trout; completed extensive work that identifies key threats to wild Brook Trout and their habitats; and developed conservation strategies to protect, enhance and restore wild Brook Trout. EBTJV has recently completed refining the subwatershed status map to the catchment scale and NJDFW conducts surveys to assess the status of Brook Trout in catchments that lack survey data. This data, as well as data from stream surveys conducted as part of other activities, is entered into FishTrack (NJDFW's computerized freshwater fisheries database) and shared with the EBTJV. (Federal F-48-R, Project I) (Hamilton)

In 2016 a total of 113 stream surveys conducted under a variety of jobs and/or funding sources provided data that can be used to document the occurrence of wild Brook Trout. Of these, 22 surveys were specifically initiated to determine if known wild Brook Trout populations had been extirpated or if wild Brook Trout might be present in stream catchments not previously surveyed (location selection based upon factors such as suspected presence in catchment upstream of a catchment having wild Brown or Rainbow Trout, general topography, and aerial photography). At 5 of the 22 sites the stream could not be electrofished due to the lack of water.

Wild Brook Trout from Barkers Mill Brook

The status of wild Brook Trout in these stream surveys is summarized below and followed by a table that lists the surveys conducted in 2016 with presence/absence of wild trout species indicated.

- 34 streams (63 surveys) documented the presence of wild trout (Brook, Brown, and/or Rainbow Trout).
- 25 streams (48 surveys) had wild Brook Trout. The wild trout species composition in these streams was: 16 had only Brook Trout, 7 had both Brook and Brown Trout, and 2 had Brook, Brown, and Rainbow Trout.

- 2 streams never before surveyed were inhabited by wild Brook Trout (Musconetcong River (trib.) (NW of Stephensburg) and Musconetcong River (trib.) (S of Asbury)). The S of Asbury tributary also had wild Brown Trout.
- Brook Trout was documented for the first time in the mainstems of 2 streams already classified as *Trout Production* - Buckhorn Creek and Little Flat Brook. Only wild Brown Trout had been previously documented in their mainstems.
- 5 streams, where past surveys documented the presence of wild Brook Trout, did not yield any wild Brook Trout. These streams are Black Brook (trib.) (McAfee), Shawanni Creek, Cresskill Brook, Black Brook, and Rinehart Brook.
- 18 streams (36 surveys) documented wild Brown Trout.
- 3 streams (6 surveys) documented wild Rainbow Trout.

Presence/absence of wild trout species in 113 stream surveys conducted during 2016, listed by major watershed (BKT= Brook Trout; BNT=Brown Trout; RBT=Rainbow Trout). Streams specifically surveyed to assess wild Brook Trout are boldfaced. Streams were surveyed using the standard sampling protocol (150 m stretch electrofished) unless noted by "+". *WTS* indicates the stream was regulated as a *Wild Trout Stream* in 2016. A trout species was considered wild when young-of-the-year fish were present ("X"). When only trout considered older than young-of-the-year were present, fin wear and erosion was used to distinguish between wild fish ("X*****") and fish of hatchery origin. Boldfaced "**X**" denotes new finding of wild Brook Trout.

Stream	County	Location	Wild trout species			Results
			BKT	BNT	RBT	page #
Upper Delaware (North) & Wallkill Region *(Shimers Brook to Paulins Kill and Wallkill River watersheds)*						
Beerskill Creek	Sussex	Cemetery Road	X			A1
Big Flat Brook	Sussex	Between Rt. 206 and Rt. 560	X*			A2
Big Flat Brook +	Sussex	Below Rt. 560 to near Rt. 206 (6 surveys)	X	X*	X	24
Big Flat Brook	Sussex	Downstream of Rt. 560				A3
Big Flat Brook	Sussex	Upstream Blewett Tract (St #1)	X*			A4
Big Flat Brook (trib.) (Lk Ashroe)	Sussex	Brook Road	X			A5
Black Creek (trib.)(McAfee)	Sussex	Rt. 517		X*		A6
Black Creek (trib.) (McAfee)	Sussex	Golf club access road		X*		A7
Black Creek (trib.) (McAfee) +	Sussex	Golf club water treatment area		X*		A8
Flat Brook	Sussex	Three Bridges (Flatbrook WMA)	X*			A9
Forked Brook	Sussex	Grau Road	X			A10
Little Flat Brook	Sussex	Layton-Hainesville Road	**X***			A11
Little Flat Brook +	Sussex	Layton-Hainesville Road				106
Little Flat Brook	Sussex	Near confluence w Big Flat Bk				A12
Mud Pond Outlet Stream +	Sussex	Mountain Road	X*			A13
Paulins Kill +	Warren	Rt. 94 – off Paulins Kill Trail				A14
Paulins Kill +	Warren	Lambert Rd. Bridge				A15
Paulins Kill +	Warren	Below Columbia Lake Dam (5 surveys)				100
Paulins Kill +	Warren	Rt. 46				A16
Shawanni Creek	Sussex	Strubble (Dimon) Road				A17
Shawanni Creek	Sussex	Mountain Road		X*		A18
Sparta Glen Brook	Sussex	Rt. 620 Sparta Glen Park	X*			A19
Tillman Brook	Sussex	Tillman Road	X			A20

(continued)

Upper Delaware (South) Region						
(Delawanna Creek to Lockatong Creek watersheds)						
Barkers Mill Brook	Warren	Barkers Mill Road bridge	X			A21
Barkers Mill Brook	Warren	Townsbury Road	X			A22
Barkers Mill Brook	Warren	Cemetery Road.	X			A23
Barkers Mill Brook	Warren	Near confluence w Pequest R.	X			A24
Beaver Brook (trib.) (E of Manunka Chunk)	Warren	Upper Sarepta Rd (Beaver Bk WMA)				A25
Buckhorn Creek	Warren	Rt. 519	**X**	X		A26
Buckhorn Creek	Warren	Roxburg Station Road		X		A27
Buckhorn Creek (trib.) (Hutchison) +	Warren	River Road				No water
Buckhorn Creek (trib.) (Roxburg)	Warren	Grist Mill Road		**X**		A28
Buckhorn Creek (trib.) (Summerfield)	Warren	Buckhorn Drive (Buckhorn Creek WMA)	X			A29
Hakihokake Creek	Hunterdon	Bridge Street, downstream of bridge		X		A30
Hakihokake Creek	Hunterdon	Bridge Street, behind library		X		A31
Jacobs Creek	Mercer	Pennington-Titusville Road				A32
Jacobs Creek	Mercer	Bear Tavern Road (Rt.579)				A33
Musconetcong River (trib.) (NW of Stephensburg)	Warren	Heiser Road	**X**			A34
Musconetcong River (trib.) (S. of Asbury)	Hunterdon	River Road	**X**	X*		A35
Musconetcong River (trib.) (W. of Asbury) +	Warren	Bloomsbury Road				A36
Pequest River (trib.) (SE of Shiloh) +	Warren	Shades of Death Road				No water
Pohatcong Creek +	Warren	Municipal Drive		X*		
Stephensburg Brook (WTS)	Morris	Stephensburg Road	X	X		A37
Trout Brook (Hope) (trib.) (Shiloh)	Warren	Shiloh Road				A38
Trout Brook (Hope) (trib.) (Shiloh) +	Warren	4 sites off State Park Road				No water
West Portal Creek +	Hunterdon	13 surveys at multiple locations	X	X	**X***	57,122
Upper Passaic Region						
(Pompton, Pequannock, Wanaque, Ramapo, Upper Passaic, Whippany, & Rockaway River watersheds)						
Whippany River (trib.) (Brookside)	Morris	Stoney Hill Road		X	X	A39
Whippany River (trib.) (W. of Watnong Brook)	Morris	Patriots Path off Inamere Rd				A40
Lower Passaic & Upper Atlantic Region						
(Lower Passaic, Saddle, Hackensack, Pascack, & Elizabeth River watersheds)						
Bear Brook (Park Ridge)	Bergen	Brae Road				A41
Bear Brook (Park Ridge)	Bergen	Laurel Hill/Arrowhead Roads				A42
Bear Brook (Park Ridge)	Bergen	Glendale Road				A43
Cresskill Brook	Bergen	Duck Pond Road				A44
Cresskill Brook	Bergen	Deer Hill Road				A45
Elizabeth River, W/Br +	Union	Threrau Terrace				148
Passaic River +	Morris	Columbia Turnpike, Florham Pk				64
Passaic River +	Essex	Camp Lane boat ramp, Fairfield				64
Passaic River +	Bergen	River Road, Elmwood Park				64

(continued)

		Raritan Region				
		(Raritan River watershed)				
Black Brook (*WTS*)	Hunterdon	Van Syckles Road		X*		A46
Hickory Run (WTS)	Hunterdon	Hickory Run Road	X			A47
Hickory Run (*WTS*)	Hunterdon	High Bridge-Califon Road	X*	X		A48
Millstone River	Somerset	Griggstown Causeway				A49
Millstone River	Somerset	Blackwells Mill Road bridge				A50
Raritan River S/B	Morris	Claremont Stretch (old stocking point)	X	X	X	A51
Raritan River S/B	Morris	Claremont Stretch (Fiber Optic)	X	X		A52
Raritan River S/B	Hunterdon	Ken Lockwood Gorge, Boulder Field	X*	X	X	A53
Raritan River S/B	Hunterdon	Ken Lockwood Gorge, below trestle		X		A54
Raritan River S/B (trib.) (Drakestown)	Morris	Joy Drive	X			A55
Raritan River S/B (trib.) (SW of Budd Lake)	Morris	Rt. 46	X			A56
Rinehart Brook (*WTS*)	Morris	Hacklebarney State Park		X		A57
Rockaway Creek	Hunterdon	Lamington Road				A58
Rockaway Creek, S/Br.	Hunterdon	Off Railroad Avenue				A59
Rockaway Creek, S/Br.	Hunterdon	Rt. 22				A60
Rocky Run (*WTS*)	Hunterdon	Rocky Run Road	X			A61
Stony Brook (WTS)	Morris	Columbia Trail Walking Bridge	X*	X		A62
Sun Valley Brook	Morris	Stedwick Road	X*			A63
Sun Valley Brook	Morris	Wolfe Road	X*			A64
Sun Valley Brook	Morris	Upstream of confluence w Raritan R, S/Br				A65
Trout Brook (*WTS*)	Morris	Hacklebarney State Park	X			A66
Turkey Brook (*WTS*)	Morris	Stephens Mill Road	X	X		A67
Willhoughby Brook (*WTS*)	Hunterdon	Rt. 31	X	X		A68
		Lower Delaware Region				
		(Assunpink Creek to Maurice River watersheds)				
Assunpink Creek	Mercer	Quaker Bridge Road				A69
Burnt Mill Branch	Gloucester	Rt. 40				A70
Masons Run (trib.) (Pine Hill)	Camden	Downstream of golf course access road				A71
Rancocas Creek, SW/Br	Burlington	Main Street Bridge				A72
Scotland Run	Gloucester	Rt. 40				A73
		Lower Atlantic Region				
		(Sloop Creek to Dennis Creek watersheds)				
Marsh Lake Branch	Atlantic	Downstream of Cedar Lake				A74
Morses Mill Stream	Atlantic	W. Moss Mill Road				A75
Skit Branch	Burlington	Carranza Road				A76
Wading River, W/Br	Burlington	Below Chatsworth Lake				A77

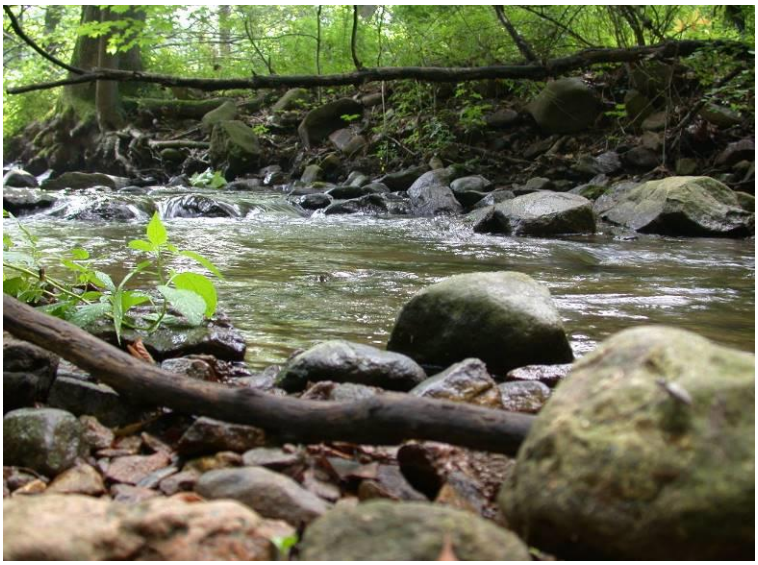
Wild Trout Stream Regulation Assessment

NJDFW has documented reproducing trout populations in nearly 200 streams (or stream segments) statewide, but only a handful of these (36) are currently designated as *Wild Trout Streams* (*WTS*). The majority of the *WTS* are tributaries to larger, trout-stocked streams. However, *WTS* are not stocked with hatchery trout, but rather rely upon their wild, naturally reproducing trout populations to provide a recreational fishery.

Wild Brown Trout Van Campens Brook (2015)

The *WTS* regulation is more stringent than the statewide general trout regulation and has changed little since it was adopted in 1990. Over time several streams have been added or taken off the *WTS* list. More notably, in 2008 when the general statewide minimum harvestable size for trout was increased from 178 to 305 mm (7 to 9 in) this change was also made to the *WTS* regulation. Currently the regulation provides for a limited harvest of only two trout daily, from the Opening Day of the trout season in April through September 15. The minimum size limit on trout is 229 mm (9 in), except for three streams (Van Campens Brook, Pequannock River, and Wanaque River) that produce large Brown Trout and must be at least 305 mm (12 in) to harvest. Fishing gear restrictions also apply (artificial flies/lures only, no bait or bait scent allowed).

Many of the streams currently designated as *WTS* are relatively small, contain limited numbers of (or no) harvestable-sized wild trout, and have limited (or no) public access. In 2014 a multi-year assessment was initiated to review the *WTS* regulation, collect and analyze data, and develop regulations that will better address recreational fishing opportunities for, and conservation needs of, the state's wild trout fisheries. This effort is being guided by a team of Bureau biologists. Fish population data were collected from streams in 2014 and 2015 using established sampling protocols (150 m stretch electrofished in July and August). In 2014, 46 electrofishing surveys were conducted on the 36 designated *WTS's*. In 2015, 48 electrofishing surveys conducted on 39 streams (18 *WTS*, and 21 other *Trout Production* streams not currently regulated as *WTS*). (Federal Grant F-48-R, Project I) (Collenburg, Hamilton, Shramko)



Willoughby Brook (Hunterdon), regulated as a Wild Trout

In 2016, five additional electrofishing surveys were conducted during the summer on three *Trout Production* streams (see table below) to supplement survey data previously collected in 2014 – 2015.

Results of 5 electrofishing surveys conducted on 3 streams during 2016 in New Jersey as part of a statewide *Wild Trout Stream* (*WTS*) regulation assessment project. All trout captured were considered wild (not hatchery) in origin (young-of-the-year fish considered wild; older fish determined to be wild based on fin wear and erosion). BKT= Brook Trout; BNT=Brown Trout; RBT=Rainbow Trout.

Stream	County	Location	Number of trout				Results page #
			BKT	BNT	RBT	Total	
Upper Delaware (South) Region *(Delawanna Creek to Lockatong Creek watersheds)*							
Buckhorn Creek	Warren	Rt. 519	20	1	0	21	A26
Buckhorn Creek	Warren	Roxburg Station Road	0	1	0	1	A27
Upper Passaic Region *(Pompton, Pequannock, Wanaque, Ramapo, Upper Passaic, Whippany, & Rockaway River watersheds)*							
Whippany River (trib.) (Brookside)	Morris	Stoney Hill Road	0	13	71	84	A39
Raritan Region *(Raritan River watershed)*							
Raritan River, South Branch	Morris	Claremont (Old stocking point)	7	44	1	52	A51
Raritan River, South Branch	Morris	Claremont (Fiber optic crossing)	19	13	0	32	A52

Underwater photograph of a wild Brown Trout from the Claremont Stretch of the South Branch of the Raritan River from 2013.

From January through June the team of Bureau biologists invested considerable time compiling, analyzing, and reviewing pertinent information including:

(1) Analysis of data from 94 stream surveys conducted in 2014 and 2015 (historical stream survey data (pre-2014) was also reviewed). The results of this analysis were presented at the annual public trout meeting held at the Pequest Trout Hatchery on February 27.

(2) Summary of fish stocking permits issued by the Bureau in 2015 and 2016 for private trout stockings, with breakdowns by species and stocking location.
(3) A review of scientific literature on hooking mortality of trout relative to gear types (artificials, bait, number of hooks, and hook style). This information was summarized in an article (*The Truth About Hooks & Lures*) published in the 2017 New Jersey Freshwater Fishing Digest
(4) The 2016 Wild Trout Survey, an online survey designed to obtain angler feedback concerning New Jersey's wild trout fishing opportunities.

The Wild Trout Survey, which was released to the public on March 2, 2016, had a total of 291 anglers participate in the 25 question survey. Anglers were asked if they supported or opposed the current Wild Trout Stream Regulations and how they felt about several possible new Wild Trout Stream Regulations. The following bullets are highlights from the survey.

- 90% of participating anglers felt that the most important attribute to having a good day of fishing for wild trout is not based on the number of trout caught or even the size of the trout caught, but just seeing evidence of wild trout in their stream.
- 87% said catching just one wild trout is important to having a good day fishing.
- 95% of the anglers said that a scenic location without a lot of other anglers was important to having that good day of fishing.
- In contrast, 60% of participants stated that catching big fish was NOT important to them when it comes to having a good day on the water.
- 61% are not in support of the current *2 fish per day creel limit* while only 26% support it.
- 75% answered that they want a *Catch & Release* Regulation on all wild trout streams (only 14% opposed this).
- 74% would like *Catch & Release* Regulations on Brook Trout streams, while 60% answered that they would support *Catch & Release* Regulations on wild Brook Trout, but allow harvest on wild Brown Trout & wild Rainbow Trout (19% oppose this).
- 78% of anglers were not in support of the current hook point regulation that allows up to 3 treble hooks or 9 hook points (8% supported).
- Anglers were asked about all different hook point combinations, but the most unified responses were: 65% of anglers support *single hook only* (15% oppose this) and 69% want *barbless hooks only* (13% oppose).
- 70% of participating anglers stated that they support the current *Artificials Only (No bait or scents)* gear restriction while only 19% oppose the current regulation.

GIS mapping was also an integral component of the regulation development process. Once the comprehensive review of information was completed, the team then formulated draft regulations which were presented to staff at a series of meetings held August through October. All Bureau professional staff participated and provided input during this internal review process. Multiple staff meetings were necessary to achieve consensus on various components of the draft regulations. The Bureau's recommendations will be finalized and presented to the Fish and Game Council early in 2017 for their review and comment. A legal process must then be followed before any changes can be made to the current *WTS* regulation (the Council proposes changes to the 2018-2019 Fish Code which are published in the New Jersey Register, initiating a sixty-day public comment period, followed by Council adoption). It is anticipated that in 2017 Bureau staff will give presentations to the angling public at various meetings to outline the proposed Wild Trout regulations and solicit their feedback.

Protection and Restoration of Inland Fisheries and Aquatic Habitats: Cold Water

To protect New Jersey's critical aquatic resources, fisheries biologists provide technical assistance to conservation, stream restoration, dam removal, and related Land Use projects each year. Land Use projects are coordinated through the Division's Environmental Review program. This input is directed towards minimizing land use change impacts to the state's fisheries resources. This is typically accomplished through the use of timing restrictions during critical fish spawning periods, protection of riparian buffers, and project modification, assuring best use practices are implemented at all times. However, at times a more in depth review and comments are necessary on specific projects.

Boulder placement during habitat improvement project at Sparta Glen Brook.

In 2016 staff provided technical assistance to the following projects related to our coldwater resources:

Cresskill Brook - This sole *Trout Production* stream in the Hackensack River drainage and tributary to Tenakill Brook had an on-stream cement swimming pool. In 2011, the swimming pool was demolished and the stream was restored through the cooperation of the property owner, the NJDFW, and Trout Unlimited. On 7/18/16 the restored section was backpack electrofished for the first time. One trout, estimated to be 178 – 229mm (7 – 9 in) was observed, but evaded capture (pages A44 - A45). It is conjectured, that perhaps, extremely high flows due to Hurricane Sandy in 2012 was the final blow to this marginal wild Brook Trout population. This *Trout Production* stream will be monitored in this restored section for the next 2-3 years. Additional surveys will be conducted, up and down stream of this site, to determine if the trout population has, indeed been extirpated. (Boriek)

Eastern Brook Trout Joint Venture (EBTJV) - A diverse group of partners, including state fish and wildlife agencies, federal resource agencies, Indian tribes, academic institutions, and non-governmental organizations are working to conserve Brook Trout and their habitats in the eastern United States. Established as the Eastern Brook Trout Joint Venture (EBTJV) in 2005, this Fish Habitat Partnership has produced a range-wide population assessment of wild Brook Trout; identified key threats to wild Brook Trout and their habitats; and developed conservation strategies to protect, enhance and restore wild Brook Trout. In 2015 EBTJV used fish survey data collected over the previous decade (provided by partners) to update the range-wide population assessment to a fine scale (catchment rather than subwatershed level previously used). This assessment data has been used by EBTJV, its partners, and other scientists to identify Brook Trout patches and strongholds, to develop models that predict Brook Trout occurrence and habitats vulnerable to climate change, and to develop decision support tools for riparian and fish habitat restoration that can help guide conservation efforts. Trout Unlimited is finalizing their Brook Trout Conservation Portfolio Analysis, which is

another tool that will aid biologists and resource managers involved in making decisions on allocating resources to benefit Brook Trout conservation. In 2016 BFF staff attended two EBTJV meetings and also proposals submitted to EBTJV for funding were scored using EBTJV scoring criteria. (Federal Grant F-48-R, Project II) (Hamilton and Shramko)

Hakihokake Creek - Hakihokake Creek is classified Trout Production and is stocked annually with catchable-size trout in the spring. In 2011, during Hurricane Irene/Tropical Storm Lee, the flood waters surging down the creek through the town of Milford (Hunterdon County) carved a new stream channel. Local residents have expressed interest in having the channel restored back to its original location and Trout Unlimited is considering assisting them with this effort. In 2016 the new channel reach, and a reach immediately upstream, were electrofished to assess both the fishery and habitat..Wild Brown Trout were present in both sections and were more abundant in the newly created stream channel section. Restoring the stream to its original channel may not be warranted, from a fisheries management perspective, as the new channel section is generally providing good habitat for trout another fish species. However, the badly eroding stream banks in the new channel stretch should be stabilized to reduce sediment inputs, and the stream section upstream would benefit from in-stream habitat enhancement.

Sparta Glen Brook Restoration - Sparta Glen Brook Restoration project aims to restore a section of Sparta Glen Brook that was devastated by a massive landslide from a microburst in August of 2000 that dumped 16 inches of rain in a very short period of time. After a partial rebuild, the site again was severely damaged by Hurricane Irene in 2011. The Fred S. Burroughs North Jersey Chapter of Trout Unlimited has partnered with the Township of Sparta to restore this section of stream back into its natural state. This Spring, in-stream habitat restoration was performed in an attempt to revert the stream back to what it was prior to the two flood / landslide events.

An electrofishing survey was done on July 15, 2016 to determine the status of the fish population and wild Brook Trout population after the restoration efforts. One would not expect to find an increase in the wild Brook Trout population this soon after habitat restoration efforts as there has not been enough time or a complete breeding cycle since the habitat work was completed. Multiple breeding cycles should occur before an assessment of success or failure of the restoration efforts can be determined. This survey was done to determine if wild Brook Trout are still in the area after the work was done, and to

One of two Brook Trout captured in 2015 within the 150 m survey on Sparta Glen Brook

assess the overall fish population post habitat restoration. Two adult/juvenile wild Brook Trout were found in 2016. This is exactly the same number of wild Brook Trout found in 2015 and indicates that the habitat restoration efforts did not have a negative impact on the small wild Brook Trout population found previously. Overall, the survey found 333 individual fish representing 5 different species. The 333 individual fish found is comparable but less than the 443 individual fish collected in 2015. This decrease in overall numbers is somewhat expected following extensive in-stream habitat manipulation, but should continue to be monitored to determine if individual numbers recover to pre-habitat restoration levels. Additional information is compiled in Appendix A (page A19). (Federal Grant F-48-R, Project II) (Shramko)

West Portal Creek: Brook Trout Restoration Project (Hunterdon County) - A catastrophic fish kill occurred on May 5, 2016 in West Portal Creek, a *Trout Production* tributary to the Musconetcong River. As a result of the clean-up associated with a truck fire on I-78, the truck's detergent cargo spilled into the creek killing thousands of fish residing in a three-mile section of the creek. The wild trout population in the creek had been dominated by Brown Trout, a non-native trout species, although some wild Brook Trout also resided in the creek. The Bureau of Freshwater Fisheries determined that the most prudent course of action would be to initiate management actions that would restore native fishes to the creek. Emphasis was placed on restoring wild Brook Trout, the only trout species native to New Jersey that is in decline statewide and soon to be designated state Special Concern, and Slimy Sculpin (a rare fish species soon to be listed state Threatened).

Detergent in West Portal Creek, May 5

Same location, May 6

Representative aquatic organisms killed

Electrofishing surveys conducted periodically in 2016 (May – September) in the section of the creek affected by the pollution event (as well as further upstream) documented a residual, but sparse fish population. The Bureau selectively removed all non-native trout encountered during these surveys (49 Brown Trout, 2 Rainbow Trout, and 1 hybrid Tiger Trout). Wild Brown Trout compete directly with wild Brook Trout for cover, food, and spawning habitat, and can negatively impact the occurrence and abundance of wild Brook Trout. Eliminating (or reducing the number of) Brown Trout from the creek will improve the chance of successful Brook Trout re-colonization. All native species encountered during electrofishing were returned to the creek, including 24 wild Brook Trout (other species returned included Slimy Sculpin, American Eel, Blacknose Dace, Longnose Dace, Creek Chub, White Sucker, and Common Shiner). Fish surveys to assess the recovery of the fishery, document reproduction of trout species, and remove non-native trout will continue in 2017. Additional information concerning the detergent spill is found on page 121. (Federal Grant F-48-R, Project II) (Hamilton)

COOLWATER / WARMWATER FISHERIES

Coolwater Fisheries Assessment

The Coolwater Fisheries Assessment was initiated in 2013 to assess coolwater fisheries that are maintained by annual stockings (Muskellunge, Northern Pike, Walleye, and Hybrid Striped Bass). In 2013 the focus was on developing sampling techniques and protocols for assessing Muskellunge, which are stocked in ten waterbodies statewide. Three of these lakes (Furnace Lake, Mountain Lake, and Carnegie Lake) were selected for sampling in 2013 using trap nets during the spring. In 2014 four waterbodies (Farrington Lake, Pompton Lake, Lake Hopatcong, and Monksville Reservoir) were selected for spring trap netting surveys, and in 2015, a total of seven waterbodies were sampled using a total of 73 trap nets, 9 gill nets, and 5 nights of boat electrofishing to capture the target species of interest from each waterbody. This year, surveys were conducted at 12 waterbodies including, Budd Lake, Canistear Reservoir, Carnegie Lake, Cranberry Lake, Deal Lake, Echo Lake, Greenwood Lake, Little Swartswood Lake, Manasquan Reservoir, Monksville Reservoir, Mountain Lake, and Pompton Lake using a variety of sampling techniques to best capture the species of interest on each waterbody. A full report will be completed this year (Federal Grant F-48-R, Project I) (Collenburg)

Budd Lake (Morris) - Budd Lake is a 376-acre lake in Mount Olive Township that was sampled for Northern Pike using trap nets between March 8 to 11, 2016. A total of 12 trap nets were set and 99 Northern Pike were captured, ranging from 643 - 890 mm (25.3 – 35.0 in) and 1.4 - 4.9 kg (3.1 – 10.7 lbs.), indicating an abundant population. A number of Northern Pike were sent to Hackettstown Hatchery to augment brood stock collection efforts. Eggs and milt were collected from 17 Northern Pike and the fish were later returned to the lake. Crappie and perch populations were abundant and representing many size classes which provides additional recreational opportunities and a strong forage base for higher level predators. (Collenburg)

Budd Lake Northern Pike

Canistear Reservoir (Sussex) - Canistear Reservoir is a 308-acre reservoir and one of five major water supply reservoirs located within Newark-Pequannock Watershed. Sampling targeted Walleye, but Smallmouth Bass were also collected. Sampling for Walleye was done in the Fall of 2015, but in general, catch rates were low across multiple waterbodies and timing played a major role. Therefore, additional sampling was conducted this year via nighttime electrofishing on May 16, 2016. The sampling effort lasted 1 hour with a total of 32 Walleye captured ranging from 447-660 mm (17.6-26.0 in) and the largest weighing 5.6 lbs. Thirty-five Smallmouth Bass larger than stock size (180 mm) were captured ranging from 195-489 mm (7.7-19.3 in) and the largest weighing 3.4 lbs. The CPUE of both Walleye and Smallmouth Bass here indicate that this reservoir is supporting a great fishery for both. See page 67 for additional information on the Smallmouth Bass population. (Collenburg)

Walleye (26 in./5.7 lbs.)
from Canistear Reservoir

Carnegie Lake (Mercer) - Carnegie Lake is a 237-acre impounded section of the Millstone River owned by Princeton University. Primarily used for their crew teams, it is open to the public with a concrete boat ramp, ample parking, and fishing is allowed among other forms of recreation. Trap netting surveys were conducted at Carnegie Lake between April 18 -20, 2016. The target species was Muskellunge which are annually stocked by NJDFW. Unfortunately, the trap netting survey coincided with a significant die-off of mostly Gizzard Shad which are overly abundant in the lake. The die-off was caused by a protozoan that causes ick (a common freshwater fish disease) coupled with sudden temperature increases and the abundant Gizzard Shad population. Gizzard Shad, by the thousands, ended up in the trap nets interfering with the survey. Therefore, trap netting ceased after the second day of sampling. Trap netting was also conducted in 2013, which indicated White Perch and Bluegill were the most abundant species sampled in the trap nets, cumulatively 78.5% of the species composition (unlike 2016, where Gizzard Shad were, by far, the most abundant species sampled). During the 2013 sampling effort, a total of seventeen species of fish were collected during the survey, including one Tiger Muskellunge. The Tiger Muskellunge was 715 mm (28.1 inches) long and 1.85 kg (4.08 lbs.). The catch of the target species was poor with an average of only one Tiger Muskellunge caught in 11 nets. This is far below the Pennsylvania Fish and Boat Commission standard for a quality fishery of one Muskellunge for every 4 nets. Angler reports about Muskellunge fishing at Carnegie Lake are limited and when coupled with recent data indicates that the Muskellunge are struggling in this waterbody. (Collenburg)

Gizzard Shad packed trap nets
in Carnegie Lake

Cranberry Lake (Sussex) - Cranberry Lake is a 179-acre lake in Sussex County. A large portion of the shoreline is developed with private residences, but a public boat launch and an abandoned railroad right-of-way atop the earthen embankment provides access. This spring, the target species was Northern Pike. A total of 15 trap nets were set and two Northern Pike were captured during the four days of sampling between March 1 - 4, 2016. Northern Pike ranged from 661 – 760 mm (26.0 – 30.0 in) in length and weighed 1.7 – 2.6 kg (3.8-5.7 lbs.). This low catch rate indicates a low population abundance. Furthermore, angler reports have not indicated much success when fishing for Northern Pike on Cranberry Lake. However, an abundant population of Chain Pickerel, a native game species, was captured during the survey with 78 individuals ranging from 295 – 592 mm (11.6-23.3 in) and 0.1 – 1.5 kg (0.3-3.4 lbs.). (Collenburg)

Chain Pickerel (23.3 in./3.3 lbs.)
from Cranberry Lake

Deal Lake (Monmouth) - Deal Lake is a 158-acre lake that drains directly to the Atlantic Ocean. Shoreline fishing is limited by private residences in the western end of the lake but some exists in the eastern end and a public boat ramp is available. Sampling this spring focused on the target species of Northern Pike using trap nets between March 16 – 18, 2016. Northern Pike are annually stocked into this lake located in Asbury Park but has not been assessed in over 10 years. Three trap nets were set daily for a total of 9 trap nets. Five Northern Pike were captured, ranging from 560 – 707 mm (22.8 - 27.8 in) and 1.1 – 2.5 kg (2.8 - 5.6 lbs.), indicating low population abundance. Of additional note, 62 Common Carp were captured in the trap nets and removed from the waterbody. Residents around the lake and familiar with the waterbody mentioned the abundance of Common Carp and the town holds an annual fishing tournament specifically targeting them to try to control the overly abundant population. Yellow and Brown Bullhead and Black Crappie were also found in abundance. Many Black Crappie were of impressive size. (Collenburg)

Echo Lake Reservoir (Passaic) - Echo Lake Reservoir is one of five major water supply reservoirs located within Newark-Pequannock Watershed and is also one of two "Trophy Musky" waters in the state where the minimum size limit is 40 inches to encourage the growth of Muskellunge. This waterbody is a popular destination for Musky anglers and access is granted by permit only. The target species for trap netting on April 6 – 8, 2016 was Muskellunge and the catch was good, with 10 Muskellunge captured and a CPUE of 0.6 fish/net. This exceeds the trap netting standard of a quality Muskellunge fishery set by Pennsylvania of one Muskellunge for every four nets set (0.25 fish/net). The Muskellunge were large, which is reflected by a PSD of 100, PSD_p of 90, and PSD_m of 50. They ranged in size from 927 – 1275 mm (36.5 – 50.2 in) and weighed 5.5 – 15.2 kg (12.1 – 33.5 lbs.). The Muskellunge fishery here appears to be abundant and will continue to provide plenty of excellent recreational opportunities. (Collenburg)

Echo Lake Muskie (50.2 in./33.1 lbs.) brought back to Hackettstown State Fish Hatchery for broodstock

Greenwood Lake (Passaic) - Greenwood Lake is a 1,920-acre lake located in New Jersey and New York. Sampling this spring focused on Muskellunge and Walleye. Hackettstown State Fish Hatchery crews set trap nets between April 5 and 16, 2016 to collect Muskellunge for broodstock. This data, along with historical broodstock collection data, was used to assess the Muskellunge and Walleye fishery. Catch of the target species, Muskellunge, was great, with a total of 38 captured with a Catch per Unit Effort (CPUE) of 2.7 fish/net. Although the broodstock collection effort of Muskellunge did not follow the same standard protocol set by Pennsylvania, it greatly exceeded the Pennsylvania trap netting standard for a quality Muskellunge fishery of one Muskellunge for every four nets set (0.25 fish/net), which is an impressive number of Muskellunge regardless. Walleye were also captured during spring broodstock collection at a CPUE of 3.9 fish/net which meets the standard for spring trap netting for Walleye on large reservoirs (>500 acres) set by Pennsylvania of 3.6 fish/net representing a quality fishery. Walleye were also specifically targeted during nighttime electrofishing on April 25, 2016. A total of 18 Walleye ranging from 200 – 678 mm (7.9 – 26.7 in) and 0.06 – 3.09 kg (0.1 – 6.8 lbs.) for a CPUE of 13.7 Walleye/hour. Of the 17 Walleye that were larger than stock size (250 mm), all of them exceeded 15 inches, 41% exceeded 20 inches, and 24% exceeded 25 inches. Walleye seem to be doing well and angler reports and past broodstock collection show indications that their catch rates are increasing. For bass assessment information see page 71. (Collenburg)

Walleye (26.7 in./6.8 lbs.)
from Greenwood Lake

Dual Smallmouth Bass
from Greenwood Lake
(both over 18 inches & 2.6 lbs.)

Little Swartswood Lake (Sussex) - Little Swartswood Lake is an 82-acre natural lake located partially in Swartswood State Park with a free boat ramp and small parking area. At Little Swartswood Lake the target species was Tiger Muskellunge and was sampled using trap nets between March 29 – 31, 2016. A total of nine trap nets were set and no Tiger Muskellunge were captured. The NJDFW annually stocks Tiger Muskellunge here, but catching none is an indication that the population is low in abundance. Anglers indicated to crews, they see Tiger Muskellunge being caught, but not in a great abundance and ice fishing is composed of primarily Chain Pickerel or Yellow Perch. As the coolwater assessment is becoming finalized, further investigation into stocking rates, sizes, and the population structure is necessary to determine the causative factors of the low numbers of Tiger Muskellunge in Little Swartswood Lake. See page 85 for 2016 electrofishing data. (Collenburg)

7.6-lb. Largemouth Bass from
Little Swartswood Lake

Manasquan Reservoir (Monmouth) - Manasquan Reservoir is a 720-acre reservoir located within the Monmouth County Parks system. The waterbody has a large concrete boat ramp, ample parking, as well as a visitor center located adjacent to the ramp. A total of four gill nets were set between October 18 – 19, 2016 to target and assess the Hybrid Striped Bass population. During sampling last year, a total of three Hybrid Striped Bass were captured indicating low population abundance. In casual conversations with anglers, many indicated catching few, if any. The gill nets this year were set in different locations to sample other areas of the lake. A total of nine Hybrid Striped Bass were captured. These numbers are still low and provide additional evidence that is adding to the growing concern of a struggling Hybrid Striped Bass population, providing only marginal recreational opportunities. For bass assessment data see page 73. (Collenburg)

Hybrid Striped Bass from Mansquan Reservoir (2015)

Monksville Reservoir (Passaic) – Monksville Reservoir is a 505-acre reservoir located in Longpond Ironworks State Park in West Milford Township. It has great access with two boat ramps, parking for approximately 100 cars and trailers, and trails around portions of its perimeter. A spring nighttime electrofishing survey was conducted on April 14, 2016 to assess the Walleye that are annually stocked by NJDFW. A total of 1.25 hours of electrofishing was conducted and 23 Walleye were captured ranging from 460 – 667 mm (18.1-26.3 inches) and 0.860 – 3.036 kg (1.9-6.7 lbs.). This is a good catch rate for Walleye indicating a quality fishery. Coupled with trap netting data collected in 2015 where 41 Walleye were captured at a Catch Per Unit Effort (CPUE) of 2.6/net, the Walleye population is doing well. (Collenburg)

Trophy Monksville Reservoir Walleye

46.9 in. and 29 lbs. Muskie from Monksville Reservoir (2015)

Mountain Lake (Warren) - At Mountain Lake the target species was Muskellunge. This 122-acre lake located in Liberty Township was sampled for Muskellunge using trap nets between March 29 – 31, 2016. A total of nine trap nets were set and nine Muskellunge were captured ranging from 264-947 mm (10.4-37.3 inches) and 0.77-6.62 kg (1.7-14.6 lbs.). This catch rate indicates a very abundant Muskellunge population. Despite this being one of the waterbodies regulated as a Trophy Musky Water (having a minimum keeper size of 40 inches), no Muskellunge captured exceeded that size. Electrofishing was also conducted on October 3 to investigate the Largemouth Bass population. During electrofishing for 1.29 hours, seven Muskellunge were encountered, four landed on the boat, and three others effected by the electrical current, but were not netted. This additional sampling further indicates the abundant numbers of Muskellunge. Still, one concern is that the Muskellunge are not surpassing the 40-inch threshold the Trophy Musky regulation is intended to create. The forage base appears fine, however such an abundance of Muskellunge may be limiting growth through intraspecific competition for resources. (Collenburg)

Muskie (37.3 in / 11.6 lbs. from Mountain Lake

Muskie (35.9 in / 14.6 lbs. from Mountain Lake

Pompton Lake (Passaic) - Pompton Lake is a 147-acre lake created in 1776 by impounding a section of the Ramapo River. Shoreline access is relatively limited, but there is a public municipal boat ramp. Sampling this spring focused on the target species of Northern Pike between March 22 – 25, 2016. A total of 12 trap nets were set and 16 Northern Pike were captured ranging from 636 – 890 mm (25.0 – 35.0 in) and 1.4 – 4.9 kg (3.1 – 10.9 lbs.). This catch rate indicates a low to moderately abundant Northern Pike population. There is an abundance of panfish and Yellow Perch representing many age classes which indicates a great forage base supports the fishery. (Collenburg)

General Fisheries Surveys

Northern Pike Electrofishing Surveys on Passaic River

Beginning in the year 2000, the Passaic River has received 2,200 six-inch fingerling Northern Pike, annually. It also receives additional surplus pike, ranging in size from two to four inches. The pike are stocked at more than 25 locations from the Lower Chatham Bridge at the Morris-Essex County line to Pennington Park in Paterson. Locations from Hawthorne to Garfield, above the Dundee Dam on the Bergen County side of the river, are also stocked. In recent years, this fishery has become very popular, with anglers reporting pike weighing up to 20 pounds and measuring in the low 40-inch range. Sampling was conducted in 2016 to quantify the pike's population in the river. The below three sampling sites were chosen for their access (boat ramp) and will be resampled in future years.

Passaic River Northern Pike

Passaic River (Morris) – A boat electrofishing (0.64 hours) survey was conducted on the Passaic River, Florham Park on October 11, 2016. The fish assemblage consisted of 11 species including Northern Pike (4), Black Crappie (15), Yellow Perch (50), Common Carp (35), Common Shiner (100), Largemouth Bass (5), Brown Bullhead (10), American Eel (5), Channel Catfish (1), and White Sucker (35). The length range of the Northern Pike was 558 – 837mm (22.0 – 33.0 in). The weight range of the Northern Pike was 0.96 – 4.19 kg (2.1 – 9.2 lbs.). The relative weights (73, 82, 83 and 102) of the four Northern Pike collected indicate that three were of sub-optimal weight for their length. One was slightly above the optimal weight for its length. It is recommended that annual electrofishing to monitor the fishery be conducted. (Boriek)

Passaic River (Essex) – A boat electrofishing (1.46 hours) survey was conducted on the Passaic River, in the area of Fairfield on October 11, 2016. The fish assemblage consisted of 8 species including Northern Pike (8), Brown Bullhead (5), Common Carp (10), Yellow Perch (35), White Sucker (10), Largemouth Bass (3), Chain Pickerel (1) and Bluegill (17). The length range of the Northern Pike was 370 – 921 mm (14.5 – 36.3 in). The weight range of the Northern Pike was 0.46 – 6.522 kg (1.0 – 14.4 lbs.). The relative weights (69, 69, 72, 77, 84, 91, 100 and 118) of the eight Northern Pike collected indicate that six were of sub-optimal weight for their length. Two were of optimal weight for their length. It is recommended that annual electrofishing be conducted. (Boriek)

Passaic River (Passaic) – A boat electrofishing (0.74 hours) survey was conducted on the Passaic River, in the area of Elmwood Park on October 12, 2016. The fish assemblage consisted of 9 species including Brown Bullhead (20), Common Carp (13), Yellow Perch (5), Smallmouth Bass (4), Black Crappie (2), American Eel (3), Bluegill (6), and White Sucker (7). An Angel Fish, undoubtedly stocked illegally, was observed but evaded capture. No Northern Pike were collected or observed. It is recommended that annual electrofishing be conducted. (Boriek)

Lake Inventories

Successful management of New Jersey's warm and cool water fisheries resource is based upon specific knowledge of their physical, chemical, biological, and use characteristics. Such knowledge may serve to direct immediate management recommendations or be used as a baseline, upon which to recognize future changes, requiring remedial management efforts. Under this activity physical, chemical, and biological data is collected utilizing standard sampling techniques. Physical parameters include morphometry, bathymetry, access, watershed, and aquatic vegetation characteristics. Chemical parameters include general water chemistry and sediment nutrient characteristics. Biological parameters include fish species composition, abundance (catch-per-unit-effort), length frequency distribution, and calculated indices of population structure and dynamics such as proportional stock density (PSD), relative weight (W_r), age, and growth. The data are analyzed and results are used to develop management recommendations and prepare an individualized fisheries management plan for the waterbody. These plans are summarized and published for dissemination to the angling public. (Federal Grant F-48-R, Project I) (Smith)

Lake Inventory: Round Valley Reservoir

In 2016 a lake inventory was conducted on Round Valley Reservoir. Sampling and management recommendations focused on the warmwater fish population. Construction of Round Valley Reservoir began in 1965 and water levels reached 97.3% capacity by 1973. The reservoir was opened to public shoreline fishing in 1968 and to boat anglers in 1969. The reservoir is formed by earthen dams and water is pumped in from the South Branch Raritan River. The reservoir is rather unique for New Jersey supporting both coldwater and warmwater fish populations. The reservoir has been stocked with Rainbow and Brown Trout since its creation and supports an abundant reproducing Lake Trout populations. (Smith and Crouse)

Round Valley Reservoir is one of the most popular fishing locations in Northern New Jersey, due in part to its size and the ability to utilize gasoline powered outboard motors. Boaters are restricted to outboards less than 10 hp. There are two public boats ramps, both are maintained by the Division of Fish and Wildlife. One is double wide concrete ramp and paved parking areas the other a gravel ramp with an unpaved parking area.

Photo by John Young

Round Valley Reservoir's Lake Trout population has been intensively managed and monitored since the program's inception in the 1970's. Trout angling and stocking remain the most popular at the reservoir, though a rather substantial warmwater fish population exists.

Materials and Methods

Water quality parameters were measured in the lake at various locations, including dissolved oxygen, conductivity, pH, and temperature. A total of four electrofishing surveys were completed. Night surveys were conducted in the spring (May 23 and June 8) and in the fall (October 13). One daytime survey was completed on November 7. Length and weight measurements were taken on all game and panfish species collected and proportional stock densities (PSD), relative stock densities (RSD), and relative weights (W_r) were calculated. Scales were removed from a sub-sample, mounted, and aged. Back-calculation was used to obtain information on the growth history of year classes. A total of 80 locations were sampled by shoreline seining on November 6. The annual Lake Trout population assessment was also conducted (page 32).

Largemouth Bass (8.85 lbs.) caught in Round Valley Reservoir in 2016 via electrofishing

Fisheries Results

Round Valley has rich species diversity with twenty-three species collected during the 2016 sampling at this lake. Complete results of the inventory can be found in Appendix G (Round Valley Reservoir Fisheries Management Plan). The following management objectives and recommendations were drafted.

Management Objectives

1. Continue to manage Round Valley Reservoir's the two-story fishery.
2. Improve the size structure and growth of Lake Trout and Rainbow Trout.
3. Improve the size structure and growth of both Largemouth and Smallmouth Bass.
4. Improve the forage base for all sportfish and reduce biological demand on all prey species, including Bluegill.The management objectives for Round Valley Reservoir have been established to provide the best recreational fishing opportunities for anglers. Management objectives are most often achieved through regulatory changes, stocking, and habitat manipulation.

Recommendations

1. Maintain current Lake Trout regulations to reduce the density of 15 to 24-inch Lake Trout to increase growth and reduce predation pressure on prey species.
2. Continue to monitor Lake Trout population, on a biennial basis (as opposed to the existing annual monitoring schedule) and evaluate current regulations and potential regulation changes.
3. Maintain Trophy Trout regulations for Rainbow and Brown Trout (minimum size of 15 inches / daily limit of 2 combined species).
4. Continue to stock approximately 6,500 trout in 2017, with consideration to adjust stocking rates in response to changing factors such as food availability, documented trout growth, lowered pool elevation, etc.
5. Additional sampling should be conducted during the spring of 2017 to further evaluate the Largemouth Bass Population. Subsequent sampling should be conducted in three to five years.
6. Continue to stock Golden Shiners in the short-term, until a determination is made as to whether it has resulted in the establishment of a reproducing population, otherwise stocking by NJDFW should be discontinued.
7. Consider potential fish habitat projects to benefit warmwater fish assemblage including, but not limited to bass, sunfish, and shiners.

Warmwater Fisheries Assessments via Electrofishing

New Jersey has over 400 impoundments open to the general public for fishing and thousands more in private ownership scattered throughout the state. These lentic environments offer excellent fishing opportunities for a variety of species such as bass, sunfish, crappie, and pickerel. These species naturally reproduce in the waterways and often do not require active stocking to sustain their populations. The Bureau of Freshwater Fisheries conducts abbreviated fisheries surveys on lakes and ponds throughout the state to assess the status of popular game species, compared to full inventories on others. Electrofishing surveys are conducted at various waterbodies throughout the state to assess the current status of the bass populations. Lakes are assessed based on the catch per unit effort (CPUE) for stock size fish (Largemouth Bass ≥ 8 in.) as determined from the electrofishing survey. CPUE is a measure of the number of fish caught per hour. Fish populations are further evaluated utilizing stock density indices that provide a numerical descriptor of length-frequency data. These indices include PSD, PSD-P, and PSD-M (formerly PSD, RSD_p, and RSD_m). Calculations for each parameter are made to determine a proportional size distribution of certain size fish that is within the stock size. The PSD-P is simply the percentage of fish sampled greater than the "preferred" size (Largemouth Bass ≥ 15 in.). Standard lengths are used for each species. The PSD-M is the percentage of fish sampled greater than the "memorable" size (Largemouth Bass ≥ 20 in.). Sampling results are used to determine if supplemental stockings or adjustments to current regulations are necessary.

Surveys were completed at 32 locations in 2016. Assunpink Lake had the highest CPUE for Largemouth Bass at 111 bass/hour during daytime electrofishing. The two largest bass encountered electrofishing, not including those from the Round Valley Reservoir Inventory, were from Parvin Lake on October 24, weighing 7.35 and 7.40 lbs. (Hunter & Angler Fund)

Assunpink Lake (Monmouth) – Assunpink Lake is a 225-acre impoundment located within the Assunpink Wildlife Management Area, Upper Freehold Township. The lake is one of the five waterbodies managed as a *Lunker Bass Lake* and one of the most utilized Wildlife Management Areas in the state. Two daytime electrofishing surveys were completed in 2016. The first survey was completed on March 23, 2016 to assist pathologist Dr. Jan Lovy with the collection of Bluegill for testing as a follow-up to the spring 2015 fill kill. Assunpink Lake has annual fish kills during the spring, occurring after ice out when temperatures begin to rise. Kills of varying species have been attributed to both bacteria and parasites. The electrofishing survey revealed that Yellow Perch were more abundant than during previous sampling. Largemouth Bass were observed in good number (n=24) and in good condition. Not all Largemouth Bass were collected, hence a CPUE was not calculated. A daytime boat electrofishing survey was conducted on October 21, 2016 to assess the Largemouth Bass population. Sampling occurred around the perimeter of the lake concentrating on the dam, island, and aquatic vegetation edges. A total of 139 Largemouth Bass were collected, in 1.0 hours of electrofishing, of which 115 were >200 mm (8 in) stock size. The CPUE was 115 bass/hour. A PSD of 36 and a PSD-P of 12 were calculated for Largemouth Bass, indicating a slightly unbalanced population. In comparison a daytime electrofishing survey was completed in July of 2015 resulting in a total of 47 Largemouth Bass collected. The CPUE was 33 bass/hour for stock sized bass. A PSD of 47 and PSD-P of 23 indicated a balanced population. The Largemouth Bass population should continue to be monitored regularly to determine the effects of fishing pressure and changes in habitat. An electrofishing survey is planned for spring 2017 to determine possible effects of ice fishing. The primary management objective should be to maintain and improve the Largemouth Bass population. No additional stocking of Largemouth Bass is recommended at this time. Stocking of Channel Catfish should be evaluated to determine possible negative effects on the bass population. (Smith)

Burnt Mill Pond (Cumberland) - A boat electrofishing survey was completed at Burnt Mill Pond to evaluate the fish population on July 12, 2016. Burnt Mill Pond, also known at Arbor Lake is approximately 20-acres and owned by the City of Vineland. A dam replacement was completed in the spring of 2016 and the lake was refilled. The City of Vineland created an improved boat launching area during the reconstruction of the dam, however parking is extremely limited. The lake was significantly lowered following a dam failure (approximately five years ago), allowing the growth of willow trees and cattails throughout the lake. Narrow channels through the willow trees provide good habitat for fish recently stocked by NJDFW. There were no adult Largemouth Bass collected or observed during the 30-minute survey. Young-of-the-year (YOY) Chain Pickerel, a species not stocked by NJDFW, were observed to be rather abundant, but not collected. Additional species collected include Pumpkinseed, Creek Chubsucker, Golden Shiner, and Pirate Perch. Brown Bullhead, Bluegill, and Largemouth Bass YOY were recently stocked. No additional sampling or stocking is planned at this time. (Smith)

Canistear Reservoir (Sussex) - Canistear Reservoir is a 308-acre reservoir and one of five major water supply reservoirs located within Newark-Pequannock Watershed. In 2015, sampling for Walleye was done, but in general, catch rates were low across multiple waterbodies and it was presumed that timing played a major role in the low catch rates. In 2016, sampling focused on targeting Walleye, but Smallmouth Bass were also collected. The nighttime boat electrofishing survey on May 16, 2016 lasted 1 hour and a total of 32 Walleye were captured ranging from 447-660 mm (17.6-26.0 in) and the largest weighed 2.5 kg (5.6 lbs.). Thirty-five Smallmouth Bass larger than stock size (180 mm) were captured ranging from 195-489 mm (7.7-19.3 in) and the largest weighed 1.5 kg (3.4 lbs.). The CPUE of both Walleye and Smallmouth Bass indicate that this reservoir is supporting a great fishery for both. See page 57 for more information. (Collenburg)

Cedar Lake (Cumberland) – Cedar Lake is a 57-acre impoundment of Cedar Creek located in the town of Cedarville. Two surveys were completed in 2016 to assess the fish population. A seining survey was completed during the summer to evaluate the native fish population and a daytime boat electrofishing survey was completed on October 28, 2016 to evaluate the Largemouth Bass population. A major dam reconstruction project is planned in the near future. The bass population has not been evaluated in recent years by NJDFW despite reports of good bass fishing. A total of 18 Largemouth Bass were collected in 1.0 hours of electrofishing, of which 15 were >200 mm (8 in) stock size. The CPUE was 15 bass/hour for stock size bass. The CPUE was rather low and most likely attributed to weather conditions. A PSD of 93 and a PSD-P of 67 were calculated for Largemouth Bass indicating an unbalanced population. Despite being unbalanced, the current bass population should provide good fishing opportunities. Other species encountered include Creek Chubsucker, Black Crappie, Golden Shiner, Chain Pickerel, American Eel, Bluegill, Brown Bullhead, Gizzard Shad, Yellow Perch, and Common Carp. The dam reconstruction project should be completed utilizing a coffer dam to protect the existing fish population. A seining and electrofishing survey should be completed after the dam reconstruction project is completed. No stocking is recommended at this time. Seining was also conducted in 2016 (page 80). (Smith)

Columbia Lake (Warren) - Columbia Lake (48 acres) was electrofished on July 22, 2016 to determine the status of the fish population. The sampling was done as part of the Paulins Kill Restoration Project (page 99). This pre-dam removal assessment of the fish population found 95 individual fish, comprised of 12 different species. The lake temperature was 24.2ºC. Fish species found included Largemouth Bass (17), Smallmouth Bass (5), Bluegill (7), Pumpkinseed Sunfish (10), Redbreast Sunfish (3), Black Crappie (1), Chain Pickerel (5), Yellow Bullhead (1), Yellow Perch (21), White Sucker (18), and Common Carp (6). Not surprisingly, no American Shad, no Blueback Herring and no American Eels less than 200mm were found in Columbia Lake. A boat electrofishing survey was conducted last year as well and also found no American Shad, no Blueback Herring, and only 3 American Eels of which all were larger than 200 mm. The result from these two surveys, and the seven other surveys conducted upstream of the Columbia Lake Dam since 2015, continues to document that the Columbia Lake Dam is an impediment to fish movement. A dissolved oxygen / temperature survey was also completed on July 27, 2016 at two different locations. One survey was done near the deepest part of the lake near the dam and the other survey was performed at a location where a large spring enters the lake. Both surveys showed no holdover capacity for cold water species such as trout. The survey done near the dam showed oxygen levels high enough to support trout, but lacked the cold temperatures that trout need. The spring area had low enough water temperatures to support trout, but lacked adequate dissolved oxygen levels for trout. Profile data can be found on page 134. (Shramko)

Cresse Lane Ponds (Cape May) – Cresse Lane Ponds are located in Lower Township. A day time boat electrofishing survey was conducted on August 17, 2016 to evaluate the warmwater fishery. High conductivity prevented the use of electrofishing as a sampling method. Young-of-the-year (YOY) Largemouth Bass and Bluegill were collected using seines indicating successful reproduction of both species. Mosquitofish were also present. Water chemistry was recorded; pH measured 7.99, conductivity 1223 us/cm, and salinity was 0.53 ppt. This location has not been previously sampled by the NJDFW. Sampling during a wet time of year should decrease the salinity level within the pond and make electrofishing a more effective sampling method. Additional assessment of the warmwater fishery is recommended. (Boehm)

Davis Millpond (Cumberland) – Davis Millpond is a 40-acre impoundment located within the Stowe Creek Drainage, Greenwich Township. A daytime boat electrofishing survey was conducted on October 28, 2016 to assess the Largemouth Bass population. Sampling occurred around the perimeter of the lake. A total of 38 Largemouth Bass were collected, of which 36 were greater than the 200 mm (8 in) stock size. The CPUE was 36 bass/hour, based on one hour of electrofishing. A PSD of 69, RSD-P of 44 and PSD-M of 14 were calculated for Largemouth Bass indicating an unbalanced population that should provide excellent fishing opportunities. Noteworthy was the PSD-M of 14, indicating individuals greater than the memorable size of 510 mm (20 in). Five individuals fit this category and weighed 2.798 kg (6.17 lbs.), 2.782 kg (6.13 lbs.), 2.610 kg (5.75 lbs.), 2.6 kg (5.73 lbs.) and 2.516 kg (5.55 lbs.). The population appears to be making a strong rebound after impacted by suspected Largemouth Bass Virus. Previous electrofishing surveys were completed in 2011, 2012 and 2015. Stocking of young-of-the-year (YOY) Largemouth Bass was completed in 2013, 2014, and 2015. Davis Millpond has an excellent forage base comprised of Gizzard Shad and Bluegill. The bass population will be resampled over the next few years to monitor condition and any signs of Largemouth Bass Virus. No additional stocking is necessary at this time. (Smith)

Delaware Lake (Warren) – This 36-acre lake is located within the Paulins Kill WMA near the town of Columbia, and has been regulated as a *Lunker Bass Lake* since 2000. The lake is regularly stocked with Channel Catfish and was also stocked with Largemouth Bass in 2012. A boat ramp and dock are present and anglers have good shoreline access along the long, earthen spillway. The lake was previously electrofished on October 8, 2015 to assess the Largemouth Bass fishery. Because the PSD and RSD values were below the accepted ranges for a "big bass" (i.e. "lunker bass") lake it was recommended that the lake be resurveyed in 2016 and scale samples be taken to obtain age and growth data. On October 15, 2016 nearly the entire perimeter of the lake was electrofished at night. The results from this survey are summarized below and compared to the 2015 survey. A total of 108 Largemouth Bass were collected in 1.0 hours of electrofishing and of these, 92 were stock size (20 cm (8-in) or greater). In 2015, 83 bass were collected, 72 were stock size or greater. The CPUE for bass (stock size or greater) was 92 bass/hr, significantly higher than in 2015 (38 fish/hr). The largest bass captured in 2016 was 44 cm (17.5 in) and weighed 1.8 kg (3 lbs). In 2015 the largest bass captured was 491 mm (19.3 in) and weighed 2.13 kg (4.7 lbs). Considering *Lunker Bass* regulations are in effect it is surprising that larger bass were not collected in either survey. It should be noted that conductivity of the lake water is exceedingly high (specific conductance 664 uS/cm in 2016 and 597 uS/cm in 2016) and during both electrofishing surveys it was noted that bigger fish sensed the approaching electric field and avoided capture. In 2016 the water clarity was very poor due to an algal bloom and wide expanse of floating duckweed. The PSD (Proportional Size Distribution) for bass was 41 in 2016 (the same as in 2015). PSD is a numerical index used to characterize the length-frequency data and provide insight about population dynamics. Although bass PSD values for both years indicate a balanced bass population, these values barely fall within the range that indicates a balanced bass population (40–70 is the accepted range). The PSD-P for bass (Preferred $\geq$ 38 cm (15 in)) was 5 in 2016 and 6 in 2015. The PSD-M for bass (Memorable $\geq$ 51 cm (20 in)) was 0 in both 2016 and 2015. These values, as well as the PSD values for both years, are well below the accepted ranges for a "big bass" (i.e., *Lunker Bass*) lake (PSD 50–80; RSD–P 30-60; and RSD–M 10-25). More than half (60%) of the stock size bass caught in 2016 (55 fish) measured 20 – 30 cm (8 – 11.9 in). Similar results were obtained in 2015 (42 fish, 58%). This suggests smaller bass are stockpiling. Large sunfish (primarily Bluegill, and some Pumpkinseed) were noticeably prevalent during the 2015 and 2016 surveys. Other species captured (or seen but not captured) during the 2016 electrofishing survey included Black Crappie, Brown Bullhead, Channel Catfish, White Sucker, Creek Chubsucker, American Eel, Golden Shiner, and Common Carp. The results of the 2016 survey are remarkably similar to the 2015 results. The age and growth of bass collected during fall electrofishing will be determined from their scales, and relative weight (a measure of fish condition) will also be calculated for bass collected both years. Daytime electrofishing in the spring is recommended to better sample larger bass. The data collected must be further analyzed before fisheries management recommendations can be made for this waterbody. Seining data from 2016 can be found on page 83 and dissolved oxygen and temperature profile information can be found on page 134. (Hamilton)

Delaware River (Mercer) – Two boat electrofishing surveys were completed during the summer of 2016 to monitor the invasive Northern Snakehead and Flathead Catfish populations. In addition, Largemouth Bass were collected when encountered. Past electrofishing surveys have been rather unsuccessful at capturing snakeheads in the Delaware River. Electrofishing has proved most successful in backwater areas and tributary creeks where snakeheads appear to be more concentrated. A boat electrofishing survey was completed on August 24, 2016 to evaluate the Northern Snakehead and Largemouth Bass populations in the vicinity of Trenton. A total of 19 Largemouth Bass were collected with eight individuals greater than 200 mm (8 in) collected. There were no snakeheads collected or observed during the survey, however one Flathead Catfish measuring 410 mm (16.1 in) was collected. An electrofishing survey completed in 2014 also produced two Flathead Catfish just downstream around Bordentown. This section of the river should continue to be monitored for the presence of Flathead Catfish. (Smith)

Delaware River (Camden) - A boat electrofishing survey was completed on August 29, 2016 to evaluate the Northern Snakehead and Largemouth Bass populations in the vicinity of Pennsauken. A total of 13 species were observed during the survey however were no snakeheads and only three Largemouth Bass were collected. Boat electrofishing during high tide appears to be rather ineffective on the Delaware River. Future sampling should be conducted during the lower stages of the tide cycle. This site should be included in future sampling efforts to evaluate both Northern Snakeheads and Largemouth Bass as habitat appears to be favorable for both species. (Smith)

DOD Lake (Salem) – The DOD Lake WMA is a 120-acre borrow pit located in Penn Grove. A lake inventory and management plan was completed in 2002. The Largemouth Bass population has fluctuated since acquired by NJDFW in 1999. Boat electrofishing surveys to monitor the Largemouth Bass population were completed in 2010, 2011, 2014, 2015, and 2016. DOD Lake has been stocked with Musky, Tiger Musky, Smallmouth Bass, Channel Catfish, White Crappie, Largemouth Bass and Striped Bass at various times over the years. DOD Lake has received surplus stockings of Smallmouth Bass, Channel Catfish, Tiger Musky, and Musky since 2013. These stockings are not part of the annual stocking schedule. None of these species were encountered during sampling in 2016. The stocking of these species should continue in order increase diversity of the fish population and provide additional fishing opportunities. A boat electrofishing survey was completed on June 28, 2016 to evaluate the Largemouth Bass and Northern Snakehead population. A total of 45 Largemouth Bass were collected in 1.5 hours of daytime electrofishing. There were 35 bass greater than the 200 mm (8 in.) stock size indicating a CPUE of 23 bass/hour. The PSD was 89 and PSD-P was 11 indicating the population is slightly unbalanced. Northern Snakeheads were first reported in 2014 and the presence confirmed by NJDFW in 2015. Eight Northern Snakeheads were collected in 2016, measuring 225 - 530 mm (8.9 – 20.9 in). In comparison two Northern Snakeheads were collected in 2015. The snakehead population appears to be growing and will continue to be monitored to determine the impact on the Largemouth Bass population. (Smith)

Game Creek (Salem) – Game Creek is a small tributary of the Salem Canal, located in Penns Grove. A lake inventory and management plan was completed on the Salem Canal in 1999. Electrofishing surveys to monitor the Largemouth Bass were completed at either Salem Canal or Game Creek in 2007, 2010, 2012, 2013, 2014, 2015, and 2016. Salem Canal is one the most popular bass fishing locations in southern New Jersey. In 2016 a boat electrofishing survey was completed on July 22, 2016 to evaluate the Largemouth Bass and Northern Snakehead population. Previous reports by anglers suggested that Northern Snakehead may be present in the Salem Canal and Game Creek. Two adult snakeheads were captured and removed from Game Creek. A total of 38 Largemouth Bass were collected of which 35 were greater than 200 mm (8 in.) stock size. The CPUE was 35 bass/hour as determined from one hour of electrofishing. The Largemouth Bass and Northern Snakehead populations will continue to be monitored. No additional stocking is necessary at this time. (Smith)

Green Turtle Pond (Passaic) – This is a 43-acre lake located inside Long Pond Iron Works State Park. A gravel boat ramp and adequate parking are available and previous surveys indicated a good Largemouth Bass and Yellow Perch fishery despite anoxic conditions below 10-foot depth. A survey was conducted here last year and the results indicated that the population is out of balance and dominated by smaller sized individuals. Therefore, the recommendation was made to follow up in the Fall of this year to gather more data to determine a management strategy. On September 26, 2016 a nighttime boat electrofishing survey at Green Turtle Pond was conducted to evaluate the Largemouth Bass population. This year's survey lasted 0.99 hours and a total of 83 Largemouth Bass were captured ranging from 91 – 452 mm (3.6 – 17.8 in) in length and had a PSD of 26. Of the 83 individuals captured, 53 were larger than 200 mm (CPUE of 53 bass/hour). A sample of twenty Largemouth Bass were aged using scales and 15 out of 20 were age 3 or less (11 at age 3). The concern after electrofishing this waterbody last year was that the population was dominated by smaller sized Largemouth Bass with a PSD of 12. The PSD is still indicating a population dominated by smaller individuals with a PSD of 26 but recruitment, the abundant number of bass, and the available forage base are good signs that this fishery will continue to develop larger bass in the future. Sampling should continue here in the near future to monitor the fishery. See page 83 for 2016 seining information. (Collenburg)

Greenwood Lake (Passaic) – The 1,920-acre Greenwood Lake was sampled for Walleye and bass via nighttime electrofishing on April 25, 2016. The sampling effort lasted 1.25 hours and a total of 18 Walleye ranging from 200 – 678 mm (7.9 – 26.7 in) and 0.06 – 3.09 kg (0.1 – 6.8 lbs.) for a CPUE of 13.7 Walleye/hour. Of the 17 Walleye that were larger than stock size (250 mm), all of them exceeded 15 inches, 41% exceeded 20 inches and 24% exceeded 25 inches. Walleye seem to be doing well and angler reports and past broodstock collection show indications that their catch rates are increasing. Additionally, thirty-seven Largemouth Bass were captured ranging from 208 – 465 mm (8.2-18.3 in) and the largest weighing 1.7 kg (3.8 lbs.). This is a good sign for the Largemouth Bass fishery at Greenwood Lake after it was hit with Largemouth Bass Virus in 2007. Supplemental stocking of Largemouth Bass was done in the last three years and may have assisted to boost the numbers of a population that had declined. The sampling effort indicates both a Walleye and Largemouth Bass fishery that is well balanced. Other noteworthy catches were many sizable Black Crappie, six Smallmouth Bass, and one Muskellunge exceeding 40 inches that was not netted. This effort consisted of the southern end of Greenwood Lake but additional sampling may be done next year to collect more data on the bass fishery. For Coolwater Assessment data see page 60. (Collenburg)

Jersey City Reservoir # 3 (Hudson) - A former water supply reservoir, it has been preserved as a natural space and is open to public fishing. Robert O'Donnell, Jr., Science Educator at Christa McAuliffe School (P.S. #28), Jersey City has involved the reservoir in a number of school projects. Recently, receiving The NJ Governor's Environmental Excellence Award (GEEA) for his program, Project Reservoir (http://projectreservoir.wixsite.com/2014).

In 2014, the Hackettstown State Fish Hatchery stocked the reservoir with Largemouth Bass, Brown Bullhead, and Channel Catfish. A boat electrofishing (0.55 hours) survey was conducted on the six-acre reservoir on November 1, 2016. This was the first time that this reservoir was electrofished by NJDFW. The fish assemblage consisted of 5 species including Largemouth Bass (62), Black Crappie (4), Bluegill (24), Common Carp (1), and Channel Catfish (1). Young-of-the-year (YOY) Largemouth Bass were abundant. Largemouth Bass ranged in size from: 63 - 420 mm (2.5 – 16.5 in), and their weights were to 2.0 lbs. The 62 Largemouth Bass were collected in 0.55 hours of electrofishing, of which 55 were greater than the 200 mm stock size, resulting in a CPUE of 100 bass/hour. The PSD was 96 and RSD-P was 13, indicating an unbalanced population of bass with the majority in the 325 – 374mm (12.8 – 14.7 in). These fish are, undoubtedly, from the previous stocking mentioned above. Jersey City has a "*Catch & Release*" policy at the reservoir. It is recommended that limited harvest of the Largemouth Bass be allowed to establish a more balanced population. No further sampling is recommended at this time. (Boriek)

Lake Audrey (Cumberland) – Lake Audrey is a 120-acre borrow pit acquired by NJDFW in 2004. When acquired the lake was unable to support fish, due to extremely low pH levels. NJDFW initiated a project to enhance the water quality by adding lime to the lake in 2006. The project was funded by a grant through the Cumberland County Utilities Authority and labor was provided by members of the South Jersey Bass Club Association and NJ Federation of Sportsmen Clubs. A total of 136 tons of lime was added to Lake Audrey to neutralize the pH. Artificial habitat structures, formed from wooden pallets and evergreen trees were deployed to provide much needed fish habitat. In 2007 the lake was stocked with Smallmouth Bass, Yellow Perch, Bluegill, Pumpkinseed, and Golden Shiner. A boat electrofishing survey was completed at Lake Audrey on June 30, 2016 to evaluate the Largemouth Bass and Smallmouth Bass populations. The Largemouth and Smallmouth Bass populations have steadily declined since 2012 and is directly attributed to declining pH levels. The pH level in 2016 was 4.44 and generally too low for bass and sunfish to successfully spawn. A total of four Largemouth Bass were collected during one hour of daytime electrofishing. There were no Smallmouth Bass collected or observed. The Cumberland County Federation of Sportsman has recently inquired regarding the status of Lake Audrey and future management by NJDFW. Future management activities should concentrate on the Largemouth Bass population. Should funds become available, a supplemental lime application to raise the pH is recommended. The current *Catch and Release* regulation on bass is unnecessary and should be removed during the next Fish Code cycle. No additional stocking is recommended for Lake Audrey unless the pH is increased. (Smith)

Manasquan Reservoir (Monmouth) – Manasquan Reservoir is a 720-acre water supply reservoir in Howell, maintained by the Monmouth County Park System. It is one of the state's most popular bass fishing locations. A daytime boat electrofishing survey was conducted on November 2, 2016 to assess the Largemouth and Smallmouth Bass populations. The reservoir was about six feet below normal pool, which assisted in navigating the standing timber around the perimeter. A total of 50 Largemouth Bass were collected, of which 48 were greater than 200 mm (8 in) stock size. The CPUE was 24 bass/hour, based on two hours of electrofishing. A PSD of 88, PSD-P of 54 and PSD-M of 6 were calculated for Largemouth Bass indicating a slightly unbalanced population that should provide exceptional fishing opportunities. Noteworthy was the PSD-M of 6, indicating those individuals greater than memorable size of 510 mm (20 in). Three individuals fit this category and weighed 2.630 kg (5.80 lbs.), 2.470 kg (5.45 lbs.) and 2.384 kg (5.26 lbs.). Yellow Perch and Alewife were observed to be rather abundant indicating ample forage. A total of nine Smallmouth Bass were collected. All individuals were greater than the stock size 180 mm (7 in). The largest collected measured 469 mm (18.46 in) and weighed 1.92 kg (4.23 lbs.). Supplemental young-of-the-year Smallmouth Bass should be stocked whenever available. The lake should continue to be monitored on a regular basis. For Coolwater Assessment data see page 61. (Smith)

Menantico Sand Ponds (Cumberland) – Menantico Sand Ponds WMA is a 62-acre complex of interconnected borrow pits directly attached to the tidal Maurice River. An inventory and management plans was prepared in 1997, which identified a robust Largemouth Bass population with a CPUE of 53 bass/hour for all bass. CPUE is now calculated for only those individuals greater than the 200 mm (8 in) stock size. An electrofishing survey completed in August 10, 2016 indicated a rather marginal Largemouth Bass population (n=10) ranging from 164-452 mm (6.46-17.80 in). A total of nine bass greater than the 200 mm (8 in) stock size were collected in 1.48 hours of electrofishing, indicating a CPUE of 6 bass/hour. An additional boat electrofishing survey was completed on July 11,2016 to evaluate the Largemouth Bass population. A total of 26 Largemouth Bass were collected, 23 of which were greater than the 200 mm (8 in) stock size. A CPUE of 23 bass/hour was calculated based on one hour of electrofishing. The largest bass collected was 485 mm (19.09 in) and 1.79 kg (3.95 lbs.). A total of 15 species of fish were collected electrofishing. Adult American Eels were observed to be rather abundant. A seining survey was completed on August 22, 2016 to evaluate the native fish population. Habitat within the sand ponds has significantly changed since the lake inventory was completed in 1997 and subsequently altered the fish population, as reflected during the seining survey. For 2016 seining information see page 86. (Smith)

Mercer Lake (Mercer) – Mercer Lake is a 275-acre impoundment of Assunpink Creek located within Mercer County Park. A daytime boat electrofishing survey was conducted on October 18, 2016 to assess the Largemouth Bass population. Sampling occurred around the perimeter of the lake. A total of 63 Largemouth Bass were collected, of which 61 were greater than the 200 mm (8 in) stock size. The CPUE was 40 bass/hour based on 1.5 hours of electrofishing. A PSD of 45, PSD-P of 19 and PSD-M of 4 were calculated for Largemouth Bass indicating a balanced population. Three memorable size bass (RSD-M) were collected and weighed 2.412 kg (5.32 lbs.), 2.28 kg (5.03 lbs.) and 2.254 kg (4.97 lbs.). A Bigmouth Buffalo, a species not native to New Jersey was also collected. Recently stocked Tiger

Musky were observed but not collected along with Bluegill, Pumpkinseed, Redbreast Sunfish, White Perch, Yellow Perch, Chain Pickerel, Golden Shiner, Common Carp, Brown Bullhead, American Eel, and Gizzard Shad. In comparison a daytime electrofishing survey was also completed in July 15, 2016, at which time the CPUE was 16 bass/hour for bass greater than the 200 mm (8 in) stock size. Thirty-two bass under the stock size were also collected in 2015. The PSD of 65 and PSD-P of 38 in 2015 indicated a balanced population. Electrofishing surveys from 2015 and 2016 suggest that the population has made a good recovery from Largemouth Bass Virus. Supplemental young-of-the-year Largemouth Bass were stocked in 2015 to enhance the recovery of the Largemouth Bass population. No additional stocking or sampling is necessary at this time. An electrofishing survey should be completed in spring 2018. (Smith)

Mountain Lake (Warren) - This 122-acre public lake has a public boat launch, but limited shoreline access due to numerous lakefront homes. The 2016 electrofishing survey was prompted by concern about the low number of centrarchid fish species (bass and sunfish) captured during sampling conducted earlier in the spring with trap nets to assess the Muskellunge fishery. The lake is stocked annually with Muskellunge (*Trophy Musky* fishing regulations apply; 40-inch minimum size, instead of 36-in). Catchable-sized trout are also stocked in the spring (one stocking prior to Opening Day of the trout season in April). Largemouth Bass have also been stocked, most recently in 2013. Nearly the entire perimeter of the lake was electrofished at night on 10/3/16 and a total of 85 Largemouth Bass were captured in 1.3 hours of electrofishing. Of these bass, 62 were stock size (20 cm (8-in) or greater). The CPUE for bass (stock size and greater) was 48 bass/hr. The largest bass captured was 46 cm (18.1 in) and weighed 1.8 kg (4.1 lbs). The PSD (Proportional Size Distribution) for bass was 48. PSD is a numerical index used to characterize the length-frequency data and provide insight about population dynamics (40–70 is the accepted range for a balanced Largemouth Bass population). The PSD-P for bass was 16 (Preferred $\geq$38 cm (15 in); 10–40 is the accepted range for a balanced Largemouth Bass population). Other fish species captured during the survey were Muskellunge, Chain Pickerel, Black Crappie, American Eel, Alewife, Bluespotted Sunfish, and Common Carp. The sunfish (Bluegill and Pumpkinseed) appeared to be fairly abundant, but small. The number of Muskellunge encountered (7) was considered high compared to surveys conducted by staff on other lakes that are stocked with this species. The large size of the four Black Crappies captured (34 cm (13.6 in) and 0.7 kg (1.5 lbs)) was notable. Bluespotted Sunfish is one of New Jersey's less common native sunfish species and its continued presence in this lake (first documented in 1950) is noteworthy. Interestingly, Yellow Perch were not encountered during the survey. This species, a preferred prey of Muskellunge, was last documented in the lake during trap netting conducted in 2001 by the Hackettstown State Fish Hatchery. The age and growth of bass collected during fall electrofishing will be determined from their scales, and relative weight (a measure of fish condition) will also be calculated for bass collected in 2016. In addition to the 2016 fall electrofishing survey, additional data was collected in the spring (trap nets used) to assess the Muskellunge fishery (page 63) and in the summer (shoreline seining) to assess warmwater fish reproduction (page 88). A temperature/dissolved oxygen profile conducted on at the deepest part of the lake (40 feet) indicated a one-foot layer of trout supporting water was present 16-17 feet below the surface (page 134). Fisheries management recommendations will be prepared following a collective analysis and review of all data from these recently conducted surveys. (Hamilton)

Newton Lake (Camden) – Newton Lake is a 40-acre impoundment of Newton Creek bordered by Collingswood, Oaklyn and Haddon Townships. Much of the lake is maintained by the Camden County Parks System. Newton Lake has a small paved boat ramp, ample trailer parking, and good shoreline access for anglers. The lake is family friendly with a playground and temporary restrooms nearby. A fish ladder to increase spawning habitat for Alewife and Blueback Herring was installed in the early 2000's and subsequently deemed a pathway for the invasive Northern Snakehead. A boat electrofishing survey was completed on July 19, 2016 at Newton Lake to evaluate the Largemouth Bass and Northern Snakehead populations. A total of 42 Largemouth Bass were collected, of which 39 were greater than the 200 mm (8 in) stock size. The CPUE was 39 bass/hour based on one hour of daytime electrofishing. The largest bass measured 480 mm (18.90 in) and weighed 1.695 kg (3.74 lbs.). A PSD of 56 and PSD-P of 36 indicate a slightly unbalanced population. A total of six Northern Snakeheads were collected ranging in size from 320-675 mm (12.6 - 26.6 in) and weighed 0.260-3.140 kg (.57 - 6.92 lbs.). Submerged aquatic vegetation is rather abundant in Newton Lake and provides excellent habitat for both Largemouth Bass and Northern Snakeheads. The lake will continue to be monitored for the presence of Northern Snakeheads and any impact on the Largemouth Bass population. (Smith)

Parvin Lake (Salem) – Parvin Lake is a 95-acre impoundment of Muddy Run located within Upper Pittsgrove Township. Parvin Lake is one of five lakes managed under *Lunker Bass* Regulations. It is second only to Assunpink Lake in popularity among *Lunker Bass* lakes. A daytime boat electrofishing survey was conducted on October 24, 2016 to assess the Largemouth Bass population. Sampling occurred around the perimeter of the lake. A total of 76 Largemouth Bass were collected, of which 65 were greater than 200 mm (8 in) stock size. The CPUE was 43 bass/hour for stock size bass based on 1.5 hours of sampling. A PSD of 72, PSD-P of 46 and PSD-M of 4 were calculated for Largemouth Bass indicating a slightly unbalanced population that should provide exceptional fishing opportunities. Three memorable size (PSD-M, 20") Largemouth Bass weighing 3.34 kg (7.35 lbs. 3.36 kg (7.40 lbs.) and 2.51 kg (5.54 lbs.) were collected during the survey. The Yellow Perch and Bluegill populations appear to be rather abundant compared to past sampling and may be attributed to the Centerton Lake dam failure in 2009. Centerton Lake was the next upstream impoundment of Muddy Run. Gizzard Shad of multiple year classes were observed during the electrofishing survey, which provide good forage for trophy-sized Largemouth Bass. The abundant forage and size structure of the bass were good signs of a thriving fish population. Parvin Lake was last sampled in 2012 with similar results. No additional electrofishing is necessary until spring 2018. No additional stocking is necessary at this time. A seining survey should be completed in 2017 to assess the native fish population. (Smith)

Ponder Lodge Pond (Cape May) – Ponder Lodge Pond is an 8-acre waterbody located within the Cox Hall Creek Wildlife Management Area in Lower Township. The pond is a NJDFW trout stocked waterbody and has not been previously sampled in the past. A day-time boat electrofishing survey was conducted on August 17, 2016 to assess the Largemouth Bass population. Sampling occurred around the perimeter of the lake. Total electrofishing time was 0.50 hours. A total of 25 Largemouth Bass were collected, of which 24 were >200 mm (8 in) stock size, indicating a CPUE of 48 bass per hour. A Largemouth Bass measuring 569 mm (22.4 in) and weighing 2.710 kg (5.97 lbs.) was collected during the survey. Bluegill and Pumpkinseed were also collected. Young-of-the-year (YOY) Largemouth Bass and Bluegill were collected using seines indicating successful reproduction of both species. Additional stocking of Largemouth Bass is not required at this time. Stocking of surplus Largemouth Bass in the future may be beneficial. Mosquitofish sp. were also present. (Boehm)

Prospertown Lake (Ocean) – Prospertown Lake WMA is an 80-acre impoundment of Lahaway Creek, a tributary of Crosswicks Creek in Jackson Township. The lake is bordered by Six Flags Great Adventure on one side and private forested land on the other. A lake inventory and management plan was completed in 1997. The Prospertown Lake dam failed in 2011 was reconstructed in 2012 and refilled by spring 2013. The lake was restocked with Largemouth Bass, Bluegill, Black Crappie, and Brown Bullheads in 2013. A boat electrofishing survey completed in 2014 determined that an undesirable number of Brown Bullheads were present. Only one electrofishing survey was completed from 1997 to 2011. In 2007, 27 Largemouth Bass ranging from 170 – 347 mm (6.7 – 13.7 in) were collected and tested negative for Largemouth Bass Virus. A boat electrofishing survey was completed at Prospertown Lake on June 27, 2016 to evaluate the Largemouth Bass population and remove Brown Bullheads. A total of 49 Largemouth Bass were collected in 1.25 hours of daytime boat electrofishing. The CPUE for those bass greater than 200 mm (8 in) stock size was 36 bass/hour. A PSD of 80 and PSD-P of 44 indicate a slightly unbalanced population. The PSD and PSD-P were both higher that that observed in 2015 (PSD of 50 and PSD-P of 25). Approximately 350 Brown Bullheads ranging in size from 150 – 250 mm (5.9 – 9.8 in) were removed from Prospertown Lake and relocated to Turnmill Pond, Colliers Mill WMA. No additional stocking is required at this time. Additional sampling should be completed in 2017 to monitor the Largemouth Bass population and remove additional Brown Bullheads from the lake. A seining survey should be completed to evaluate the native fish population. (Smith)

Rainbow Lake (Salem) – Rainbow Lake WMA is a 77-acre impoundment of Muddy Run, a tributary of the Maurice River in Pittsgrove Township. Rainbow Lake is annually one of the most popular WMA lakes for bass tournaments. A lake inventory and management plan was completed in 2001 soon after it was acquired by NJDFW. The lake had a good bass and sunfish population at that time. The high hazard dam failed in May 2007 and was replaced later that fall. The lake was restocked with adult fish collected from Harrisonville Lake in December 2007. A boat electrofishing survey was completed on July 1, 2016 to evaluate the Largemouth Bass population. A total of 39 Largemouth Bass were collected during 1.5 hours of electrofishing. There were 27 bass greater than the stock size indicating a CPUE of 18 bass/hour. A PSD of 52 and PSD-P of 33 indicate a balanced population. No additional electrofishing sampling is necessary at this time, however a seining survey to assess the native fish population is recommended for 2017. Stocking of surplus young-of-the-year (YOY) Largemouth Bass is recommended to enhance the bass population. (Smith)

Rising Sun Lake (Monmouth) – Rising Sun Lake is a 38-acre impoundment located within the Assunpink Wildlife Management Area near the town of Roosevelt. A daytime boat electrofishing survey was conducted on 10/20/16 to assess the Largemouth Bass population. Sampling occurred around the perimeter of the lake. A total of 116 Largemouth Bass were collected, of which 107 were greater than 200mm (8 in) stock size. The CPUE was 184 bass/hour based on 0.58 hours of electrofishing. A PSD of 39 and PSD-P of 2 were calculated for Largemouth Bass indicating an unbalanced population. The size structure has improved since 2015, at which time the CPUE was 34 bass/hour, PSD was 13 and PSD-P was 4. Stocking of Golden Shiners and Yellow Perch is recommended in 2017 to improve the forage base. The lake should be resampled in the fall 2017 to evaluate the Largemouth Bass population size structure and condition. Rising Sun Lake should be removed from the bi-annual Channel Catfish stocking list to alleviate competition with Largemouth Bass. (Smith)

Shaws Mill Pond (Cumberland) – Shaws Millpond WMA is a 30-acre impoundment of Pages Run, a tributary of Nantuxent Creek in Lawrence Township. A boat electrofishing survey was completed on July 12, 2016 to evaluate the Largemouth Bass population. Electrofishing proved rather unsuccessful with only four adult Largemouth Bass collected. A total of nine species were collected during the 30-minute survey. Adult Golden Shiner and young-of-the-year (YOY) Largemouth Bass were observed to be abundant, but were not collected. A lake inventory was completed in 2002 that indicated the lake had a good bass population. The CPUE was 36 bass/hour in 2002 for all bass, including those smaller than the 200 mm (8 in) stock size. For seining summary see page 91. A supplemental electrofishing survey should be completed during the spring or fall when less vegetation is present to further evaluate the bass population. No additional stocking of warmwater fish is necessary at this time. (Smith)

Split Rock Reservoir (Morris) – On October 11, 2016 a nighttime boat electrofishing survey was conducted on this 550-acre lake to evaluate the Largemouth and Smallmouth Bass populations. The reservoir is one of Jersey City's water supply reservoirs and the DEP recently (2015) purchased land around the reservoir to allow additional access via shoreline. A lake inventory was conducted here in 2007 to determine the status of the lake and help guide management. It was determined that an excellent Largemouth and Smallmouth Bass fishery was present (CPUE of Largemouth Bass and Smallmouth Bass was 40 fish/hour and 52 fish/hour, respectively). At that time, it was determined that the lake should be managed strictly for its excellent bass fishery. The survey conducted this year lasted 2.0 hours and a total of 35 Largemouth Bass greater than stock size (200 mm) and 10 Smallmouth Bass greater than stock size (180 mm) were captured. This CPUE (17 Largemouth Bass/hour and 5 Smallmouth Bass/hour) was much lower than when the last survey was conducted here. The cause of the low catch rate in bass here may be due to multiple factors including sampling time. An additional survey will be conducted in 2017 to determine if any action is necessary. (Collenburg)

Stone Tavern Lake (Monmouth) – Stone Tavern Lake is a 52-acre impoundment located within the Assunpink Wildlife Management Area. A daytime boat electrofishing survey was conducted on October 17, 2016 to assess the Largemouth Bass population. Sampling occurred around the perimeter of the lake. A total of 56 Largemouth Bass were collected, of which 53 were greater than 200mm (8 in) stock size. The CPUE was 53 bass/hour based on one hour of electrofishing. A PSD of 83 and PSD-P of 24 indicate a slightly unbalanced Largemouth Bass population. Stone Tavern was last stocked with Largemouth Bass in 2011. Stone Tavern should be removed from the Channel Catfish stocking list to maintain and enhance the Largemouth Bass condition and size structure. (Smith)

Union Lake (Cumberland) – Union Lake WMA is an 898-acre impoundment of the Maurice River and the largest lake in southern New Jersey. A boat electrofishing survey was completed on September 2, 2016 to evaluate the Largemouth Bass population. A total 14 Largemouth Bass were collected during the 1.33-hour survey. The largest individual was 507 mm (20.5 in) and 2.255 kg (4.97 lbs.). Thirteen of the fish were greater than the 200 mm (8 in) stock size. A rather significant algae bloom was present, including large areas of filamentous algae, which is not typical for Union Lake. It is presumed that the hot dry summer could have contributed to the conditions. A lake inventory was completed in 2015, which failed to adequately asses the Black Crappie and Smallmouth Bass populations. Sampling utilizing trap nets during the spring of 2017 is recommended to ascertain the current status of the Black Crappie population. A supplemental electrofishing will be completed in March targeting Largemouth and Smallmouth Bass. No additional stocking is required at this time however stocking of surplus Smallmouth Bass is recommended. (Smith)

Wheaton Glass Works Pond (Cumberland) – A boat electrofishing survey was completed at the Wheaton Glass Works Pond in response to a council request. The privately owned borrow pit pond is approximately 1.5 acres and wooded around its perimeter. Laydown trees, willows, and bladderwort serve as the primary habitat in the pond. A total of 55 Largemouth Bass were collected in 0.66 hours of daytime electrofishing. Fifty-one of the bass were greater than the 200 mm (8 in) stock size. There were no bass greater than 380 mm indicating the population is not balanced. The bass population is rather abundant and unbalance based on limited angler harvest. A total of 19 adult Bluegill were collected during 0.25 hours of electrofishing. The population consists mainly of larger individuals greater than 200 mm indicating the population is unbalanced. The current fish population should provide good angler success, however few larger bass are present. Pumpkinseed, Yellow Perch, and Mosquitofish sp. were also present. The pond is currently not open to the public for fishing. No additional management activities are required unless the pond is opened to public fishing. (Smith)

Wilson Lake (Gloucester) – Wilson Lake is a 58-acre impoundment of Scotland Run, a tributary of the Maurice River located within the county owned Scotland Run Park. Wilson had a major dam repair and the lake was significantly lowered during the winter of 2014/2015. Largemouth Bass were restocked in 2015. A daytime boat electrofishing survey was conducted on November 3, 2016 to assess the warmwater fish population. A total of 18 Largemouth Bass were collected, of which 16 were greater than 200 mm (8 in) stock size. The CPUE was 21 bass/hour for stock size bass based on 0.75 hours of electrofishing. A PSD of 56 and PSD-P of 19 indicate a balanced population. The Chain Pickerel population appears to be rather abundant, but most were small and less than the harvestable size (15 in). The forage base is rather limited in the lake with only a few large Bluegill and Yellow Perch observed. Stocking of Golden Shiners is recommended to enhance the forage base. Seining was also conducted in 2016 (page 92). No additional sampling is planned for 2017. (Smith)

Warmwater Fisheries Assessments / Reproduction Checks / Native Fishes via Seining

Shoreline seining was conducted in 49 lakes and ponds in July through mid-September to assess the status of warmwater fish reproduction, which aids in the management of their fisheries and helps assess stocking success or need. These data are also beneficial in documenting the presence of both native and invasive species. (Hunter and Angler Fund)

Bluegill (top) and Pumpkinseed (bottom) collected with a 20' x 4' seine.

Allamuchy Pond (Warren) - This 49-acre lake is within the Pequest River watershed and located off County Rt. 517, within Allamuchy Mountain State Park. The fishery was surveyed by NJDFW in 1979 and Largemouth Bass (5), Pumpkinseed (5), and American Eel (1) were documented (sampling gear unknown). The owner at the time (Catholic Sisters) operated a convent, and public access to the lake was restricted to the steep bank adjacent to the highway. Once the property changed hands (now owned by the Allamuchy Township Board of Education) Parks and Forestry constructed a small car top ramp for boating (electric motors only). Sampling to obtain current data on the fishery was conducted on August 8, 2016. Eight locations were sampled using a 20'x 4' seine to assess fish reproduction. This effort was hampered by dense aquatic vegetation and steep drop-offs. Species and number of fish collected included Largemouth Bass (11), Bluegill (343), Pumpkinseed (3), and Mosquitofish sp. (7). A temperature/dissolved oxygen profile conducted at the deepest part of the lake (27 feet) indicated trout supporting water was not present (page 134). More information about the fishery is needed before specific fishery management and/or fish stocking recommendations can be made for this lake. Shoreline electrofishing is recommended, however, the absence of a formal boat launch may preclude this sampling activity. (Hamilton)

Ames Lake (Morris) – This 14-acre lake located in Rockaway Township has not been assessed since an electrofishing survey was done here in 1987, with little data collected. This lake is stocked with Channel Catfish. During this sampling event 15 seine pulls were conducted and a number of Largemouth Bass (55) were collected. Only a small amount of young-of-the-year sunfish (17) were present, although it may have been too early in the season to collect them. However, a good number of adults and immatures were captured (41), indicating that the population of Largemouth Bass and sunfish species are well balanced. Creek Chubsucker (6), Yellow Perch (14), and Chain Pickerel (5) were also found. Of note, a species that was not originally found in the surveys conducted in the 80's was a common native Bluespotted Sunfish (12). In the near future, an electrofishing survey should be conducted to monitor this small but popular waterbody. (Collenburg)

Atsion Lake (Burlington) – Atsion Lake is a 62-acre impoundment of the Mullica River located within Wharton State Forest. The lake is a popular recreational area offering camping, swimming, fishing, and paddling opportunities. Sampling for native pinelands fishes was conducted on August 12, 2016. A total of 12 locations were sampled using a 20'x4' seine around the perimeter of the lake. Eleven species were collected which consisted of Pumpkinseed (321), Swamp Darters (63), Blackbanded Sunfish (55), a species soon to be designated state Special Concern, Black Crappie (27), Creek Chubsucker (7), 7 young-of-the-year (YOY) Largemouth Bass, 7 YOY Chain Pickerel, Bluespotted Sunfish (6), Pirate Perch (3), American Eel (2), and Yellow Bullhead (1). YOY, intermediate, and adult Pumpkinseed were all collected. Water chemistry was recorded; pH measured 4.50. The presence of YOY Black Crappie was of interest. Further sampling is required to assess the fishery. No stocking is planned at this time based on the present native fish community present, and location within pinelands. (Boehm)

Cedar Lake (Atlantic) – Cedar Lake is an impoundment on the Great Egg Harbor River watershed. The lake is located within Cedar Lake Wildlife Management Area, and is approximately 30 acres in size. This location has not been previously sampled by the NJDFW. Sampling for native pinelands fishes was conducted on July 14, 2016. A total of six locations were sampled along the perimeter of the lake using a 20'x4' seine. A total of six species were collected which included Blackbanded Sunfish a species soon to be designated state Special Concern (17), Chain Pickerel (2), Golden Shiner (4), Enneacanthus sp. (19), Bluegill (73), and Swamp Darter (5). Water chemistry was recorded; pH measured 5.98 and conductivity was 56.4 us/cm. No further sampling is needed at this time, and stocking is not recommended in the future. (Boehm)

Cedar Lake (Cedarville, Cumberland) – Cedar Lake is a 57-acre impoundment of Cedar Creek located in the town of Cedarville. A dam restoration or removal is currently being discussed at this location. Two surveys were completed in 2016 to assess the fish population. A seining survey was completed on July 28, 2016 to evaluate the native fish population and a daytime boat electrofishing survey was completed in the fall to evaluate the Largemouth Bass population. Cedar Lake was previously sampled in 2005 for native fishes utilizing minnow traps. This method was determined to be rather ineffective, with only Bluegill and Pumpkinseed collected. The abundant filamentous algae limited seining locations in the lake. A total of eight species consisting of Largemouth Bass (1), Brown Bullhead (25), American Eel (1), *Enneacanthus* sp. (2), Yellow Perch (3), Chain Pickerel (1), Bluegill (81), and Pumpkinseed (2), were collected from eight seining locations. An electrofishing survey was also conducted in 2016 (page 67). A seining and electrofishing survey should be completed after the dam reconstruction project is completed. No stocking is recommended at this time. (Smith)

Chatsworth Lake (Burlington) – Chatsworth Lake is an impoundment of the West Branch of the Wading River located in the town of Chatsworth. The lake is within the 10,243-acre Franklin Parker Preserve owned by the New Jersey Conservation Foundation, and is approximately 50 acres in size. This location has not been previously sampled by the NJDFW. Sampling for native pinelands fishes was conducted on June 21, 2016. The lake does not have a boat ramp or suitable launching area for trailered boats which limited access to sampling locations. A total of three locations were sampled using a 20'x 4' seine. Species collected included Blackbanded Sunfish (23), Bluespotted Sunfish (5), Banded Sunfish (3), Chain Pickerel (3), Pirate Perch (1), and Swamp Darter (42). Swamp Darters were most numerous with 25 young-of-the-year (YOY) and 17 adults collected. YOY, intermediate, and adult Blackbanded Sunfish were all collected. All species collected during this survey are considered native pinelands fishes. Water chemistry was collected and pH measured 4.40. The absence of non-native fish collected during sampling can be attributed to the physiological effects of low pH. Low pH can act as a barrier preventing the establishment of non-native fishes within pinelands waters. This waterbody should not be stocked due to the native fish community present, which includes Blackbanded Sunfish a species soon to be designated state Special Concern. Additional sampling is not needed at this time. (Boehm)

Clint Mill Pond (Cape May) – Clint Mill Pond is a 10-acre impoundment of Sluice Creek located within Beaver Swamp Wildlife Management Area. Sluice Creek is tidal up to the base of Clint Mill Pond. The pond itself is small and boggy in nature which lends support that it was originally constructed for waterfowl habitat in the past. Sampling for native pinelands fishes was conducted on August 15, 2016. A total of four locations were sampled using a 20' x 4' seine around the perimeter of the lake. Two species were collected which included Redfin Pickerel (1) and Brown Bullhead (4). Limited access and a soft lake bed made effective seining difficult. Water chemistry was recorded; pH measured 4.07. This location was last sampled in June 1972. Seining results in 2016 were similar to the 1972 survey, consisting of Redfin Pickerel, Chain Pickerel, Mud Sunfish, and Eastern Mudminnow. No further sampling is needed. Based on the lack of potential to develop a recreational fishery and the present native fish community no stocking is planned in the future. (Boehm)

Coopers Park Pond (Bergen) – Previously seined by NJDFW in 1995, only one Largemouth Bass and no sunfish were collected at that time. A reproductive check was conducted at Coopers Park Pond (3 acres) in Bergenfield on August 25, 2016. Nine seine (20' x 4') hauls around the perimeter of the pond revealed Banded Killifish (1), Pumpkinseed (2), invasive Green Sunfish (6), and Mosquitofish sp. (14). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass, Bluegill, and surplus Channel Catfish in 2017. (Boriek)

Cresse Lane Ponds (Cape May) – Cresse Lane Ponds are located in Lower Township. Young-of-the-year (YOY) Largemouth Bass and Bluegill were collected using seines indicating successful reproduction of both species. Mosquitofish were also present. Water chemistry was recorded; pH measured 7.99, conductivity 1223 us/cm, and salinity was 0.53 ppt. This location has not been previously sampled by the NJDFW. Additional assessment of the warmwater fishery is recommended. (Boehm)

Cumberland Pond (Cumberland) – Cumberland Pond is a 26-acre impoundment of the Manumuskin River located in the town of Millville. This location has not been previously sampled by the NJDFW. An anadromous fish assessment was conducted in the spring of 2000 directly below the dam on the Manumuskin River. This location is equipped with a fish ladder. No river herring were collected in the 2000 survey. Sampling for native pinelands fishes was conducted on July 20, 2016. The pond provided limited sampling locations along the Route 49 shoreline. Deep water and dense beds of water lily and bladderwort along the shoreline made effective seine pulls difficult. A total of two locations were sampled using a 20' x 4' seine. Species collected included the soon to be designated state Special Concern Blackbanded Sunfish (1), Banded Sunfish (5), Bluespotted Sunfish (5), *Enneacanthus* sp. (1), Pirate Perch (6), Swamp Darter (8), and Creek Chubsucker (4). All three *Enneacanthus* species native to New Jersey were collected, and the entire fish assemblage consisted of native pinelands fishes. Additional sampling was conducted on August 2, 2016 to further evaluate the native fish population. Only six seining locations were sampled via boat due to poor access. A total of nine species were collected which included Pumpkinseed (1), Pirate Perch (1), Eastern Mudminnow (9), Swamp Darter (25), Yellow Bullhead (1), Banded Sunfish (87), *Enneacanthus* sp. (20), Chain Pickerel (2), Blackbanded Sunfish, a species soon to be designated state Special Concern (8), and Mud Sunfish, a species soon to be designated state Special Concern (1). Banded Sunfish were the most abundant species collected. The pH of 4.83 and lack of non-native Centrarchids provide ideal habitat for these native species. All fish collected during sampling are considered native pinelands species. No further sampling is necessary at this time. There should be no stocking of this waterbody in order to preserve the integrity of the native fish populations. (Boehm)

Delaware Lake (Warren) - This 36-acre lake, visible from Interstate 80, is located within the Paulinskill WMA. Delawanna Creek flows through this lake before emptying directly into the Delaware River south of Columbia. Upstream of Delaware Lake the creek is classified as *Trout Maintenance*; downstream of the lake's dam the creek is classified as *Trout Production* (wild Brown Trout present). A gravel boat launch and dock are present (electric motors only) and the lake is managed as a *Lunker Bass Lake*. Fish reproduction was assessed on August 10, 2016 by shoreline seining 12 stations using a 20'x 4' seine. Fish were captured at all but one site. Species collected included Largemouth Bass (28), Bluegill (734), Pumpkinseed (22), Black Crappie (66), Golden Shiner (7), Brown Bullhead (1), Banded Killifish (10), Mosquitofish sp. (3), and 797 sunfish that were too small to individually identify to the species level. A temperature/dissolved oxygen profile was conducted at the deepest part of the lake (14 feet) and trout supporting water was not present (page 134). The lake was also electrofished in the fall to further assess the bass fishery (page 69). The abundance of warmwater fishes encountered during these surveys indicates that supplemental stocking of warmwater fish is not warranted. (Hamilton)

Durand Park Pond (Monmouth) – A reproductive check was conducted at Durand Park Pond (4 acres) in Freehold on August 29, 2016. This pond had never been previously sampled by NJDFW. Eight seine (20' x 4') hauls around the perimeter of the pond revealed Pumpkinseed (16), Bluegill (138), and Largemouth Bass (2). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass and surplus Channel Catfish in 2017. (Boriek)

East Creek Lake (Cape May) – East Creek Lake is a 62-acre impoundment of East Creek located within Belleplain State Forest. Sampling for native pinelands fishes was conducted on 8/4/16. A total of 12 locations were sampled using a 20' x 4' seine around the perimeter of the lake. Bluegills were the most abundant species collected totaling 211. Blackbanded Sunfish, a species soon to be designated state Special Concern totaled 111, and were collected at each of the 12 sampling locations. Only one young-of-the-year (YOY) Largemouth Bass was collected. Chain Pickerel (5), Creek Chubsucker (28), Yellow Perch (7), Pumpkinseed (8), Golden Shiner (6), *Enneacanthus* sp. (64), Bluespotted Sunfish (3) and Yellow Bullhead (5) were also collected. Water chemistry was recorded; pH measured 5.18. Largemouth Bass (3,000) were last stocked in 2001. Stocking of Largemouth Bass at this time is not recommended. However, taking into consideration the limited freshwater angling opportunities of the surrounding area, location within a State Forest, and a public boat ramp all lend support to additional stocking of Largemouth Bass in the future. (Boehm)

Frelinghuysen Forest Preserve Pond (Warren) – On July 29, 2016, division staff performed a reproductive check on a small pond (1.7ac) on recently acquired public property in Warren County. The NJDFW was contacted earlier in the year by the municipality to sample the pond and evaluate the fish population. The pond's water level was very low and was dominated by plant growth making sampling very difficult to near impossible. The sampling crew performed 13 seine pulls but only captured 5 Largemouth Bass and 5 Bluegills. It is difficult to assess the fish population with the pond in this condition. More sampling is necessary to determine the health of the fishery, but if these water level fluctuations are normal for this waterbody, it is likely that a "good" fishery will never fully develop. Stocking of any additional fish should not occur until further data can be gathered about the amount of water typically found in this pond especially during the summer months and more information on the existing fish population in the pond. (Shramko)

Green Turtle Pond (Passaic) – This 43-acre lake located in West Milford Township was boat electrofished in 2015 and a majority of the Largemouth Bass captured were below stocked size. Seining was conducted to provide supplemental information. A total of 16 seine pulls were conducted and not many young-of-the-year Largemouth Bass (11) were captured, but many were visible to seining crews. A number of sunfish (264) were also found indicating a well-balanced fishery. It is anticipated strong Largemouth Bass year classes will continue to follow. For electrofishing information see page 71. (Collenburg)

Harrisville Lake (Burlington) – A 40-acre impoundment of the Oswego River located within Wharton State Forest. Sampling for native pinelands fishes was conducted on July 8, 2016 using a 20'x4' seine. A total of eight locations around the perimeter of the lake were sampled. A total of six species were collected which included Chain Pickerel (3), Blackbanded Sunfish (20), Bluespotted Sunfish (3), Pirate Perch (1), Swamp Darter (6) and Creek Chubsucker (31). Dense areas of bladderwort and rush were abundant along the perimeter of the lake. All species collected during this survey are considered native pinelands fishes. Water chemistry was recorded and pH measured 4.50. The low pH and lack of non-native Centrarchids provide ideal habitat for these native species. Based on the present native fish community, which includes Blackbanded Sunfish a species soon to be designated state Special Concern, no stocking is planned in the future. (Boehm)

Haworth Park Pond (Bergen) – A reproductive check was conducted at Haworth Park Pond (8 acres) in Haworth on August 30, 2016. The fish assemblage consisted of three species including Pumpkinseed (424), Bluegill (421), Largemouth Bass (1), and unidentified Lepomis sunfish sp. (575). Previously seined in 1971, Golden Shiner, Bluegill, and Pumpkinseed were found. It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass and Channel Catfish in 2017. (Boriek)

Hyper Humus Ponds (Sussex) - Hyper Humus Ponds were originally created in the 1900's by a peat and humus mining operation belonging to the Hyper Humus Company. The ponds are only a couple of feet deep with high levels of decomposing vegetation. In the spring of 2015, a large fish kill occurred due to a process known as "winter kill". Winter kill occurs when dissolved oxygen levels decrease, which can occur when a shallow pond with large snow and ice accumulations on the surface limits the amount of sunlight to reach plants in the lake limiting photosynthesis. The plants die and decompose, which uses oxygen dissolved in the water. Dissolved oxygen levels plummet and fish die. After attempting to sample a few of the ponds in 2015 and the remaining ponds in 2016 it has been determined that all of the ponds are only a few feet deep with large amounts of decaying plant material. Hyper Humus Ponds will most likely suffer from re-occurring winter kills in the future preventing a fishery to fully develop. Sampling of the pond with a seine was attempted this summer, but the substrate, dominated by decaying plant matter, made it nearly impossible to seine in most locations. The only area capable of surveying was in a location where a dike failed. The failed dike made the substrate firm enough for staff to sample. The dike failure also concentrated the fish in this area probably due to flowing water between the two impoundments and slightly higher dissolved oxygen found in the flowing water. 12 Largemouth Bass and 52 Sunfish (43 Bluegill, 4 Pumpkinseed, 4 Bluespotted Sunfish and 1 Hybrid Sunfish) were collected. Many large Common Carp were also seen but not collected. Management of the Hyper Humus Wildlife Management Area ponds should be directed towards birds and other wildlife and not as a recreational fishery. (Shramko)

Iona Lake (Gloucester) – Iona Lake is a 36-acre impoundment of Still Run, a tributary of the Maurice River. This municipally owned lake has been annually stocked with trout since 1986 and bi-annually with Channel Catfish since 1993. No additional warmwater species have been stocked at Iona Lake. A seining survey was completed on August 9, 2016 to evaluate the native fish and Largemouth Bass population in Iona Lake. A total of 10 species were collected from 11 seining locations. Largemouth Bass (7), Pirate Perch (2), Blackbanded Sunfish (12), *Enneacanthus* sp. (22), Bluespotted Sunfish (1), Chain Pickerel (1), Golden Shiner (4), Swamp Darter (13), Brown Bullhead (4), unknown *Enneacanthus sp*. (10), and Bluegill (4) were present. Due to the presence of some of state's rare native fish species; including Blackbanded Sunfish (soon to be designated state Special Concern) and historical records Ironcolor Shiner (soon to be listed state Endangered), the stocking of warmwater fish including Largemouth Bass and Channel Catfish is not recommended. (Smith)

Lake Absegami (Burlington) –Lake Absegami is a 63-acre impoundment of the upper Bass River watershed located within Bass River State Forest. The lake is a popular recreational area offering camping, hiking, swimming, and paddling opportunities. Sampling for native pinelands fishes was conducted on July 8, 2016 using a 20' x 4' seine. A total of eight locations around the perimeter of the lake were sampled. A total of three species were collected which included Banded Sunfish (23), Chain Pickerel (12), and Swamp Darter (4). All fish collected are considered native pinelands fishes. Water chemistry was recorded and pH measured 4.38. The absence of non-native fish and low biodiversity within the lake can be attributed to the physiological effects of low pH. Lake Absegami's waters are extremely clear which is usual for the area as the majority of pinelands waters typically are tannin stained and have a light brown hue. No additional sampling is needed at this time. Based on the present native fish community and water chemistry this water should not be stocked. (Boehm)

Lake Lenape (Atlantic) – Lake Lenape is a 350-acre impoundment of the Great Egg Harbor River located in the town of Mays Landing. Sampling looking for the presence of Ironcolor Shiner, a soon to be listed state Endangered species, as well as native pinelands fishes was conducted on July 21, 2016. Fowler 1905 documented Ironcolor Shiners in Mare Run, a tributary of the Great Egg Harbor River above Lake Lenape. Additional records from 1951 indicate Ironcolor Shiners were present within the watershed. A total of eight locations were sampled using a 20' x 4' seine. A total of 11 species were collected which included Largemouth Bass (11), Chain Pickerel (3), Pumpkinseed (1), Bluegill (84), Golden Shiner (59), Black Crappie (6), Blackbanded Sunfish; a species soon to be designated state Special Concern (8), Banded Sunfish (1), Pirate Perch (1), White Catfish (1), and Swamp Darter (1).

Additional sampling for native fishes was conducted on July 26. A total of 12 locations were sampled using a 20' x 4' seine. A total of 12 species were collected which included Largemouth Bass (11), Chain Pickerel (5), Pumpkinseed (2), Bluegill (37), Golden Shiner (3), Black Crappie (3), Blackbanded Sunfish (33), Banded Sunfish (4), Bluespotted Sunfish (6), Pirate Perch (4), Swamp Darter (10), Yellow Bullhead (5), and Brown Bullhead (6). Native fishes appear to be relegated to the headwater portion of the lake near the confluence of the Great Egg Harbor River which creates more favorable habitat for them. Annual winter drawdowns significantly impact and reduces main lake habitat availability. Lake Lenape has a fish ladder with successful anadromous fish passage documented. Management geared towards the benefit of the Largemouth Bass and Black Crappie populations should continue as Lake Lenape is a very popular recreational fishery in Southern New Jersey. No supplemental stocking of warmwater fish is required at this time. Additional sampling for native fishes on the Great Egg Harbor watershed is recommended. (Boehm)

Lake Neepaulin (Sussex) - On July 22, 2016, division staff performed a reproductive check on Lake Neepaulin (25 acres) located in Wantage Township Sussex County. The Bureau was contacted last fall about the possibility of stocking warmwater fish species in Lake Neepaulin by a citizen of Wantage Township. Lake Neepaulin has been under private ownership until recently, when it changed ownership and now is a public waterbody. Subsequently, the Division of Fish and Wildlife has little background information concerning the lakes habitat, water quality and fish population. Lake Neepaulin does have a public boat launch, but it is fairly small and parking is limited to only a few vehicles and trailers. Freshwater fisheries staff collected 15 Largemouth Bass and over 300 Bluegill and Pumpkinseed Sunfish in 17 seine pulls around the perimeter of the lake. About a dozen or so additional Largemouth Bass were seen but evaded capture. No other species were collected. Survey results show a fairly balanced population between Largemouth Bass and Sunfish with no need to stock any additional warmwater fish at this time. (Shramko)

Lake Nummy (Cape May) – Lake Nummy is a 26-acre impoundment of East Creek located within Belleplain State Forest. A fish kill consisting of 200 Yellow Perch was reported in July 2011. One hundred Bluegill were stocked on 6/28/03, and 200 were stocked the following year on 6/6/02. The lake was totally drained in 2014 to repair the dam. Sampling for native pinelands fishes was conducted on 8/23/16. A total of twelve locations were sampled using a 20' x 4' seine around the perimeter of the lake. A total of three species were collected consisting of Blackbanded Sunfish; a species soon to be designated state Special Concern (18), Banded Sunfish (62), and Yellow Bullhead (4). Young-of-the-year (YOY), intermediate, and adult Banded Sunfish were all collected. All species collected are considered native pinelands fishes. Water chemistry was recorded; pH measured 4.95. Mud Sunfish, a species soon to be designated state Special Concern, were not collected during the survey but have been reported at this location in the past. Additional sampling in the future is recommended to confirm the presence of Mud Sunfish within the lake. Due to the native fish assemblage present stocking is not recommended. However, due to the lakes location within a State Park future stocking on a limited basis may be considered. (Boehm)

Lefferts Lake (Monmouth) –Last sampled in 1998, Lefferts Lake has a minimal recreational fishery due to the greatly fluctuating pH of the water. A 1975 survey found the lake to be inhabited by Largemouth Bass, Black Crappie, Bluegill, Brown Bullhead, Banded Killifish, Golden Shiner, Pumpkinseed, and Goldfish. At the request of the Director of Recreation, a reproductive check was conducted at Lefferts Lake (69 acres) in Matawan on August 22, 2016. Sixteen seine (20' x 4') hauls around the perimeter of the pond revealed Pumpkinseed (17), Bluegill (33), Largemouth Bass (4), Black Crappie (1), Bluespotted Sunfish (2), and Chain Pickerel (1). The pH was 7.59. It is recommended that boat electrofishing be conducted before stocking any warmwater fish. (Boriek)

Little Swartswood Lake (Sussex) – On August 8, 2016, division staff performed a reproductive check on Little Swartswood Lake (83 ac) in Sussex County. Staff collected 9 Largemouth Bass, 1 Redfin Pickerel, and 33 Sunfish (9 Bluegill, 6 Pumpkinseed, 4 Redbreast Sunfish, and 14 Bluespotted Sunfish) and 10 Mosquitofish sp. from 15 seine pulls. Several adult Largemouth Bass and Sunfish were observed, but not captured. Finding adequate seining locations is difficult in this waterbody as much of the shoreline drops off quickly compromising the effectiveness of the seine pull. No fish were collected due to habitat constraints on 7 of the 15 seine pulls performed. Due to the sampling difficulty, the seining data is less conclusive than usual and other sampling techniques must be used to have a better understanding of the fish population of the lake. Little Swartswood Lake was also sampled using a South Dakota style trap-net in the spring of this year (page 60). (Shramko)

Makepeace Lake (Atlantic) – Makepeace Lake is a 300-acre impoundment of the Great Egg Harbor River located within Makepeace Lake Wildlife Management Area. Sampling for native pinelands fishes was conducted on August 3, 2016. A total of eight locations were sampled using a 20'x4' seine around the perimeter of the lake. Blackbanded Sunfish (14) a species soon to be designated state Special Concern, Banded Sunfish (79), Swamp Darter (38), and Yellow Bullhead (6) were all collected during the survey. Water chemistry was recorded; pH measured 4.01, temperature 28.9 C and dissolved oxygen 6.99 mg/L. The absence of non-native species collected during sampling can be attributed to the low pH of the lake. Low pH can act as a barrier preventing the establishment of non-native fishes within pinelands waters. Additional sampling in 2017 is planned to assess *Enneacanthus* species diversity. Based on the present native fish community, and lack of potential to develop a recreational fishery no stocking is planned in the future. (Boehm)

Menantico Sand Ponds (Cumberland) – A seining survey was completed on August 22, 2016 at Menantico Sand Ponds WMA to evaluate the native fish population and reproduction of Largemouth Bass. A total of 12 locations were sampled using a 20' x 4' seine around the perimeter of the lake. Eleven species were collected which included Largemouth Bass (1), Swamp Darter (2), American Eel (7), Eastern Mudminnow (9), Chain Pickerel (2), Banded Sunfish (55), Blackbanded Sunfish (23), Bluespotted Sunfish (2), Bluegill (15), Pumpkinseed (1), Redbreast Sunfish (56), and *Enneacanthus sp*. (77). Blackbanded Sunfish, a species soon to be listed as state Special Concern, was frequently encountered in the 2016 survey, however was not found during the 1997 inventory. Another notable difference from 1997 to 2016 was the lack of Largemouth Bass. A total of 91 young-of-the-year (YOY) bass were collected from 10 seining locations in 1997, whereas only one YOY was collected in 2016 from 12 locations. An additional seining survey should be completed in 2017 targeting areas that are more favorable for Largemouth Bass and less favorable for natives. No additional stocking is recommended at this time. For 2016 electrofishing summary see page 73. (Smith)

Mill Pond (Atlantic**)** **–**Mill Pond is a 30-acre impoundment of Nacote Creek located in the town of Port Republic. The pond is the first upstream impediment encountered on Nacote Creek. Sampling for native pinelands fishes was conducted on July 6, 2016. A guard rail along Mill Road prevents launching of trailered boats into the pond. A total of six locations were sampled along Mill Road using a 20' x 4' seine. A total of nine species were collected which included Largemouth Bass (97), Chain Pickerel (4), Pumpkinseed (2), Bluegill (2), Creek Chubsucker (80), Blackbanded Sunfish (40), Bluespotted Sunfish (2), Swamp Darter (2), and Mummichug (1). Ninety-seven young-of-the-year (YOY) Largemouth Bass were collected on three seine pulls which suggests excellent recruitment for the species. Only two YOY Bluegill were collected which suggests spawning had not yet taken place at the time of sampling. Two adult Pumpkinseeds were collected, and several were observed on beds. Water chemistry was collected and pH measured 5.32 and salinity was 0.05 ppt. Juvenile Bluefish <100mm (3.937 in) were being caught by anglers below the dam and suggests the dam acts as a salinity barrier for the pond. Additional sampling is not needed at this time. This lake should not be stocked as it appears to be reverting back to a native fish assemblage, which includes Blackbanded Sunfish a species soon to be designated state Special Concern, and offers a limited fishery for Largemouth Bass due to the low pH. (Boehm)

Mountain Lake (Warren) - This 122-acre lake has a variety of warmwater fishes and is stocked annually with Muskellunge, and also with trout in the spring (stocked one time, before the Opening Day of the trout season in April). Although Parks and Forestry is the lake owner, the shoreline is dotted with private residences and public access for shoreline fishing is limited to the municipal property, which includes a fee-based swimming beach and boat launch. Only electric motors are permitted on the lake. Fish reproduction was assessed on July 27, 2016 by shoreline seining using a 20'x 4' seine. Fish were captured at 14 of the 19 sites selected for survey (no fish were found at 2 sites and 3 sites could not be seined). Species collected included Largemouth Bass (32), Bluegill (25), Pumpkinseed (6), Redbreast Sunfish (3), Bluespotted Sunfish (6), Spotfin Shiner (49), Banded Killifish (288), Mosquitofish sp. (50), and 3 sunfish (species unknown). Bluespotted Sunfish is one of New Jersey's less common native sunfish species and its continued presence in this lake (first documented in 1950) is noteworthy. A temperature/dissolved oxygen profile conducted on at the deepest part of the lake (40 feet) indicated a one-foot layer of trout supporting water was present 16-17 feet below the surface (page 134). In addition, the lake was surveyed in the spring with trap nets to assess the Muskellunge fishery (page 62) and electrofished in the fall to further assess the warmwater fishery (page 74). Fisheries management recommendations will be prepared following a collective analysis and review of all recently collected data. (Hamilton)

New Brooklyn Lake (Camden) – New Brooklyn Lake is a 40-acre impoundment on the Great Egg Harbor River watershed located in the town of Sicklerville. Sampling looking for the presence of Ironcolor Shiner, a soon to be listed state Endangered species, as well as native pinelands fishes was conducted on June 23, 2016. A total of three locations within the lake were sampled using a 20'x4' seine. A total of 10 species were collected which included Largemouth Bass (7), Pumpkinseed (2), Chain Pickerel (5), Blackbanded Sunfish (2), Bluespotted Sunfish (56), Mud Sunfish (1), Mosquitofish sp. (1), Eastern Mudminnow (2), Pirate Perch (2), and Swamp Darter (2). No Ironcolor Shiners were collected during the survey. Filamentous algae and freshwater shrimp were abundant within the lake. Water chemistry was recorded and pH measured 6.35. Within the pinelands as pH increases; generally associated with land use changes, the occurrence of non-endemic fishes also increases and may negatively impact native fish populations. This location has been sampling several times in the past with similar results and fish assemblages present. Stocking is not recommended at this time due to limited potential to develop a recreational fishery, and to emphasize the conversation of the native fish community present which includes Blackbanded Sunfish, a species soon to be designated state Special Concern. (Boehm)

Pickle Factory Pond (Cape May) – Approximately 60 acres in size, Pickle Factory Pond is an impoundment of West Creek located along the border of Belleplain State Forest. This location has not been previously sampled by the NJDFW. Sampling for native pinelands fishes was conducted on August 15, 2016. A total of 12 locations were sampled using a 20' x 4' seine around the perimeter of the lake. Eight species were collected consisting of Blackbanded Sunfish, a species soon to be designated state Special Concern (6), Banded Sunfish (9), Bluespotted Sunfish (22), Pumpkinseed (107), Chain Pickerel (1), Pirate Perch (2), Creek Chubsucker (11), and Yellow Bullhead (7). All fish collected during sampling are considered native species. Water chemistry was recorded; pH measured 4.81. Based on the present native fish community no stocking is planned in the future. (Boehm)

Pohatcong Lake (Ocean) – Pohatcong Lake is a 33-acre impoundment of Tuckerton Creek located within the town of Tuckerton. The lake is a NJDFW trout stocked waterbody. Sampling for native pinelands fishes was conducted on August 8, 2016. A total of five locations were sampled using a 20'x4' seine around the perimeter of the lake. Six species were collected which included Banded Sunfish (51), Bluespotted Sunfish (65), Largemouth Bass (5), Chain Pickerel (2), Eastern Mudminnow (1), and Pumpkinseed (3). Bluespotted Sunfish and Banded Sunfish were most abundant. With the exception of Largemouth Bass all species collected are considered native fishes. Numerous groups of young-of-the-year (YOY) Largemouth Bass were observed but not collected. A viable recreational Largemouth Bass fishery has been reported. Water chemistry was recorded; pH measured 5.51. Abundant aquatic vegetation and acidic conditions provide excellent habitat for native *Enneacanthus* species. No stocking of warmwater fish species is recommended at this time. (Boehm)

Pondside Park Pond (Bergen) – A reproductive check was conducted at Parkside Park Pond (5 acres) in Harrington Park on July 17, 2016. This pond had never been previously sampled by NJDFW. Eleven seine (20' x 4') hauls around the perimeter of the pond revealed Pumpkinseed (9), Bluegill (63), Common Carp (1), invasive Green Sunfish (2), and Mosquitofish sp. (117). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass and surplus Channel Catfish in 2017. (Boriek)

Roosevelt Commons Pond (Bergen) – Previously seined by NJDFW in 1965, only Goldfish were found at that time. A reproductive check was conducted at Roosevelt Commons Pond (0.59 acres) in Tenafly on August 25, 2016. The steep banks made seining difficult. Four seine (20' x 4') hauls around the perimeter of the pond revealed only 2 species, including the invasive Green Sunfish (6) and Mosquitofish sp. (1). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass, and Bluegills in 2017. (Boriek)

Round Valley Reservoir (Hunterdon) – In a continued effort to inventory the fisheries of Round Valley Reservoir, reproductive checks were conducted on July 6, 2016. Two seining teams of three conducted a combined 80 hauls around the perimeter of the reservoir. A total of 696 fish were captured, consisting of 13 species. The most numerous species was Banded Killifish (n=420 or 5.3 per seine haul), followed by Spotfin Shiners (n=206 or 2.6 per seine haul). The remainder of species were not very abundant, with no more than 18 individuals (0.2 per seine haul). Largemouth (n=8) and Smallmouth (n =5) were captured, indicating limited reproductive success, however electrofishing surveys conducted earlier this year indicate a high juvenile abundance of both species. It should be noted that 28 of 80 seine hauls produced no fish, which is expected with shorelines consisting primarily of pebbles and sand and that lack cover such as submerged aquatic vegetation, woody debris, and boulders. Additional surveys were conducted during 2016, including three spring and one fall electrofishing surveys (page 64), annual gillnet surveys to monitor the Lake Trout population (page 32), and three dissolved oxygen/temperature profiles (page 134). The Round Valley Reservoir Fisheries Management Plan is found in Appendix G. (Crouse)

Young-of-the-year Largemouth Bass (left) and Smallmouth Bass (right) from Round Valley Reservoir next to a No. 2 pencil for scale

Saffin Pond (Morris) - This county-owned 13-acre pond, located in the Highlands, was drained for dam repairs and refilled in 2012. Shoreline access for fishing is good and boaters must park in the lot by the main road and portage their boats. The pond's features (rocky dam surface, scattered rocks in pond bed, minimal aquatic vegetation, and 1,110 ft. elevation) made it a good candidate location for establishing Smallmouth Bass. The lake has been stocked with Smallmouth Bass fingerlings for four years (2012 – 2015) in an effort to establish a fishery for this species. Shoreline seining conducted in 2013 and 2014 revealed little in terms of successful SMB reproduction. In 2014 the perimeter of the pond was electrofished during the daytime and it was apparent that Largemouth Bass not only survived the drawdown, but were reproducing successfully, and dominating the fishery. The pond was surveyed on August 8, 2016 to assess warmwater fish reproduction and evaluate reproductive success of Smallmouth Bass. Shoreline seining using a 20' x 4' seine was attempted at 15 stations, but of these only 10 were suitable for seining. Five fish species were encountered, including Largemouth Bass (2, both YOY), Bluegill (117), Pumpkinseed (95), Yellow Perch (7), and Banded Killifish (1). A temperature/dissolved oxygen profile was also conducted at the deepest part of the lake (13 feet) and not surprisingly, trout supporting water was absent (page 134). The surveys conducted in recent years indicate that this pond is better suited for Largemouth Bass and the stocking of Smallmouth Bass was discontinued in 2016. Bridle Shiner (soon to be listed state Endangered) was found here in 2013, but not in 2014 or 2016. Weldon Brook flows through Saffin Pond and it is recommended that other locations within the watershed be sampled to determine if this native fish is presence elsewhere. (Hamilton)

Sawmill Pond (Sussex) – On June 30, 2016, division staff sampled Sawmill Pond (33ac) with a seine at 10 different sampling locations to determine the current fish species composition of the pond. Historical records show that Bridle Shiner, a rare native species soon to be listed state Endangered, were last found in the pond in 1971. Unfortunately, no Bridle Shiners were found during this survey. Largemouth Bass (24), Bluegill (76), Pumpkinseed (21), and Redbreast Sunfish (2) were the only species collected. Division staff also sampled Sawmill Pond in 2008 with a seine and did not find any Bridle Shiner. After two unsuccessful attempts to find Bridle Shiners in Sawmill Pond, it is likely that the species has been lost from this location. (Shramko)

Scarlet Oak Pond (Bergen) – This 16-acre lake located inside Ramapo Valley Reservation in Mahwah Township has not been assessed since an inventory was conducted here in 1994. Trout were stocked here annually until 2009 and Channel Catfish are stocked here on occasion. Seining was done to provide insight into the fishery's population structure and make a determination on any necessary management actions. A total of 16 seine pulls were conducted and a number of young-of-the-year Largemouth Bass (40) and Bluegill (183) were captured. The fishery appears to be well balanced and no management actions are necessary. (Collenburg)

Silver Creek Pond (Bergen) – A reproductive check was conducted at Silver Creek Pond (4 acres) in Mahwah on July 13, 2016. This pond had never been previously sampled by NJDFW. Four seine (20' x 4') hauls around the perimeter of the pond revealed Pumpkinseed (3), Bluegill (8), and Largemouth Bass (2). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass, Bluegill, and surplus Channel Catfish in 2017. (Boriek)

Shaws Mill Pond (Cumberland) – Shaws Millpond WMA is a 30-acre impoundment of Pages Run, a tributary of Nantuxent Creek in Lawrence Township. A seining survey was completed on July 28, 2016 to evaluate the Largemouth Bass and native fish population. A total of nine species including Largemouth Bass (15), Brown Bullhead (1), *Enneacanthus sp*. (5), Eastern Mudminnnow (2), Pirate Perch (1), Yellow Perch (7), Chain Pickerel (3), Golden Shiner (3), Banded Sunfish (38), Bluegill (108), Pumpkinseed (22), and unknown *Lepomis sp*. (78). were collected from ten seining locations. Noteworthy was the absence of the Mud Sunfish, a species soon to be listed as state Special Concern, from the survey. A boat electrofishing survey was also completed at Shaws Mill Pond WMA on July 12 to evaluate the Largemouth Bass population (page 77). An additional seining survey is recommended for 2017. (Smith)

Stafford Forge Impoundment #1 (Ocean) - Stafford Forge Impoundment #1 is a 48-acre impoundment of Westecunk Creek located within the Stafford Forge Wildlife Management Area. Sampling for native pinelands fishes was conducted on August 8, 2016. A total of four locations were sampled using a 20' x 4' seine around the perimeter of the lake. Four species were collected which included Banded Sunfish (12), Swamp Darter (1), Largemouth Bass (8), and Chain Pickerel (2). With the exception of Largemouth Bass all species collected are considered native pinelands fishes. Water chemistry was recorded; pH measured 4.49. This lake should not be stocked as the acidic conditions are ideal for native pinelands fishes. Low pH prevents the development of a Largemouth Bass fishery as spawning success is greatly reduced, and often sporadic under acidic conditions. No further sampling is needed at this time. (Boehm)

Thielke Arboretum Pond (Passaic) – At the request of the Director of the Arboretum, a reproductive check was conducted at the "*Catch & Release*" regulated Thielke Arboretum Pond (3 acres) in Glen Rock on August 19, 2016. This pond had never been previously sampled by NJDFW. The steep banks and rip-rapped walls made seining difficult. Ten seine (20' x 4') hauls around the perimeter of the pond revealed Largemouth Bass (16) and Bluegill (3). It is recommended that the Hackettstown State Fish Hatchery stock Bluegill, surplus Channel Catfish, and Largemouth Bass in 2017. (Boriek)

Tuckahoe Lake (Cape May) – Tuckahoe Lake is a 10-acre impoundment located within Tuckahoe Wildlife Management Area. The lake is a NJDFW trout stocked waterbody. Sampling for native pinelands fishes was conducted on August 3, 2016. A total of eight locations were sampled using a 20' x 4' seine around the perimeter of the lake. Eight species were collected which included Bluegill (56), Banded Sunfish (21), Mosquitofish sp. (11), Creek Chubsucker (7), Yellow Bullhead (6), Chain Pickerel (2), Pumpkinseed (1), and 1 young-of-the-year (YOY) Largemouth Bass. YOY, intermediate, and adult Bluegill were all collected. Water chemistry was recorded; pH measured 5.09, temperature 29.9 ℃, and dissolved oxygen 7.10 mg/L. Additional sampling in 2017 is planned to assess *Enneacanthus* species diversity. (Boehm)

Twin Lakes (Sussex) - The fish population in this 29-acre lake, located within Kittatinny Valley State Park, not far from Aeroflex Lake, had not been previously sampled by NJDFW. Sampling to obtain data on the fishery was conducted on August 11, 2016. Shoreline seining (20' x 4' seine) was very difficult due to the abundance of lily pads and milfoil, and fish were captured at only 6 of the 10 sites seined. Species collected included Largemouth Bass (2), Pumpkinseed (10), Bluegill (23), and Bluespotted Sunfish (16). Bluespotted Sunfish, one of New Jersey's less common native sunfish species, was not previously known to occur in this lake. Temperature/dissolved oxygen profiles were also conducted at the deepest part of the lake (36 feet) on 8/11/16 and 9/1/16 (page 134). On both occasions unusually low levels of dissolved oxygen (<3 mg/L) were documented in the metalimnion (middle of the water column). In most New Jersey lakes dissolved oxygen levels during the daytime are typically highest in the metalimnion during the summer due to photosynethetic activity of algae. Water transparency (secchi disk measurement) was low (3.3 ft. on 8/11/16) and then higher (11.5 ft. on 9/1/16) and it could not be determined if photosynthetic activity was responsible for this phenomenon. Although trout supporting water was documented in the 8/11/16 profile, it was not found on 9/1/16, therefore lake surface water is not recommended for upgrade from *Nontrout* to *Trout Maintenance* (page 134). The fishery in this lake must be further assessed (electrofished by boat in the spring before aquatic vegetation has fully emerged) before specific fishery management recommendations can be made. (Hamilton)

Van Saun Pond (Bergen) – Previously seined by NJDFW in 1969, only Tessellated Darters and Golden Shiners were found. A reproductive check was conducted at Van Saun Pond (3acres) in Paramus on August 11, 2016. Twelve seine (20' x 4') hauls around the perimeter of the pond revealed Pumpkinseed (18), Bluegill (2), Golden Shiner (1), Bluespotted Sunfish (2), and Mosquitofish sp. (1). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass, Bluegill, and surplus Channel Catfish in 2017. (Boriek)

Veterans Park Pond (Monmouth) – At the request of the Director of Recreation, a reproductive check was conducted at Veterans Park Pond (2 acres) in Hazlet on August 30, 2016. This pond had never been previously sampled by NJDFW. The rear portion of the pond was not seined due to heavy aquatic vegetation. Four seine (20' x 4') hauls around the perimeter of the pond revealed Bluegill (6) and Brown Bullhead (7). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass, Bluegill, and surplus Channel Catfish in 2017. (Boriek)

Whites Pond (Bergen) – A reproductive check was conducted at Whites Pond (6 acres) in Waldwick on August 18, 2016. NJDFW stocks this pond with trout in the spring. Eleven seine (20' x 4') hauls around the perimeter of the pond revealed Pumpkinseed (1), invasive Green Sunfish (7), Bluegill (60), invasive Oriental Weatherfish (7), and Mosquitofish sp. (4). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass and surplus Channel Catfish in 2017. (Boriek)

Wilson Lake (Gloucester) – Wilson Lake is a 58-acre impoundment of Scotland Run, a tributary of the Maurice River located within the county owned Scotland Run Park. A seining survey was completed at Wilson Lake on August 10, 2016 to evaluate the native fish population and reproduction of Largemouth Bass. A total of seven species including Largemouth Bass (10), Bluegill (474), Banded Sunfish (29), Bluespotted Sunfish (2), Swamp Darter (16), *Enneacanthus* sp. (31), Banded Killifish (1), and Black Banded Sunfish (4) a species soon to be listed as state Special Concern, were collected from 14 locations. A daytime boat electrofishing survey was also conducted on November 3, 2016 to assess the warmwater fish population (page 78). (Smith)

Zabriske Pond (Bergen) – Previously sampled by NJDFW in 1984, Carp, sunfish, and Yellow Perch were collected at that time. A reproductive check was conducted at Zabriske Pond (4acres) in Wyckoff on August 24, 2016. Twelve seine (20' x 4') hauls around the perimeter of the pond revealed Pumpkinseed (19), Bluegill (226), Largemouth Bass (12), and Black Crappie (3). It is recommended that the Hackettstown State Fish Hatchery stock Largemouth Bass and surplus Channel Catfish in 2017. (Boriek)

ANADROMOUS FISHERIES

A number of New Jersey's river systems serve as important migratory pathways for fish. Each spring anadromous species such as American Shad, Alewife, Atlantic Sturgeon, Blueback Herring, Sea Lamprey, Shortnose Sturgeon, and Striped Bass navigate from marine waters to fresh waters of the state to spawn. In late summer and early fall, their young return home to marine waters to remain until maturity. In contrast, catadromous species such as American Eel reside in fresh waters throughout the state and migrate to open ocean waters to spawn.

With perhaps the exception of lampreys, these species are of great ecological, recreational, and commercial value to New Jersey and many other Atlantic coast states. The monitoring and restoration of these fisheries is a fundamental aspect in ensuring the population's well being. As these species reside in both fresh and marine waters they are cooperatively management between the Bureau of Freshwater Fisheries and the Bureau of Marine Fisheries. As stocks migrate up and down the entire east coast, the management of species falls under the jurisdiction of the Atlantic States Marine Fisheries Commission (ASMFC). As a result, for New Jersey, primary management of these species falls to the Bureau of Marine Fisheries.

In March 2012 the recreational and commercial harvest of migratory river herring (Alewife and Blueback Herring) was prohibited. These regulations were put in place due to concerns about the significant coast-wide decline of river herring stocks and to comply with federal mandates outlined by the Atlantic States Marine Fisheries Commission. In 2013 a similar moratorium was placed on American Shad with the exception of the Delaware River, its bay and estuaries. The exact cause for these coast-wide declines remains uncertain, but numerous factors such as loss of spawning habitat, impediments to fish passage (i.e. dams), water quality degradation and fishing all likely played a role.

American Shad caught by angler below the Columbia Lake Dam

Freshwater efforts consist of monitoring fish passage through fish ladders, technical assistance for dam removal projects on migratory pathways, periodic confirmation of historic migratory pathways and identification of new runs. (Federal Grant F-48-R, Project I)

2016 activities include:

The **Millstone River Restoration Project** aims to restore connectivity of the Millstone River by removing dams. The Weston Causeway Dam is located just downstream of the Wilhousky Street bridge in Manville and is the first impediment to fish passage on the Millstone River. This dam is 133 feet long and 5 feet high. The Weston Causeway dam was originally a mill dam at the Weston Mill, a site includes a gristmill, sawmill, dam, and associated waterpower features. The dam was repaired with concrete in the early 20th century, but appears to retain earlier masonry elements underneath. The dam has no current purpose; the mill buildings were claimed by arson in July 1983. In recent years, the dam has partially failed and is planned to be removed in 2017 as part of a NJDEP mitigation project due to previous environmental damages by a third party. Migratory fish including American Shad, Gizzard Shad, river herring, Striped Bass, and American Eel, in addition to resident warmwater species have been documented passing the Island Farm Weir fish ladder near the confluence of the Millstone River and the Raritan River approximately 1.5 miles downstream of the Weston Causeway Dam. This system supports a diverse recreational fishery composed of over forty-four species. (Crouse)

24-inch walleye captured while boat electrofishing below the Weston Causeway Dam and Wilhousky Streeet bridge (both seen in background)

In anticipation of the removal of the Weston Causeway Dam on the Millstone River, five electrofishing surveys and a seining survey were conducted above and below the dam at the Wilhousky Street Bridge (Manville / Weston Causeway) as part of a study to determine potential fish assemblage changes as a result of the dam removal (see table below). Surveys will be conducted each of the next 3 spring and fall seasons (one fall and one spring pre-dam removal to establish a baseline and 2 fall and spring cycles post-dam removal). Surveys were led by NJDFW and assisted by partners from USFWS and Stony Brook-Millstone Watershed Association. (Hunter and Angler Fund)

Forty-five fish species collected at 6 locations along the Millstone River above and below the Weston Causeway Dam.

Fish Species	near confluence with Raritan River (e-fish)	below Weston Causeway Dam (e-fish)	below Weston Causeway Dam (seine)	above Weston Causeway Dam	below Blackwells Mills Dam (e-fish)	below Griggstown Causeway (e-fish)
Largemouth Bass	8	17	2	24	1	2
Smallmouth Bass	2	9	1	4	4	
Rock Bass		1			1	
Striped Bass		1		4	2	
Bluegill		16	11	25	43	42
Pumpkinseed		8	1	3	9	1
Redbreast Sunfish	9	43	10	37	113	48
Green Sunfish			1	1	6	4
Bluespotted Sunfish		1	10			
Black Crappie				2	1	
White Perch		3	3	2		
Shield Darter					3	7
Tessellated Darter					130	46
Channel Catfish	4	5				
White Catfish	1				2	
Yellow Bullhead		3		3	13	8
Brown Bullhead		1				
Margined Madtom					2	
Tadpole Madtom					2	2
Yellow Perch	4	22	3	11	3	
Walleye		3				
Muskellunge		1				
Chain Pickerel		9	3	11	5	2
Redfin Pickerel					1	
American Shad		15				
Gizzard Shad				2		
Common Carp	12	48		33		
Grass Carp				1		
Blacknose Dace						2
Longnose Dace					1	6
Creek Chub				2		
Fallfish					6	2
Comely Shiner		2		2	2	1
Common Shiner					8	1
Golden Shiner		6		75		
Satinfin Shiner		1		1	7	46
Spottail Shiner		1		34	76	21
Swallowtail Shiner						4
Banded Killifish					1	22
White Sucker		10		5	9	1
Creek Chubsucker		20	2		1	
Sea Lamprey					1	
American Eel	9	25		54	274	257
Mosquitofish sp.			18		2	1
Oriental Weatherfish					2	

Millstone River (near Raritan River confluence) - The first boat electrofishing survey was conducted downstream of Weston Causeway Dam near Raritan River confluence on September 27, 2016. All fish were collected for one hour (Common Carp and American Eel abundance was estimated) for a distance of approximately 700 m. An assortment of eight species were encountered including Largemouth and Smallmouth Bass, Yellow Perch, Channel Catfish, White Catfish, Common Carp, American Eel, and a variety of sunfishes (see table above). The habitat in this section of the Millstone River looked excellent to support a warmwater fish assemblage, consisting of downed trees, woody debris, and a variety of submerged and emergent aquatic vegetation. Biologists noted that they were surprised to capture so few fish, given the apparent excellent habitat. In fact, it was speculated that the electrofishing boat may not have been functioning properly, although there were no apparent problems. A survey later that morning, just upstream from this location, produced many more individual fishes and a greater species diversity, although habitat and water quality were assumed to be very similar. It will be interesting to see if numbers and species counts continue to be relatively low at this location.

Millstone River (immediately below Weston Causeway Dam) - The second boat electrofishing survey was conducted just downstream of Weston Causeway Dam on September 27, 2016. Once again, all fishes were collected for one hour over a stretch of approximately 700 m. The upper survey boundary was at the base of the Weston Causeway dam and might explain a greater abundance of fish as compared to the survey near the confluence with the Raritan River, as the failing dam resulted in a form of attraction water that served as the only "riffle" in this section of river. In fact, the only American Shad found during the first six surveys were found at the base of the dam. Nine of the fifteen young-of-the-year (YOY) American Shad were retained for laboratory identification and had a range of 103 – 131 mm (4.0 – 5.2 in). This is the first documentation of YOY American Shad in the Raritan River drainage since adult pre-spawn Delaware River American Shad were introduced in to the Raritan River in the early 1980's. A total of 25 species were documented at within this location (see table above). In order to supplement the boat electrofishing surveys downstream of the Weston Causeway Dam, a total of eight seine pulls were conducted within approximately 100 m of the dam, using both 100 ft. and 20 ft. seines. Twelve species were collected including, however only two additional species were collected (Green Sunfish and Mosquitofish sp.). In 2013 one invasive Flathead Catfish was found below the dam as well.

First Flathead Catfish documented by Biologists in Millstone River during 2013 electrofishing survey.

Millstone River (immediately above Weston Causeway Dam) - The third boat electrofishing survey was conducted on just downstream of Weston Causeway Dam on October 13, 2016. Once again, all fishes were collected for one hour over a stretch of approximately 700 m. Although juvenile American Shad were found below the dam during a previous survey, none were encountered upstream, indicating it may be an impediment to American Shad. Four juvenile Striped Bass (see photo) were found both upstream and downstream of the Weston Causeway Dam indicating it does not prevent their passage. Largemouth Bass outnumbered Smallmouth Bass 24 to 4. An abundance of large Common Carp was observed and one Grass Carp was netted that measured 41 inches and an estimated 30-35 lbs. The fish assemblage appears to be relatively similar above and below the dam (see table above), however predatory species found below the dam include, Walleye, Muskellunge, and Channel Catfish (in addition to the Flathead Catfish encountered in 2013).

10-inch Striped Bass from Millstone River

Millstone River (below Blackwells Mills Dam) - An electrofishing survey was conducted with a Smith Root electrofishing barge approximately five miles upstream of the Weston Causeway Dam on the Millstone River at the base of the Blackwells Mills Dam. The fish assemblage was very diverse at this location, with 31 species documented (see table above). Two Striped Bass were found, indicating that they have the ability to traverse the Weston Causeway Dam. This site was also accessible to an abundance of American Eels, totaling 274 (125 < 200 mm and 149 ≥ 200 mm) and one Sea Lamprey. Two species soon to be designated state Special Concern include Comely Shiner and Shield Darter. It should be noted that both of our state's madtom species were found here as well, this is significant because there are very few sites in NJ in which Margined Madtoms are found this far south and Tadpole Madtoms found this far north. Of the 731 individual fish that were encountered, very few are non-native piscivores (6 combined Largemouth Bass, Smallmouth Bass, and Rock Bass) and 42 Bluegills. The only invasive fish regulated as a potentially dangerous species was encountered upstream of the dam include Oriental Weatherfish (n=2) and Green Sunfish (n=6). This was the first time the Oriental Weatherfish was found in the Millstone Watershed.

Millstone River (below Griggstown Causeway) - An additional electrofishing survey was conducted with a Smith Root electrofishing barge approximately nine miles upstream at the Griggstown Causeway. This site was selected to obtain baseline fish assemblage information, as the Blackwells Mills Dam is also being considered for removal. The fish assemblage was diverse at this location, with 22 species documented, 18 of which are native to NJ (see table above). The most abundant fish at this location was the American Eel, composing 257 of the 526 fishes found, most of which were collected in the rip-rap under the bridge. No anadromous species were encountered. Two species soon to be designated state Special Concern were found, including Comely Shiner and Shield Darter. Tadpole Madtoms were found at this location, which is one of the few locations in NJ it is found north of the geologic fall line. The only invasive fish regulated as a potentially dangerous species was Green Sunfish (n=4).

The **Musconetcong River Restoration Partnership** is a multi-disciplinary team of agencies, organizations, and individuals working to improve and restore the Musconetcong River. Partners include the Musconetcong Watershed Association, USDA Natural Resources Conservation Service, National Oceanographic and Atmospheric Administration (NOAA), US Fish & Wildlife Service, National Park Service, Army Corps of Engineers, NJDEP (various agencies including NJDFW), American Rivers, North Jersey Resource Conservation and Development, Trout Unlimited, private landowners, and others. The Partnership works with willing dam owners to secure funding from conservation-minded organizations and government programs to remove antiquated dams and restore river health. The Musconetcong River drains 158 square miles of rural New Jersey and is a major tributary of the Delaware River, the longest undammed river east of the Mississippi River. According to state record, there are 34 regulated dams located along the length of the Musconetcong, portions of which are designated in the National Wild & Scenic Rivers program. From 2008 – 2015 the Partnership, led by the Musconetcong Watershed Association, orchestrated the removal of four dams on the river's mainstem (Finesville Dam and Riegelsville Dam on the lower Musconetcong River, and two dams near Hackettstown, the Gruendyke Mill Dam and Sebers Dam). During this time period the remnants of the Riegelsville Dam, the lowermost dam on the river (situated on a Wildlife Management Area) were also demolished. (Federal Grant F-48-R, Project II) (Hamilton)

In 2016, the Hughesville Dam located approximately four miles upstream from the river's confluence with the Delaware River was successfully removed. This project entailed removal of accumulated sediment behind the dam, breaching the dam and removing the dam material, restoring the stream channel above and below the dam to a natural condition (pools and riffles established), and stabilizing/revegetating the river banks and riparian zone. Although the construction activities associated with the dam removal only took four months, the planning process leading up to the removal took four years. The dam site was periodically inspected by NJDEP staff (Dam Safety and NJDFW) to ensure that the construction activity was proceeding as outlined and to observe conditions of the river (turbidity and sediment deposition) downstream of the project site. Migratory fishes can now move freely from the Delaware River upstream to the next barrier, the Warren Glen Dam. This 37-foot high dam is significantly larger than the Hughesville Dam and Partnership efforts to remove this dam are proceeding slowly, in part because of the magnitude of the project. The Army Corps of Engineers has taken the lead in removing the Bloomsbury Dam, located upstream.

The three photographs above represent various stages of removal of the Hughesville Dam.
(left: pre-removal, middle: after initial breach, right: complete dam removal)

Letters supporting proposals for funding were provided to the following organizations in 2016:

- Musconetcong Watershed Association – Proposal for restoration activities in the Musconetcong River, submitted to the National Fish and Wildlife Foundation (NFWF) and Eastern Brook Trout Joint Venture.
- NJ Audubon Society – Proposal for riparian restoration activities in the Upper Delaware Watershed, submitted to the National Fish and Wildlife Foundation (NFWF).

The **Paulins Kill River Restoration Project** is a multi-faceted partnership led by the Nature Conservancy, with goals of restoring connectivity to NJ's third largest tributary to the Delaware River and improving both riparian and in-stream habitat. One major aspect of the project is the removal of the Columbia Lake Dam, which was built by the Jersey Central Power and Light Company (JCP&L) in 1909. This 18-foot high, 330-foot long dam is located on the Paulins Kill less than ¼ mile upstream from its confluence with the Delaware River. The dam impounds a 32-acre reservoir that stretches more than 1.5 miles upstream of the dam. The State of New Jersey owns both the dam (sold by JCP&L in 1955) and 1,098 of the surrounding acres, and manages it as the Columbia Wildlife Management Area. Hydropower ceased being produced at the site in the spring of 2016 as the license to generate the hydropower was surrendered as part of the possible dam removal process. The impacts that this dam has on the Paulins Kill are significant; cutting off access to historic spawning grounds by American Shad, impeding passage of other migratory fish like American Eel and Sea Lamprey, disrupting the river's natural hydrology and sediment transport, and warming the water impounded behind the dam, among other effects. The ultimate desired ecologic outcome for the removal of the Columbia Lake Dam is to improve the overall health of this section of the Paulins Kill and maximize conservation and recreational benefits for nearby communities and businesses.

Columbia Lake Dam

Paulins Kill Smallmouth Bass

Beginning in the spring of 2015, the Bureau of Freshwater Fisheries began a multiyear sampling plan of the Paulins Kill to document and measure current fish assemblages prior to the proposed removal of the dam. The following is a summary of the NJDFW's 2015 and 2016 sampling efforts. Additional sampling is planned for the spring of 2017 and will continue into future years to document pre and post dam removal fish assemblages. (Federal Grant F-48-R, Project II) (Shramko)

Ten sampling locations, in 17 field days, for a total of 499 man hours have been used in 2015 and 2016 to collect data for this study. Seven sampling techniques were utilized; stream electrofishing, boat electrofishing, gill nets, trap nets, seines, cast nets and a dissolved oxygen / temperature probe with varying levels of success. The Paulins Kill being a large, wide and deep river complicates sampling which is why so many different sampling techniques have been utilized. Below average water levels during the spring of 2015 aided sampling efforts, however 2016 water levels were closer to average making sampling more difficult.

Overall, 2,313 individual fish representing 41 different species were collected, inspected and released. Anadromous fish species such as American Shad (33) and Blueback Herring (1) were documented below the Columbia Lake Dam, but not found above the Dam indicating that the Dam is a barrier to fish passage of these anadromous species. 461 American Eels (365 smaller than 200mm) were found in 2 locations below the Columbia Lake Dam. This compares to only 87 American Eels (8 smaller than 200mm) found in 8 locations above the Dam. These data illustrate that the Columbia Lake Dam is restricting the passage of this catadromous species as well. For more information, see page 68 and Appendix A (pages A14-A16) Additional sampling locations below the dam will continue in the spring of 2017.

American Shad caught electrofishing below the Columbia Lake Dam

Protection and Restoration of Inland Fisheries and Aquatic Habitats: Anadromous

In order to protect New Jersey's critical aquatic resources, fisheries biologists participate in or provide input on a number projects each year. Bureau staff provides technical assistance related to conservation, stream restoration, dam removal projects, and Land Use projects.
Land Use projects are coordinated through the Division's Office of Environmental Review. This input is directed towards minimizing land use change impacts to the state's fisheries resources. This is typically accomplished through the use of timing restrictions during critical fish spawning periods, protection of riparian buffers, and project modification, assuring best use practices are implemented at all times. However, at times a more in depth review and comments are necessary on specific projects.

In 2016 staff provided technical assistance to the following project related to our anadromous fisheries resources:

Monitoring the Passage of American Shad on the Raritan River - The Island Farm Weir Fish Ladder on Raritan River has been monitored by the NJ Bureau of Freshwater Fisheries from 1996 through 2003, and 2005, 2011, and 2012. The final report for JOB I-5: American Shad Restoration in the Raritan River, was submitted in January 2013. Beginning in the spring of 2013, the Department of Marine and Coastal Sciences at Rutgers University conducted the monitoring under the direction of Dr. Olaf Jensen, assisted by graduate student, Orion Weldon. Bureau staff assisted Rutgers staff with the clean out of the ladder in the spring of 2016. (Hunter and Angler Fund) (Boriek)

Monitoring the Outmigration of American Shad on the Delaware River - Bureau personnel assisted the Pennsylvania Fish Commission with the seining (300' seine) of young-of-the-year (YOY) Delaware River American Shad (AMS) at the Delaware Water Gap site on October 13, 2016. The Bureau conducted the annual seining (four seine hauls / site / month) during the months of August September and October at five sites on the Delaware River from 1979 - 2010. The Pennsylvania Fish Commission took over the survey in 2011. The survey is conducted to satisfy a requirement of the Atlantic States Marine Fisheries Commission. The October 13, 2016 Delaware Water Gap YOY American Shad total catch was 112. No river herring or Striped Bass were collected. (Boriek)

NATIVE SPECIES

New Jersey is home to nearly 60 Native Fishes, which form a significant component of the state's aquatic biological diversity and natural resource heritage. A list of fish species found in New Jersey can be found in Appendix D. While many native fish species are common, abundant, and widely distributed, such as Pumpkinseed, Blacknose Dace, and White Sucker, there also some that are of conservation concern and have limiting habitat and water quality requirements such as the Brook Trout, Bridle Shiner, Blackbanded Sunfish, and Slimy Sculpin. Many factors including land use changes, habitat loss, decline in water quality, and presence of invasive species threaten the survival of all aquatic biota, primarily those most sensitive.

Slimy Sculpin (soon to be listed Threatened)

The loss of any of these unique fish species through human impact is an undesirable outcome. In addition, natural factors such as climatic variations and watershed succession may dictate the future decline or expansion of fishes that are on the periphery of their established ranges. Further study is required to determine the current abundance and distribution of these nongame fishes throughout the state, including additional fisheries surveys, gathering additional fisheries data from other agencies, mapping, and determination of status for each species, all of which will result in the formation specific management objectives.

Shield Darter (soon to be designated Special Concern)

<u>Status Evaluation of Native Freshwater Fishes</u>

A formal review process led by the NJDFW's Endangered and Nongame Species Program was conducted in 2014 and 2015 to determine the status of our native freshwater fishes, known as the **Delphi Technique**. It is a systematic method for reaching consensus among experts in which absolute, quantitative answers are either unknown or unattainable. It is an iterative process characterized by anonymity among the participating experts, controlled feedback via the principal investigator and a statistical estimator of group opinion. By structuring the group communication process, the Delphi Technique helps the group reach a consensus of opinion by incorporating all available data and disseminating those data among all participants. The Delphi will assist the NJDFW's efforts towards updating New Jersey's State Wildlife Action Plan. To assist the Delphi efforts, the NJDFW created species distribution maps using GIS, based on data collected from 2000 through 2012. (Hunter and Angler Fund) (Crouse)

Brook Trout
(soon to be designated Special Concern)

Delphi Results
Sixty-five species were evaluated by an expert panel during round one, in which status selections, confidence levels, and comments were submitted by reviewers and compiled by ENSP staff. The Bureau of Freshwater Fisheries made recommendations on five non-consensus species (as indicated by a *). Results are listed below.

Endangered: Bridle Shiner*, Ironcolor Shiner, Shortnose Sturgeon

Threatened: Slimy Sculpin

Special Concern: American Brook Lamprey*, Blackbanded Sunfish*, Brook Trout, Comely Shiner, Mud Sunfish*, Northern Hogsucker, and Shield Darter

Secure/Stable: (32 species) American Eel, Banded Killifish, Banded Sunfish, Blacknose Dace, Bluespotted Sunfish, Brown Bullhead, Chain Pickerel, Common Shiner, Creek Chub, Creek Chubsucker, Cutlip Minnow, Eastern Mudminnow, Eastern Silvery Minnow, Fallfish, Gizzard Shad, Golden Shiner, Margined Madtom, Mummichog, Pirate Perch, Pumpkinseed, Quillback, Redbreast Sunfish, Redfin Pickerel, Satinfin Shiner, Sea Lamprey, Spotfin Shiner, Spottail Shiner, Swallowtail Shiner, Swamp Darter, Tadpole Madtom, Tessellated Darter, White Catfish, White Perch, White Sucker, Yellow Perch, Yellow Bullhead

Not Applicable: Black Bullhead, Bluntnose Minnow, Bowfin*, Longnose Gar, Pearl Dace

No Opinion (therefore removed): Alewife, American Shad, Blueback Herring, Fourspine Stickleback, Gizzard Shad, Hickory Shad, Hogchoker, Ninespine Stickleback, Rainbow Smelt, Rainwater Killifish, Spotfin Killifish, Threespine Stickleback

Unknown: Eastern Mosquitofish* (consensus of only 2 panelists)

A formal report on the status review was completed NJDFW's Endangered and Nongame Species Program and the findings were presented to the Endangered and Nongame Species Advisory Committee (ENSAC) during one of their regular meetings on March 16, 2016. During this time, committee members voted to accept the results, including Bureau of Freshwater Fisheries' recommendations for non-consensus species, and supported future listing and designations. The next step will be assigning official status via the state rulemaking process.

American Brook Lamprey
(soon to be designated Special Concern)

State Wildlife Action Plan

During 2015 and 2016 the Bureau of Freshwater Fisheries participated in the ten-year revision of the State Wildlife Action Plan (SWAP). The SWAP is a strategic and cost-effective mechanism to preserve the state's wildlife resources for the future. Recovery of species that have reached threatened or endangered status is typically more-costly than preventative actions that keep species populations from reaching such declines. Proactive management actions identified in the SWAP are intended to keep species from becoming federally (and state) threatened and endangered. NJDFW is currently updating the 2005 Wildlife Action Plan as required by Congress to continue to receive federal State Wildlife Grants. More importantly, New Jersey's update will serve as a blueprint for conserving our wildlife heritage. The plan will identify priority actions addressing known threats facing our targeted species and habitats that we, as a conservation community, can implement in the next ten years. (Hunter and Angler Fund) (Crouse)

Blackbanded Sunfish
(soon to be designated Special Concern)

A variety of tasks were required, including the prioritization of approximately 60 native fish species to determine those Species of Greatest Conservation Need. For these species, additional information was compiled to demonstrate species distribution, habitat information, state and range-wide status, etc. Species of Greatest Conservation Need were evaluated using several processes that resulted in the selection of eight Focal Species which were grouped into the following categories: Brook Trout, Pinelands Fishes (Banded Sunfish, Blackbanded Sunfish, Mud Sunfish, and Swamp Darter), and Vulnerable Minnows (Bridle Shiner, Comely Shiner, and Ironcolor Shiner).

Mud Sunfish (soon to be designated Special Concern)

A Threat Assessment was conducted for each species, aimed at identifying a standard list of threats that act as stressors to negatively impact each species. Threats are organized in a hierarchy in which broader (Level 1) threats are subdivided into more specific threats (Levels 2 and 3). Examples of Level 1 threats include development, agriculture, invasive species, pollution, etc., while Level 3 threats are much more specific. A scoring system was created to evaluate priority watersbodies (both lentic and lotic), using a multitude of data including fish presence/absence, diversity indices, landcover/landuse layers, etc. in an attempt to prioritize the states waters that are in the greatest need of conservation. Finally, the Bureau participated in two stakeholder meetings, aimed to address threats to the top 107 species of greatest conservation need to be identified in upcoming revisions to the SWAP.

Native Species Data Collection Efforts

During 2016, 34 waterbodies were surveyed, specifically targeting native fishes. The highest priority sites were those in which the Bridle or Ironcolor Shiners (soon to be listed state Endangered) were previously documented. Secondary priorities were sites that had species soon to be listed state Threatened or soon to be designated state Special Concern. This year the majority of those sites were located in the Lower Delaware River Drainage or Lower Atlantic Drainage to inventory for the presence of the four acid tolerant sunfish species (Blackbanded, Banded, Bluespotted, and Mud Sunfish). Additional sites were surveyed for a variety of other reasons. Sites and significant species accounts are in table below.

List of sites surveyed in 2016 searching for less common freshwater fish species.

Stream	Survey Date	Significance	Page #
Upper Delaware North & Wallkill Region (Shimmers Brook to Paulins Kill and Wallkill River watersheds)			
Hyper Humus Ponds (Sussex)	7/26/16	Paulins Kill Restoration Project with unknown fish assemblage. Bluespotted Sunfish in 2016.	84
Little Flatbrook (Sussex)	8/9/16	Bridle Shiner found 2003. Bridle Shiner found approx. 4 miles upstream in 2016.	NA
Sawmill Pond (Sussex)	6/30/16	Historic Bridle Shiner 1952. None in 1971, 2008, or 2016. Likely extirpated.	91
Raritan Region (Raritan River watershed)			
Rockaway Creek (Hunterdon)	7/12/16	Historic Bridle Shiner 1969. None in 2016. Shield Darter found in 2016.	A58
Rockaway Creek S/Br (Hunterdon)	8/3/16	Historic Bridle Shiner 1977. None in 2016. Shield Darter in2016.	A59
Rockaway Creek S/Br (Hunterdon)	8/3/16	Historic Bridle Shiner nearby 1977. None in 2016. Shield Darter in 2016.	A60
Lower Delaware Region (Assunpink Creek to Maurice River watersheds)			
Assunpink Creek (Mercer)	6/20/16	Historic Ironcolor Shiner in 1917. None in 2015.	A69
Burnt Mills Branch (Gloucester)	8/16/16	Historic Ironcolor Shiner in 1973. None found in 2015. Mud Sunfish in 2016.	A70
Iona Lake (Gloucester)	8/9/16	Historic Ironcolor Shiner, Blackbanded, Banded, & Mud Sunfish in 1955. No Ironcolor Shiner in 2016. Blackbanded, Bluespotted Sunfish & unknown *Enneacanthus* sp. in 2016.	85
Menantico Sand Pond (Cumberland)	8/22/16	Blackbanded, Banded, & Bluespotted Sunfish in 2016.	87
Rancocas Creek SW/Br (Burlington)	8/31/16	Historic Ironcolor Shiner in Rancocas tribs. near Browns Mills in 1905. None in 2015.	A72
Scotland Run (Gloucester)	8/24/16	Ironcolor Shiner and Bluespotted & Blackbanded Sunfish in 2002. Ironcolor Shiner & Bluespotted & Mud Sunfish in 2016	A73
Shaws Mill Pond (Cumberland)	7/28/16	Mud and Blackbanded Sunfish in 1957. Banded Sunfish in 1969. Banded Sunfish in 2016.	91
Wilson Lake	8/10/16	Blackbanded, Banded, Bluespotted, & Mud Sunfish in 1952. Blackbanded & Bluespotted Sunfish & unknown *Enneacanthus* sp. in 2016.	93

List of sites surveyed in 2016 searching for less common freshwater fish species (continued).

		Lower Atlantic Coastal (Sloop Creek to Dennis Creek watersheds)	
Atsion Lake (Burlington)	8/12/16	Blackbanded, Banded, Bluespotted, & Mud Sunfish in 1955. Blackbanded & Bluespotted Sunfish in 2016.	81
Cedar Lake (WMA) (Atlantic)	7/14/16	Blackbanded & unknown *Enneacanthus* sp. found in 2016.	81
Chatsworth Lake (Burlington)	6/21/16	Blackbanded, Banded, & Bluespotted Sunfish in 2016.	81
Clint Mill Pond (Cape May)	8/15/16	Banded & Mud Sunfish in 1972. None in 2016.	82
Cumberland Pond (Cumberland)	7/20 & 8/2/16	Blackbanded, Banded, Bluespotted, & Mud Sunfish found 2016.	82
East Creek Pond (Cape May)	8/4/16	Blackbanded, Banded, Bluespotted, & Mud Sunfish 1952. Blackbanded & Bluespotted Sunfish & unknown *Enneacanthus* sp. 2016.	83
Harrisonville Lake (Burlington)	7/8/16	Blackbanded & Bluespotted Sunfish 1969. Mud Sunfish 1994. Blackbanded & Bluespotted Sunfish 2016.	84
Lake Absegami (Burlington)	7/8/16	Banded Sunfish 2016.	85
Lake Lenape (Atlantic)	7/21 & 7/26/16	Ironcolor Shiner, Blackbanded, Banded, Bluespotted, & Mud Sunfish 1951. Blackbanded, Banded, & Bluespotted Sunfish 2016.	85
Lake Nummy (Cape May)	8/23/16	Blackbanded, Banded, & Mud Sunfish 1953. Bluespotted 1955. Blackbanded & Banded Sunfish 2016	86
Makepeace Lake (Atlantic)	8/3/16	Blackbanded & Banded Sunfish 2016.	87
Marsh Lake Branch (Atlantic)	7/20/16	No rare natives found 2016.	A74
Mill Pond (Atlantic)	7/6/16	Blackbanded & Bluespotted Sunfish 2016.	88
Morses Mill Stream (Atlantic)	7/7/16	No rare natives found 2016.	A75
New Brooklyn Lake (Camden)	6/23/16	Ironcolor Shiner 1964. Blackbanded, Banded, Bluespotted, & Mud Sunfish 1952. Blackbanded, Banded, Bluespotted, & Mud Sunfish & no Ironcolor Shiner 2016.	88
Pickle Factory Pond (Cape May)	8/15/16	Blackbanded, Banded, & Bluespotted Sunfish 2016	89
Pohatcong Lake (Ocean)	8/8/16	Bluespotted Sunfish 1969. Banded & Mud Sunfish 1982. Banded & Bluespotted Sunfish 2016.	89
Skit Branch (Burlington)	6/22/16	Blackbanded Sunfish 2016.	A76
Stafford Forge Impoundment #1 (Ocean)	8/8/16	Banded & Mud Sunfish 1967. Banded Sunfish 2016.	91
Tuckahoe Lake (Cape May)	8/3/16	Mud Sunfish 1950. Banded & Bluespotted Sunfish 1999. Banded Sunfish 2016.	92
Wading River W/Br	6/21/16	Blackbanded Sunfish 1953. Banded Sunfish 1977. Blackbanded, Banded, & Bluespotted Sunfish 2016.	A77

In addition to the sites that were surveyed specifically for rare native species, all 237 fisheries surveys conducted by the Bureau contribute valuable information to the status and distribution of fishes, including some of New Jersey's less common native fishes. The table below lists species soon to be listed as state Endangered, Threatened, or Special Concern. The number of sites in which each species was found during 2016, along with the number of sites that mark the first time each species was documented at that location are also found in the table below.

List of soon to be listed as state Endangered, Threatened, or Special Concern, including number of locations in which each species was encountered during 2016.

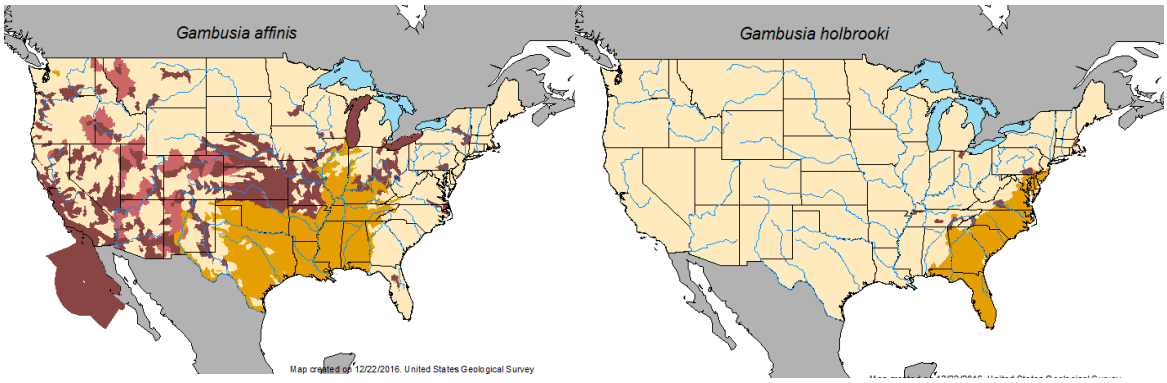
Species	Proposed status after Delphi and ENSAC review	Number of sites	New sites in FishTrack Database
Bridle Shiner	Endangered	1	Approx. 4 miles upstream from a 2003 location
Ironcolor Shiner	Endangered	1	0
Slimy Sculpin	Threatened	17 (8 from 3 streams)	2
American Brook Lamprey	Special Concern	4 (2 from 1 river)	1
Brook Trout (see Wild Brook Trout Assessment page 48)	Special Concern	48 (28 from 6 streams or rivers)	4
Blackbanded Sunfish	Special Concern	17	5
Comely Shiner	Special Concern	4 (4 from 1 river)	0
Northern Hog Sucker	Special Concern	3	1
Mud Sunfish	Special Concern	4	2
Shield Darter	Special Concern	12 (7 from 3 rivers)	4 (2 from 1 river) all near known populations

Bridle Shiner (soon to be listed Endangered)

Ironcolor Shiner (soon to be listed Endangered)

Mosquitofish

The Eastern Mosquitofish (*Gambusia holbrooki*) is native to the southeastern United States, its range possibly extending into the southern portion of New Jersey. The Western Mosquitofish (*Gambusia affinis*) is native to the south-central United States (see figures below). The non-native Western Mosquitofish has been widely introduced as a mosquito-control agent and are currently raised at the Hackettstown State Fish Hatchery (up to 2.5 million/year) and supplied to the county Mosquito Control Commissions. Discerning Eastern and Western Mosquitofish is difficult, as their physical characteristics are very similar and in fact hybridization and hatchery rearing processes can further confound the differences. The recent status evaluation of native fishes did not result in a status assessment for Eastern Mosquitofish. Contributing factors for their "undetermined" status pertained primarily to difficulty in proper identification and uncertainty of native range in NJ.



Range maps of Western Mosquitofish (G. affinis) (left) and Eastern Mosquitofish (G holbrooki) (right) from USGS NonIndigenous Aquatic Species website https://nas.er.usgs.gov/

The NJDFW has documented mosquitofish in an increasing number of locations in the wild in recent years. They were captured from 25 sites statewide in 2016. Many of them were retained for future laboratory identification and are temporarily referenced generally as Mosquitofish sp. Their increased distribution is believed to be a result of mosquito control related stockings. If the Eastern Mosquitofish are truly native and found very infrequently, they may warrant a protective measure to secure their future. Conversely, the non-native Western Mosquitofish may be acting as an invasive species and their establishment throughout the state may warrant management actions to minimize their spread.

Protection and Restoration of Inland Fisheries and Aquatic Habitats: Native Species

In order to protect New Jersey's critical aquatic resources, fisheries biologists participate in or provide input on a number projects each year. Bureau staff provides technical assistance related to conservation, stream restoration, dam removal projects, and Land Use projects.

Land Use projects are coordinated through the Division's Office of Environmental Review. This input is directed towards minimizing land use change impacts to the state's fisheries resources. This is typically accomplished through the use of timing restrictions during critical fish spawning periods, protection of riparian buffers, and project modification, assuring best use practices are implemented at all times. However, at times a more in depth review and comments are necessary on specific projects.

INVASIVE SPECIES

Aquatic Invasive Fishes Management

New Jersey is host to over 85 freshwater fish species and of these nearly 60 are native. Native fishes contribute to the biological integrity of aquatic communities and may also be economically, recreationally, and culturally important. Introductions of invasive, non-native fish and aquatic plants are a growing concern of natural resource managers in New Jersey and elsewhere because of their potential to dominate and destroy aquatic ecosystems causing irreversible economic and cultural damage. (Federal Grant F-48-R, Project I) (Smith)

In New Jersey ten species of fish have been identified having the potential to become a significant threat to indigenous animals, the environment, or public safety hazard. Collectively they are referred to and regulated as "potential dangerous fish," which include: Asian Swamp Eel, *Monopterus albus*, Bighead Carp, *Hypophthalmichthys nobolis*, Brook Stickleback, *Culaea inconstans*, Flathead Catfish, *Pylodictis olivaris*, Grass Carp (diploid), *Ctenopharyngodon idella*, Green Sunfish, *Lepomis cyanellus*, Oriental Weatherfish, *Misgurnus anguillicaudatus*, snakeheads, *Channa spp*., Silver Carp, *Hypophthalmichthys molitrix,* and Warmouth, *Lepomis gulosus.* To date, all but the Silver Carp have been documented in New Jersey waters. Possession and/or release of live potentially dangerous fish species is prohibited and when these species are encountered while angling they must be destroyed.

Locations surveyed by NJDFW in 2016 for invasive fish species are listed and described in detail in table below. Green Sunfish were excluded from this table, as they are now fairly widespread, found at 21 locations in 2016, 12 of which are new documentations. Green Sunfish are now found in 15 of 21 counties.

Nineteen Locations sampled by NJDFW for invasive species (excluding Green Sunfish) in 2016

Location	Drainage	Date	Species Targeted	Sampling Gear	Run Time (Hours)	Number of Fish
Delaware River (Trenton)*	Delaware River	8/4/16	Flathead Catfish	Electrofishing	1.5	1
DOD Lake*	Delaware River	6/28/16	Northern Snakehead	Electrofishing	1.6	8
Game Creek	Salem River	7/22/16	Northern Snakehead	Electrofishing	1.0	2
Millstone River	Millstone River	9/28/16	Oriental Weatherfish	Electrofishing	0.88	2
Mullica River	Mullica River	8/5/16	Northern Snakehead	Electrofishing	1.0	0
Newton Lake	Newton Creek	7/19/16	Northern Snakehead	Electrofishing	1.0	6
Silver Lake	Cooper River	6/23/16	Asian Swamp Eel	Electrofishing	1.0	47
Silver Lake	Cooper River	7/14/16	Asian Swamp Eel	Electrofishing	1.06	38
Whites Pond	Saddle River	8/24/16	Oriental Weatherfish	Seining	NA	7

* Sampled as part of other field activities

Asian Swamp Eel

Monitoring and control of the Asian Swamp eel has been limited to backpack electrofishing removal methods. The complexity of the habitat and physiological adaptability of the Asian Swamp Eel significantly hinders chances of successful eradication.

Asian Swamp Eel

Silver Lake (Camden) – Backpack electrofishing surveys have been conducted annually at Silver Lake to monitor the Asian Swamp Eel population since 2008, when they were first discovered there. In 2016 two backpack electrofishing surveys were completed at Silver Lake (10 acres) on June 2 and July 14, 2016 to monitor the invasive Asian Swamp Eel population. A total of 47 Swamp Eels were removed during 1.0 hours of electrofishing on June 23 and 38 were removed during 1.06 hours of electrofishing on July 14. Increased monitoring and removal efforts will continue in 2017. The catch-per-unit-effort (CPUE) of 42 fish/hr.) was slightly lower than 2015 but still higher than the mean CPUE (34/hour) since sampling began in 2008. (See table and figure below). (Smith)

History of Asian Swamp Eel collection at Silver Lake, Camden County.

Year	Number of Asian Swamp Eels Collected	Total Run Time (hrs)	Catch per unit effort (CPUE)
2008	355	7.73	46
2009	189	11.68	16
2010	224	7.68	29
2011	159	4.09	39
2012	119	2.85	42
2013	305	5.9	51
2014	123	4.36	29
2015	78	1.31	59
2016	85	2.06	42
Total	1637	47.66	34

CPUE (fish/hour) of Asian Swamp Eels collected from Silver Lake 2008 – 2016.

Northern Snakehead

DOD Lake (Salem) – The DOD Lake WMA is a 120-acre borrow pit located in Penn Grove. A lake inventory and management plan was completed in 2002. The Largemouth Bass population has fluctuated since acquisition by NJDFW in 1999. Boat electrofishing surveys to monitor the Largemouth Bass population were completed in 2010, 2011, 2014, 2015 and 2016. DOD Lake has been stocked with Musky, Tiger Musky, Smallmouth Bass, Channel Catfish, White Crappie, Largemouth Bass, and Striped Bass since the lake was acquired. DOD Lake has received surplus stockings of Smallmouth Bass, Channel Catfish, Tiger Musky, and Musky since 2013. These stockings are not part of the annual stocking schedule. None of these species were encountered during sampling in 2016. The stocking of these species should continue in order increase diversity of the fish population and give anglers additional fishing opportunities.

Seasonal Technician Kyle Civalier holding a Northern Snakehead from Cooper River Lake 2015

In 2016 a boat electrofishing survey was completed on June 28, 2016 to evaluate the Largemouth Bass and Northern Snakehead population. A total of 45 Largemouth Bass were collected in 1.5 hours of daytime electrofishing. There were 35 bass greater than the 200 mm (8 in.) stock size indicating a CPUE of 23 bass/hour. The PSD was 89 and PSD-P was 11 indicating the population is slightly unbalanced. Northern Snakeheads were first reported in 2014 and the presence confirmed by NJDFW in 2015. Eight Northern Snakeheads were collected in 2016, measuring 225 - 530 mm (8.9 – 20.9 in). In comparison, two Northern Snakeheads were collected in 2015. The snakehead population appears to be growing and will continue to be monitored to determine the impact on the Largemouth Bass population. (Smith)

Newton Lake (Camden) – Newton Lake is a 40-acre impoundment of Newton Creek bordered by Collingswood, Oaklyn and Haddon Township. Much of the lake is maintained by the Camden County Parks System. Newton Lake has a small paved boat ramp, ample trailer parking, and good shoreline access for anglers. The lake is family friendly with a playground and temporary restrooms nearby. A fish ladder to increase spawning habitat for Alewife and Blueback Herring was installed in the early 2000's and subsequently deemed a pathway for the invasive Northern Snakehead.

A boat electrofishing survey was completed on July 19, 2016 at Newton Lake to evaluate the Largemouth Bass and Northern Snakehead populations. A total of 42 Largemouth Bass were collected, of which 39 were greater than the 200 mm (8 in) stock size. The CPUE was 39 bass/hour based on one hour of daytime electrofishing. The largest bass measured 480 mm (18.90 in) and weighed 1.695 kg (3.74 lbs.). A PSD of 56 and PSD-P of 36 indicate a slightly unbalanced population. A total of six Northern Snakeheads were collected ranging in size from 320-675 mm (12.6 - 26.6 in) and weighed .260-3.140 kg (.57 - 6.92 lbs.). Submerged aquatic vegetation is rather abundant in Newton Lake and provides excellent habitat for both Largemouth Bass and Northern Snakeheads. The lake will continue to be monitored for the presence of Northern Snakeheads and any impact on the Largemouth Bass population. (Smith)

Oriental Weatherfish

The Oriental Weatherfish (*Misgurnus anguillicaudatus*), one of ten fish species regulated as an invasive species in NJ, was recently confirmed in 2015 in a small tributary to the Neshanic River in Flemington, Hunterdon County. This marks the second watershed in which this common aquarium fish has been documented in NJ. The first documentation was in the Saddle River in 2001. NJDFW staff responded to an angler that reported catching three in a minnow trap.

Live Oriental Weatherfish (above)
Sexual dimorphism male on left and female on right (below)

Upon further field investigation in 2015, 73 Oriental Weatherfish were documented and removed by NJDFW staff at several locations, including adjacent tributaries, downstream in the Neshanic River, and approximately 11 miles downstream from the original encounter South Branch of the Raritan River at Studdiford Drive in Hillsborough Twp. In 2016, two Oriental Weatherfish were found in the Millstone River below the Blackwells Mills Dam. The Millstone River is within the Raritan Watershed and is approximately 26 river-miles from the initial location found in 2015. This lack of containment within a pond or small tributary makes the success of any eradication plan highly unlikely. Further field sampling is necessary to determine the extent of their distribution within the watershed. (Crouse)

Miscellaneous Non-native Species

Several species that are non-native to New Jersey waters were reported and confirmed in 2016 by NJDFW personnel (see table below). Although the species listed below are not legally regulated as potential dangerous fish species, they have potential to cause ecological and economic harm in New Jersey.

A Bigmouth Buffalo (*Ictiobus cyprinellus*) was collected at Mercer Lake during a daytime boat electrofishing survey on October 18, 2016. Typically found in the Mississippi River drainage and lower Great Lakes, the origin of this fish is unknown. A 14-lb. Redtail Catfish (*Phractocephalus hemioliopterus*) was caught by an angler on August 30, 2016 at Duck Pond in Secaucus and reported to NJDFW (see photo on right). Redtail Catfish are native to South America, and are common in the aquarium trade. However, they can quickly outgrow their captive holdings leading to illegal releases it into nearby waters. A freshwater Angelfish (*Pterophyllum* sp.), native to the Amazon River basin of South America, was observed on the Passaic River near Elmwood Park during a daytime Northern Pike boat electrofishing survey on October 12, 2016. Angelfish are

14-lb. Redtail Catfish

extremely popular within the aquarium pet trade and are commonly kept by aquarists. Eleven Tilapia (*Oreochromis* sp.) were collected via dipnet from Carnegie Lake on April 20, 2016 by the NJDFW (see photo below). Tilapia are native to the African continent, and are a popular food fish raised in the aquaculture market. Up to six additional Tilapia were observed but not collected. The source of this angelfish is mostly likely the result of an illegal release of a pet fish. Releasing or stocking any fish in the state of New Jersey is illegal without a permit issued by the NJDFW. All the above mentioned fish are considered non-native within the state of New Jersey. Fish collected by NJDFW personnel were removed and disposed of.

Location	Drainage	Date	Species	Number	Gear
Mercer Lake	Assunpink Creek	10/18/2016	Bigmouth Buffalo	1	Electrofishing Boat
Carnegie Lake	Millstone River	4/20/2016	Tilapia sp.	11	Dipnet
Passaic River	Passaic River	10/12/2016	Angelfish	1	Visual Observation
Duck Pond	Hackensack River	8/30/2016	Redtail Catfish	1	Angler Catch

11 Tilapia averaging 12 inches from Carnegie Lake

Aquatic Invasive Plant Management

Water chestnut, a non-native aquatic plant species that can rapidly colonize a waterbody once it is established, is becoming increasingly prevalent in New Jersey's waters. Early detection is the key to Water Chestnut control, since smaller populations are easier to eliminate than larger ones. It also costs less to control a small infestation because plants can be individually hand-pulled. A large population requires the use of mechanical harvesters or application of aquatic herbicides to achieve control. It can be difficult and costly to eradicate water chestnut given this plant's hardiness (seed pods remain viable for 10+ years) and abundance. Water chestnut is now found in approximately 24 waterbodies in 10 counties. Most new sightings are brought to our attention by anglers, who typically mention that they were made aware of the problem via recent invasive species articles in NJDFW's Freshwater Fisheries Digest. (Federal Grant F-48-R, Project I) (Smith)

Water chestnut seed pods: immature (left) and mature (right).

Newly Identified Locations in 2016

Water Chestnut was only found in one new location in 2016. An isolated Water Chestnut plant was found in Round Valley Reservoir on June 6, during a reproduction check. This plant was removed from the reservoir.

Solitary Water Chestnut plant found in Round Valley Reservoir on June 6, 2016.

FISH HEALTH

Cyanobacteria

Cyanobacteria, unlike more typical green algae, can produce toxins which can cause rashes on humans and pose a risk to animals drinking or swimming in affected areas of a waterway. A cyanobacterial Harmful Algal Bloom (HAB) is the name given to the excessive growth, or "bloom", of cyanobacteria, some of which can produce one or more types of potentially harmful toxins. These "blooms" often result in a thick coating or "mat" on the surface of a waterbody, often in late- summer or early fall. It is important to note that some blooms are due to common green algae and not cyanobacteria and, when present, cyanobacteria do not always produce cyanotoxins (HAB's Fact Sheet, NJDEP)

A cyanobacteria bloom was documented by NJDEP's Bureau of Freshwater and Biological Monitoring (BFWBM) at Assunpink Lake on Monday, October 3, 2016. A sample was collected and the cyanobacteria (blue green algae) anabaena sp. was identified. An initial screening test indicated toxin levels of microcystins > 10µg/l. Freshwater Fisheries staff prepared signs advising users of the lake of the harmful bacteria and potential effects if they or their pets were to come into contact in areas where the bloom was occurring. As a precautionary measure anglers were advised not to eat any fish caught from the lake while the bloom was present.

Further testing on October 4 and 5 confirmed the presence of high concentration of toxins in samples of the bloom. Additional lab analysis indicated Microcystins > 20 µg/l. This is in the WHO guidance as high recreational risk BFWBM recommended keeping the advisory in place. A dog trial scheduled in the vicinity of the lake was cancelled due to concerns of dogs entering the lake in the vicinity of the bloom. On October 11, 2016 no further evidence of the cyano bloom or toxins were detected at Assunpink and the advisory was removed.

A cyanobacteria bloom was also documented at Shepherd Lake located within Ringwood State Park in Passaic County on October 7, 2016. Although cyanobacteria were documented, unlike Assunpink Lake, little to no toxin was detected. The lake was posted with an advisory as a precautionary measure. (Barno)

Drought Watch/Warning

Exceptionally low flows plagued New Jersey's waterways for most of 2016. Impacts of extended dry weather patterns were further intensified by consecutive days of extreme temperatures during the summer. Stream temperatures in the Musconetcong River, in a Trout-Maintenance classified section, were documented in excess of lethal limits for trout. The combined low flows and high temperatures took a considerable toll on the state's aquatic resource. Fortunately, some coldwater, groundwater fed headwater streams no doubt were spared the full brunt of these impacts. On July 25, 2016, an official Drought Watch was issued for most of northern New Jersey. Persisting dry weather patterns resulted in a Drought Warning being declared on October 21, 2016 for 14 counties within the North (east and west), Central and Coastal North Water Supply Regions (Administrative Order 2016-10). Northern reservoir levels, especially Spruce Run and Round Valley Reservoirs were particularly low. Monksville Reservoir was also lowered for the first time in ten years.

A Drought Warning results in established minimum passing flow requirements to be reviewed and often reduced within affected areas. Drought conditions during the summer months are typically far more detrimental, than cooler seasons, due to reduced water temperatures, adequate oxygen, etc. However, due to the existing exceptionally low stream conditions the newly proposed passing flows are well beyond any flows that we have experienced in some cases in over 60 years. As a result, impacts to aquatic biota under these extreme conditions are difficult to predict.

Fish Health Rules

Expanded Fish Health testing requirements for private fish culture facilities, proposed in 2015, took effect in March 2016. The changes include testing for major salmonid pathogens for trout regardless of the type of waterbodies being stocked, and requiring fish health testing for warmwater species. In an effort to reduce the risk of potential disease transfer into NJDFW's Pequest Trout Hatchery, the Pequest Trout Hatchery is now the only source of trout for the Pequest River Drainage beginning in 2016. The use of trout as bait, which are often purchased from private fish culture facilities, was also prohibited within the drainage. The Pequest Trout Hatchery and the Hackettstown State Fish Hatchery were already established as the only sources of fish for the Pequest Wildlife Management Area and Trout Brook (Hackettstown), since Fish Health Regulations were incorporated into the Fish Code in 2008. (Barno)

Only one organization stocks a privately owned stream stretch with trout within the drainage. The organization was provided surplus trout from the Pequest Trout Hatchery, at fair market value, to maintain recreational opportunities for stocked trout within this private stretch.

Fish Kill Investigations

Field investigations are conducted in response to reports of fish kills, distressed fish, unknown fish parasites, or to address potential pathogen issues in wild fish. These investigations are often a collaborative effort between the Bureau of Freshwater Fisheries staff (Federal Grant F-48-R, Project II) and the fish pathologist in the NJDFW's Office of Fish and Wildlife Health and Forensics (under Grant FW-69-R administered by that Office). In 2016, the Bureau of Freshwater Fisheries responded to fish kills at eleven waterbodies:

Assunpink Lake (Monmouth) – Spring fish kills have become a common occurrence at Assunpink Lake which is a popular fishing destination for bass and regulated as a *Lunker Bass Lake*. Bluegill is a species commonly affected. Division Fish Pathologist identified bacteria closely related to *Pseudomonas mandelii* as the cause of extensive fish kills at both Assunpink and Swartswood Lakes in the Spring 2015. This species has not been previously noted as a fish pathogen, though in fish kills at both lakes the bacterium caused systemic infection in the fish.

It is believed that the spring is a stressful season for the fish, causing immunosuppression and opportunistic infection with pathogens. In addition to bacterial agents, parasites may also cause mortality in fish populations. To better understand the parasites in the Bluegill populations in Assunpink Lake, Fish Pathologist, Dr. Jan Lovy had Bureau staff collect 40 Bluegills in March, and another 30 Bluegills in September to determine if parasite prevalence is greater in the spring than in the summer. Laboratory results are still pending.

Bargaintown Lake (Atlantic) – Bargaintown Lake is an impoundment of Patcong Creek located in the town of Bargaintown. A fish kill investigation was conducted on September 13, 2016 following a report of dead catfish received on September 9, 2016. Upon arrival no dead or dying fish were present. No foreign odors or chemicals were observed. Largemouth Bass, Bluegill and Mummichog were observed swimming along the bank. Water chemistry from the lake was recorded; dissolved oxygen measured 5.31mg/L, salinity 0.04ppt, and temperature 24.1 C (75 F). Present water chemistry conditions readily support aquatic life. No further action was warranted.

Bedminster Pond (Somerset) - A minor fish kill was reported to the Bureau in a small pond located off of Route 202/206 North in Bedminster Township. A Division Conservation Officer investigated and observed approximately 20 dead fish, identified as Gizzard Shad and Common Carp. No odor or sheen were observed, suggesting no dump or spill. Division fish pathologist, Dr. Jan Lovy, suspects this to be a typical spring mortality pattern, possibly due to an opportunistic bacteria or parasite due to warmer water temperatures with Gizzard Shad being very susceptible. It was determined that no further action is warranted at this time.

Budd Lake (Morris) - A fish kill was investigated at Budd Lake on June 1, 2016. It was estimated that the kill affected approximately 700 White Perch, 20 Black Crappie, 2 Bluegill, and 5 Bullhead Catfish. Majority of the dead fish were found near the public beach and the boat docks. Water temperatures ranged from 21°C to 27°C depending on depth. Dissolved oxygen was adequate (between 7-9 mg/L) throughout most of the water column, though lower at the bottom. Five White Perch and two Black Crappies were submitted to the Fish Pathology Laboratory for analysis.

Division Fish Pathologist, Dr. Jan Lovy, determined the cause of the kill was related to columnaris disease caused by *Flavobacterium columanare*, a bacterial infection in the gills and skin. This bacterium causes necrosis of skin and gill tissue. The bacterium is found throughout the aquatic environment and can cause disease in stressed fish populations. With Budd Lake being a relatively shallow lake and sudden increase to above average temperatures, it was likely that the predisposing stressor was the quick warming of water temperatures that occurred just prior to the kill that led to the columnaris outbreak.

Carnegie Lake (Mercer) – This 237-acre lake was sampled for Muskellunge by Bureau staff using trap nets between April 19 – 20, 2016 as part of the Coolwater Fisheries Stocking Assessment Project. Unfortunately, a significant die-off of Gizzard Shad coincided with the netting effort on the lake. Dr. Jan Lovy, the Division's fish pathologist, identified samples collected by Bureau staff to have a gill disease caused by the protozoan parasite, *Ichthyophthirius multifiliis*. This is a common outbreak that can occur in the spring, but do to the significant number of Gizzard Shad affected was alarming to local residents. Due to the extensive die-off trap netting efforts were discontinued after two days.

Cohansey River Tributary (Cumberland) - A fish kill in an impoundment on a tributary of the Cohansey River, Cumberland County was reported to the Bureau of Freshwater Fisheries on August 1, 2016. The impounded area is formed by a water control structure (floodgate) downstream of Bridgeton-Greenwich Rd. Three small tributaries, including Mounces Creek, Mill Creek and Wheaton Run drain into the impoundment upstream of the water control structure. The floodgate was replaced approximately two to three months ago. The previous structure failed many years ago and was no longer operating as designed, resulting in a much larger impoundment area than desired. The new structure, now operating properly, has reduced the amount of impounded water.

On August 2, 2016, approximately 500-1000 postmortem adult Common Carp, ranging from 10-15 lbs., were observed throughout the impoundment. Common Carp are an invasive species that are found commonly throughout the state. In addition, a few postmortem Channel Catfish, Brown Bullhead and White Perch were observed. Live Mummichogs were observed feeding on the decomposing fish. The Cohansey River appeared to be close to high tide, downstream of the floodgate, at the time of the inspection. Water chemistry was collected from the bridge on Bridgeton-Greenwich Rd. Dissolved oxygen, temperature and salinity were all adequate to support a fish population.

Water Chemistry
Dissolved Oxygen 7.14 mg/l
Salinity 0.31 ppt
Temperature 28.7 C
Salinity Downstream of Floodgate 7.56 ppt

The fish kill appears to be the result of the recent heat wave with numerous days in excess of 90 degrees. The combination of a very shallow impoundment, super heating of the water and a high concentration of large fish in a small area resulted in the significant fish kill.

Deer Path Park Pond (Hunterdon) - As a result of a significant rain event on Sunday July 31, there was a complete failure of the dam at Deer Path Park Pond, owned by Hunterdon County Parks. Fisheries Biologist arrived on site to evaluate on Monday morning. The 2-acre pond was reduced to a stream channel, cutting through decades of accumulated silt, with very few fish left behind. It is assumed that the majority of the fish were swept downstream approximately one mile, into the South Branch of the Raritan River via an unnamed tributary. Staff waded downstream along the tributary and observed the impacts of the high flows including erosion, sediment deposition, and vegetation damage. Approximately 50 dead fish, consisting of Bluegills, Black Crappie, and Largemouth Bass were observed within the wooded floodplain once the water receded, however the total loss was difficult to document as they were very dispersed within the wide floodplain. No fish salvage is necessary. The Division will restock this pond with an assortment of warmwater fish if/when the dam is rebuilt.

Deer Path Park Pond reduced from 2 acres to a stream channel anda small shallow pool after its dam failed in 2016

Jacob's Creek (Mercer) - Two Green Sunfish and one Creek Cub collected during a Bureau electrofishing survey of Jacob's Creek were submitted to the Pequest Fish Health Lab. The stream had particularly low flow; water temperature was 15.3°C, dissolved oxygen was low (2.04 mg/L), and pH was neutral at 7.13. All three fish had visible lesions. The Creek Chub had a deeply ulcerating lesion that went through the skin and muscle. The fish was unlikely to survive this deeply penetrating wound. The State Fish Pathologist detected a small number of fungal hyphae (Saprolegnia sp.) and several cysts caused by a parasite (dermocystidium-like organism) within the lesion. Dermocystidium is a parasite that belongs to the class Mesomycetozoea, which are organisms at the boundary of the animal and fungal divergence. These parasites are known to cause skin infections in various fish species. Considering the advanced progression of the skin lesion in the Creek Chub it is uncertain if this parasite was the primary cause of the large skin/muscle ulceration. This skin infection was likely the result of endemic parasites/fungi combined with poor water conditions.

One Green Sunfish had a severe skin lesion that extended deep into the musculature. No bacteria or fungi appeared associated with the lesion. Inspection of the tissue showed severe dermatitis extending into the musculature with cell death occurring throughout the lesion suggesting a viral origin, though this could not be confirmed.

Lily Lake (Cape May) – Lily Lake is a small impoundment located in the town of Cape May Point. A fish kill investigation was conducted on August 11, 2016. Fish kills at this location have been reported in the past. Upon arrival, the lake appeared significantly lower than normal and 11 submerged aerators were operational. No foreign odors or chemicals were observed. Several hundred dead adult fish were reported by local public works employees consisting primarily of Largemouth Bass and Bluegill. The dead fish were removed prior to the on-site inspection by Bureau personnel. At the time of inspection, well water was being pumped directly into the lake by the township at a reported rate of 100,000 gallons a day in an effort to remedy the fish kill. High salinity levels were observed within the well water and the recommendation to stop pumping into the lake was given. Saltwater intrusion from past flood events and saline groundwater conditions were also noted. Low dissolved oxygen and high salinity levels were found within the lake. Water chemistry from the lake was recorded; dissolved oxygen measured 1.93mg/L, salinity 0.98ppt, and temperature 30.9 C (87.6 F). Low dissolved oxygen levels appear to be the primary cause of the fish kill. Water chemistry was also collected directly over an operating submerged aerator and 50 meters away from the aerator. Dissolved oxygen levels were similar at both locations and indicated that the aerators do not effectively increase dissolved oxygen levels within the lake.

Memorial Day Weekend Fish Kills - Fish kills were reported at four lakes over Memorial Day weekend. All kills reported involved relatively small numbers of fish and seem to last several days with diminishing mortality. A sudden increase in air temperature led to dramatic increases in water temperatures. Many warmwater species such as bass, sunfish and crappies are also spawning which puts added stress on the fish. Interestingly, all kills reported were for lakes located within the Northwest area of the state. No similar fish kills were reported for waterbodies located in the central or southern areas of the state which also experienced the same dramatic increases in water temperatures.

Greenwood Lake (Passaic) – A small number of Alewives, bass, and crappie were reported to have died starting just prior to the holiday weekend. Die off diminished over the course of the weekend. Due to the relatively small extent of the kill and that it was diminishing neither New York nor New Jersey biologists felt further investigation was warranted.

Lake Hopatcong (Morris/Sussex) – A local resident reported to NJ Parks and Forestry staff that a small fish kill (less than 100 sunfish) had occurred in a small cove near Halsey and Raccoon Island around Memorial Day. When contacted, the resident indicated that fish were no longer dying and the and that he (and the snapping turtles) had disposed of most of the fish carcasses. Unfortunately, the cause of death could not be determined from decomposing fish. The resident was advised to contact us in the event more fish begin to die, so we could collect fish (distressed/dying/freshly dead fish) and provide them to our fish pathologist for examination in the lab. No further reports of dead or dying fish were received and it is suspected that the fish were stressed by the recent hot weather and more prone to bacterial disease infections.

Paulins Kill Lake (Warren) - Approximately 15 dead catfish were reported. No other fish reported.

Upper Greenwood Lake (Passaic) – Approximately 250 dead pickerel, sunnies, bass, crappie, and catfish were reported to have died over the holiday weekend. Similar to the Greenwood Lake fish kill dead fish were seen over the course of three days but the number of dead fish diminished each day. No further investigation warranted.

Pitman Golf Course (Gloucester) - A fish kill was reported on August 2, 2016 at the Pitman Golf Course by the Gloucester County Health Department. Approximately 25 Common Carp, ranging in size from 12 to 16" were affected. Live mosquito fish were observed in the three ponds on the golf course. The ponds which were all less than one acre in size all had a noticeable odor and were discolored. The water appeared to have an unusual black color and sheen, which is characteristic of the discharge of sewage effluent. The dissolved oxygen levels in the ponds ranged from .03 mg/l to 0.16 mg/l and were too low to support fish. Inspection further upstream of Golf Club Rd. indicated that the anaerobic water originated from presumably a failed residential septic system which was leaching into the stream feeding the pond. The dissolved oxygen in the unnamed tributary of Chestnut Branch (stream) was also below levels to sustain fish at 1.7 mg/l. The findings were reported back to the Gloucester County Health Department. Golf Course staff were informed that the fish kill will continue until the source of sewage effluent is identified and corrected.

Raritan River S/Branch (Hunterdon) – Two Rainbow Trout, captured from the South Branch of the Raritan River, Ken Lockwood Gorge section on July 20, 2016, were submitted to the Fish Pathology Laboratory. The trout were captured by the Bureau of Freshwater Fisheries during routine sampling of the river (page A53). The Rainbow Trout had noticeable skin lesions on their sides. The trout appeared to be hatchery-stocked fish according to the condition of the pectoral, pelvic, and dorsal fins. One fish had signs of a systemic bacterial infection and the atypical strain of *Aeromonas salmonicida* was isolated from the kidney of this fish. The atypical strain is believed to be *A. salmonicida achromogenes* based on identification and growth characteristics. The clinical signs of infection in the Rainbow Trout were similar to other reports of salmonids and other species with atypical furunculosis.

An angler also reported catching an eleven-inch Rainbow Trout also within the Ken Lockwood Gorge Wildlife Management Area. The trout was reported to have a red, blister-like boil the size of a golf ball on its body. Unfortunately, the angler released the fish back into the river.

West Portal Creek Fish Kill - On May 5, 2016 a catastrophic fish kill occurred on West Portal Creek, a small *Trout Production* stream that flows into the Musconetcong River. A truck fire had occurred on Interstate 78 the previous evening and during the ensuing clean-up a large amount of detergent lethal to aquatic biota washed into West Portal Creek. Bureau of Freshwater Fisheries staff responded and determined that a 2.8-mile section of the creek, from the I-78 bridge to the Musconetcong River, was impacted by this spill. On May 5, 2016, NJDFW collected 1,109 dead fish (13 species) at four sites totaling a distance of 3/4 mile. Nearly 50% of the dead fish collected

Detergent in West Portal Creek, May 5

Same location, May 6

Representative aquatic organisms killed

were wild (not stocked) Brown and Brook Trout and all year classes of trout were affected. Salamanders, crayfish, and macroinvertebrates were also killed. The loss of wild Brook Trout, which are few in number in this stream, is of grave concern. Brook Trout is the only trout species native to New Jersey and it is estimated that today they survive in less than half their original range in our state. This species has recently been identified as a Species of Special Concern in New Jersey. West Portal Creek is among the most southern of New Jersey's *Trout Production* streams inhabited by wild Brook Trout. Another fish species impacted by the spill, the Slimy Sculpin (soon to be listed as state Threatened), rivals trout as an excellent indicator of cold, clean water, and a healthy ecosystem.

A short-term (5 day) bioassay study was later initiated on May 11, 2016 to assess if conditions in West Portal Creek remained toxic to fish. Test fish (fingerling rainbow trout from the Pequest Trout Hatchery) were placed in cages at six locations and checked daily. After the first two days of the study all test fish were alive. The Bureau then initiated a project to actively restore native fishes (Brook Trout and Slimy Sculpin) to the creek (described more fully in the Conservation and Restoration of Fish Habitat and Technical Assistance – Coldwater section on page 56)

Fish Salvages

Permitted fish salvages are necessary under a variety of circumstances, such as substantial water lowering events related to projects such as the dredging of a lake or the repair of a dam. These salvages are typically conducted by trained private aquatic consultants and are conducted under controlled circumstances, during the more favorable conditions encountered in the fall and can be a relatively simple exercise. On the other hand, every year, as the result of a catastrophic dam failure or merely a minor leak, compounded with increased water temperatures and diminished oxygen levels during the summer, countless fish are threatened with demise. During emergency situations on state owned property such as Wildlife Management Areas or those managed by the Division of Parks and Forestry, the Bureau of Freshwater Fisheries may mobilize to conduct fish salvages to rescue fish and relocate them to suitable waters. (Hunter and Angler Fund)

Clove Brook (Sussex) – Staff from the Bureaus of Freshwater Fisheries, Fish Production and Law Enforcement performed a fish salvage in Clove Brook, at the base of the Clove Lake dam. Fish from the lake slowly make it over the dam when water is spilling over the dam. Due to the lack of rainfall there was little overflow. Fish became trapped in a deep twelve-foot pool at the base of the dam. Fish were distressed (gulping at the surface) due to the lack of flow and subsequent low oxygen due to the large number of fish congregated in the pool area. Approximately 20 dead fish were observed. Division staff netted approximately 2,000 fish (bass and sunfish) from the pool area and returned them to the lake. (Barno)

SURFACE WATER CLASSIFICATION

Surface Water Classification Assessments

Trout are useful bioindicators of stream health as excellent water quality and habitat are necessary for their survival and successful reproduction. In 1968, the Bureau of Freshwater Fisheries initiated the process of identifying and classifying New Jersey waters according to their suitability to support trout. Five years later, a classification system for New Jersey waters was developed. The Bureau's classification system, although already in use by various programs within the Department, was formally recognized in 1981 under the state's newly adopted *Surface Water Quality Standards* (SWQS).

Today, waters of the state are classified according to their suitability to support trout. Lakes are classified on their ability to support trout year round, whereas streams are classified on the occurrence of natural reproduction and the presence or absence of trout and/or trout associated species (Hamilton and Barno 2006). Ultimately, the more suitable a waterway is to supporting trout the higher the classification and the more protection it will receive. The Department's Land Use Regulation Program, through Stream Encroachment, Freshwater Wetlands, and the more recently developed storm water rules acknowledge the fragile nature of these ecosystems and provide additional protective measures.

Although a vast amount of work has been accomplished in classifying New Jersey waters, waters continue to be classified and reclassified according to their trout supporting capabilities, when justified by additional field investigation data collected by NJDFW. These data are interpreted and recommendations for surface water classification changes are provided to DEP's Bureau of Water Monitoring and Standards, Environmental Analysis Restoration and Standards, who ultimately integrate changes to the SWQS through an established rule making process. (Federal Grant F-48-R, Project I) (Crouse)

Stream Assessments for Surface Water Classification

During the summer months, a 150-meter section of stream is electrofished (single-pass) using one or more backpack electrofishing unit or a generator positioned on land or in a barge, with 2-3 hand-held anodes (Appendix B). All fish are captured and enumerated by species (total length measurements taken on all salmonids). Physicochemical parameters measured include water temperature, dissolved oxygen, pH, alkalinity, conductivity, specific conductance, and stream width, depth, and substrate type. The EPA Rapid Bioassessment habitat assessment protocol is used to assess in-stream habitat and riparian conditions (Barbour et al. 1999) with regional modifications (Appendix C). (Federal Grant F-48-R, Project I)

Double backpack electrofishing crew

In 2016 six electrofishing surveys were conducted on four streams specifically for classification purposes by the Bureau under Grant F-48-R, Project I. All four streams were unnamed tributaries, however NJDFW recommends individually listing them with the names provided: Musconetcong

River (trib) (NW of Stephensburg), (Musconetcong River (trib) (S. of Asbury), Whippany River (trib) (W. of Watnong Brook), and Bear Brook (Park Ridge). Four of the six stream surveys resulted in recommendations to upgrades their current SWQS classifications (see Table 2) and two surveys resulted in confirming existing default classifications (see Table 4).

Data from 53 additional stream electrofishing surveys, also conducted in 2016 under a variety of other jobs and/or funding sources are valuable in confirming existing classification as well as identifying potential upgrades (Table 1). Twelve stream surveys conducted in 2016 support potential surface water classification changes, six of which are upgrades to *Trout Production* and two to *Trout Maintenance* (Table 2).

Table 3 consists of two stream segments in which apparent naming discrepancies occur in the Courtesy Copy of Title 7 of the New Jersey Administrative Code N. J. A. C. 7:9B Surface Water Quality Standards Statutory Authority: N.J.S.A. 58:10A-1 et seq., 58:11A-1 et seq., and 13:1D-1 et seq. Re-adopted: October 17, 2016 Last Amended - January 18, 2011 (43 N.J.R. 174(b)) http://www.nj.gov/dep/rules/rules/njac7_9b.pdf . Both stream segments are individually listed, however they should be listed as tributaries, not as they are currently listed.

In addition to recommending changes to existing surface water classifications, since 2006 NJDFW has reported surveys in which data confirm existing surface water classifications. The 2016 data confirmed the classifications of 28 stream segments, therefore no action is required (Table 4). At times, electrofishing surveys yield data that neither confirm an existing use (classification), nor warrant a change to the existing use (classification), as classifications are not downgraded unless proven the existing use can not be re-established. This was true for surveys at eighteen locations in 2016, therefore no action is required (Tables 5).

Table 2. Summary of recommended surface water classification changes supported by 12 surveys conducted in 2016 by NJDFW. Reproducing trout species determined by the presence of young-of-the-year trout. A current surface water classification enclosed by brackets indicates a default surface water classification (i.e. the waterbody is not specifically listed in NJ's Surface Water Quality Standards, N.J.A.C. 7:9B). I.O. = Incidence of Occurrence; NA = Not Applicable (due to presence of trout reproduction).

Waterbody	Waterbody section	Midpoint of survey		Current surface water classification	Recommended surface water classification	I.O. value	Reproducing trout species	Survey date	Page
		Lat. (N)	Long. (W)						
Upper Delaware (South) Region (Delawanna Creek to Lockatong Creek watersheds)									
*Buckhorn Creek (trib) (Roxburg)	Entire length, including all tributaries	40º46'41.3"	75º5'56.1"	[FW2-TP(C1)]	FW2-TP(C1)	NA	Brown	8/26/16	A28
*Buckhorn Creek (trib) (Summerfield)	Entire length, including all tributaries	40º48'12.2"	75º3'12.6"	[FW2-TP(C1)]	FW2-TP(C1) [d]	NA	Brook	8/16/16	A29
*Musconetcong River (trib) (NW of Stephensburg)	Entire length, including all tributaries	40º47'59.2"	74º52'47.3"	[FW2-TM(C1)]	FW2-TP(C1)	NA	Brook	7/22/16	A34
*Musconetcong River (trib) (S of Asbury)	Entire length, including all tributaries	40º46'30.8"	74º0'16.6"	[FW2-TM(C1)]	FW2-TP(C1)	NA	Brook & Brown [c]	8/5/16	A35
Upper Passaic Region (Pompton, Pequannock, Wanaque, Ramapo, Upper Passaic, Whippany, & Rockaway River watersheds)									
*Whipanny River (trib) (W of Watnong Brook)	Entire length	40º48'53.9"	74º30'21.6"	[FW2-NT]	FW2-NT	12.7	none	9/2/16	A40
Lower Passaic & Upper Atlantic Region (Lower Passaic, Saddle, Hackensack, Pascack & Elizabeth to Toms River watersheds)									
*Bear Brook (Park Ridge)	Source to Spring Valley Road, including all tributaries	41º2'28.6"	74º3'47.9"	[FW2-NT(C1)]	FW2-NT(C1)	9.3	none	8/17/16	A41
*Bear Brook (Park Ridge)	Spring Valley Road to Woodcliff Lake, including all tributaries	41º1'56.0"	74º3'20.6"	[FW2-NT(C1)]	FW2-TM(C1)	22.6	none	8/24/16	A42
*Bear Brook (Park Ridge)	Spring Valley Road to Woodcliff Lake, including all tributaries	41º1'53.3"	74º3'11.7"	[FW2-NT(C1)]	FW2-TM(C1)	50.1	Brown [e]	8/5/16	A43
Raritan Region (Raritan River watershed)									
Raritan River S/Br (Ken Lockwood Gorge)	River and tributaries within Ken Lockwood Gorge WMA [b]	40º42'7.5"	74º52'4.8"	FW2-TM(C1)	FW2-TP(C1)	NA	Brook [c] Brown & Rainbow	7/20/16	A53
Raritan River S/Br (Ken Lockwood Gorge)	River and tributaries within Ken Lockwood Gorge WMA [b]	40º41'47.2"	74º52'18.2"	FW2-TM(C1)	FW2-TP(C1)	NA	Brown	7/20/16	A54

Table 2 (continued)

Raritan Region (Raritan River watershed) (continued)									
*Raritan River S/Br (Trib.) (Drakestown)	Entire length	40º51'9.5"	74º46'01.4"	[FW2-NT]	FW2-TP(C1) [a]	NA	Brook	7/5/16	A55
*Raritan River S/Br (Trib.) (SW of Budd Lake)	Entire length	40º51'25.0"	74º46'00.1"	[FW2-NT]	FW2-TP(C1) [a]	NA	Brook	7/5/16	A56

[a] Potential change also supported by survey data collected in 2011 and previously submitted to NJDEP Water Monitoring and Standards Survey in Memo dated March 11, 2013, titled Recommended Changes to Individual Surface Water Quality Classifications.
[b] New boundaries suggested in Memo titled Recommended Changes to Individual Surface Water Quality Classifications (March, 11 2013).
[c] Young-of-the-year trout not present, however trout from older year classes present.
[d] Potential change also supported by data collected in 2006.
[e] Stocked trout
* Indicates unnamed tributary as recognized by SWQS. Name given is recommended by NJDFW.

Table 3. Stream segments in which apparent naming discrepancies occur in the Courtesy Copy of Title 7 of the New Jersey Administrative Code N. J. A. C. 7:9B Surface Water Quality Standards Statutory Authority: N.J.S.A. 58:10A-1 et seq., 58:11A-1 et seq., and 13:1D-1 et seq. Re-adopted: October 17, 2016 Last Amended - January 18, 2011 (43 N.J.R. 174(b)) http://www.nj.gov/dep/rules/rules/njac7_9b.pdf. Both stream segments are individually listed, however they should be listed as tributaries, not as they are currently listed.

Waterbody	Waterbody section	Midpoint of survey		Current surface water classification	Recommended surface water classification	I.O. value	Reproducing trout species	Survey date	Page
		Lat. (N)	Long. (W)						
Upper Delaware (South) Region (Delawanna Creek to Lockatong Creek watersheds)									
*Beaver Brook (trib) (E of Manunka Chunk) [a]	Entire length, including all tributaries	40º51'31.7"	74º2'40.8"	FW2-TM	FW2-TM	25.6	none	8/15/16	A25
*Big Flat Brook (trib) (Lake Ashroe) [b]	Entire length, including all tributaries	41º11'56.6"	74º48'54.8	[FW2-TP(C1)]	FW2-TP(C1)	NA	Brook	7/1/16	A5

[a] This stream segment is misnamed in N. J. A. C. 7:9B Surface Water Quality Standards as "Beaver Brook (Hope) (E of Manunka Chunk) - Entire length, including all tributaries." It is a tributary to Beaver Brook (Hope). The name proposed for individual listing is bases off of data collected in 2006 and 2016
[b] This stream segment is misnamed in N. J. A. C. 7:9B Surface Water Quality Standards as "Big Flat Brook (Tuttles Corner) - Outlet stream from Lake Ashroe to its confluence with Big Flat Brook." It is a tributary to Big Flat Brook. The name proposed for individual listing is bases off of data collected in 2005 and 2016

Table 4. Electrofishing surveys conducted in 2016 by NJ Division of Fish & Wildlife that *confirm existing surface water classifications* as indicted in New Jersey's Surface Water Quality Standards, N.J.A.C. 7:9B. No action is required. Reproducing trout species is determined by the presence of young-of-the-year trout. Data are found in report titled "2016 Investigation & Management of NJ's Freshwater Fisheries Resources."

Waterbody	Waterbody section	Midpoint of survey		Current surface water classification confirmed	I.O. value	Reproducing Trout Species	Date	Page
		Lat. (N)	Long. (W)					
Upper Delaware North & Wallkill Region (Shimmers Brook to Paulins Kill and Wallkill River watersheds)								
Beerskill Creek (Shaytown)	Boundary of High Point State Park to confluence with Little Flat Brook	41º15'34.9"	74º47'34.6"	FW2-TP(C1)	NA	Brook	8/4/16	A1
Forked Brook (Stokes State Forest)	Entire length	41º14'20.9"	74º44'42.3"	FW2-TP(C1)	NA	Brook	8/4/16	A10
Flat Brook (Walpack)	Flatbook-Roy Wildlife Management Area boundary to the Delaware River, except segments described below	41º11'05.9"	74º51'09.1"	FW2-TM(C1)	30.6	Brook [a] & Rainbow [c]	7/9/16	A9
Tillman Creek (Walpack)	Entire length	41º9'28.4"	74º51'27.7"	FW1-TP	NA	Brook	7/29/16	A20
Upper Delaware (South) Region (Delawanna Creek to Lockatong Creek watersheds)								
Barkers Mill Brook (Independence)	Entire length	40º51'17.4"	74º53'29.1"	FW2-TP(C1)	NA	Brook	7/27/16	A21
Barkers Mill Brook (Independence)	Entire length	40º51'27.5"	74º53'47.8"	FW2-TP(C1)	NA	Brook	7/27/16	A22
Barkers Mill Brook (Independence)	Entire length	40º51'43.9"	74º54'1.0"	FW2-TP(C1)	NA	Brook	7/28/16	A23
Barkers Mill Brook (Independence)	Entire length	40º51'50.0"	74º54'9.7"	FW2-TP(C1)	NA	Brook	7/28/16	A24
Buckhorn Creek (Hutchinson)	Entire length	40º47'41.0"	74º4'55.9"	FW2-TP(C1)	NA	Brook & Brown	8/23/16	A26
Buckhorn Creek (Hutchinson)	Entire length	41º46'56.7"	74º6'12.4"	FW2-TP(C1)	NA	Brown	8/23/16	A26
Hakihokake Creek (Milford)	Entire length, including headwaters known as Little York Creek	40º34'3.8"	75º05'40.8"	FW2-TP(C1)	NA	Brown	8/11/16	A30
Hakihokake Creek (Milford)	Entire length, including headwaters known as Little York Creek	40º34'0.4"	75º05'34.1"	FW2-TP(C1)	NA	Brown	8/11/16	A31
Stephensburg Brook (Stephensburg)	Entire length	40º47'34.7"	74º52'16.6"	FW2-TP(C1)	NA	Brook & Brown	7/21/16	A37

Table 4. (continued)

Upper Passaic Region (Pompton, Pequannock, Wanaque, Ramapo, Upper Passaic, Whippany, & Rockaway River watersheds)								
Whippany River (trib) (Brookside)	Entire length	40º48'14.6"	74º34'0.3"	FW2-TP(C1)	NA	Brown & Rainbow	9/2/16	A39
Lower Passaic & Upper Atlantic Region (Lower Passaic, Saddle, Hackensack, Pascack & Elizabeth to Toms River watersheds)								
Cresskill Brook (Demarest)	Duck Pond Rd. bridge to Tenakill Brook	40º56'41.7"	73º56'36.5"	FW2-NT(C1)	17.0	none	7/18/16	A45
Raritan Region (Raritan River watershed)								
Hickory Run (Califon)	Entire length	40º42'55.8"	74º51'45.5"	FW2-TP(C1)	NA	Brook	7/11/16	A47
Hickory Run (Califon)	Entire length	40º42'45.8"	74º51'27.2"	FW2-TP(C1)	NA	Brook & Brown	7/11/16	A48
Raritan River S/Br (Middle Valley)	Dam (located 390 ft upstream of Flanders-Drakestown Road) downstream to, but not including Lake Solitude, including all tributaries not individually listed [b]	40º47'42.2"	74º45'54.4"	FW2-TM(C1)	NA	Brook Brown & Rainbow	7/25/16	A51
Raritan River S/Br (Middle Valley)	Dam (located 390 ft upstream of Flanders-Drakestown Road) downstream to, but not including Lake Solitude, including all tributaries not individually listed [b]	40º47'21.5"	74º46'14.8"	FW2-TM(C1)	NA	Brook & Brown	7/25/16	A52
Rinehart Brook (Hacklebarney)	Entire length	40º44'40.0"	74º44'10.0"	FW2-TP(C1)	NA	Brown	7/26/16	A57
Rockaway Creek Mainstem (Whitehouse)	Confluence of North and South Branches to Lamington River	40º37'45.4"	74º44'8.5"	FW2-NT	9.6	none	7/12/16	A58
Rocky Run (Lebanon)	Entire length	40º41'41.0"	74º54'36.9"	FW2-TP(C1)	NA	Brook	7/26/16	A61
Round Valley Reservoir (Clinton)	Entire Waterbody	39º47'28.5"	75º0'29.6"	FW2-TP(C1)	NA	Lake	7/26/16	App I
Stony Brook (Washington)	Entire length	40º47'49.6"	74º45'17.3"	FW2-TP(C1)	NA	Brook [a] & Brown	8/2/16	A62
Trout Brook (Hacklebarney)	Entire length	40º45'05.0"	74º43'52.5"	FW2-TP(C1)	NA	Brook	7/14/16	A67
Turkey Brook (Mt. Olive)	Entire length	40º50'18.7"	74º44'29.7"	FW2-TP(C1)	NA	Brook & Brown	7/21/16	A68
Willhoughby Brook (Buffalo Hollow)	Entire length	40º40'18.5"	74º54'49.5"	FW2-TP(C1)	NA	Brook & Brown	7/1/16	A69

Table 4. (continued)

Lower Delaware Region (Assunpink Creek to Maurice River watersheds)								
Scotland Run	MAURICE RIVER MAIN STEM (Willow's Grove) Source to the boundary of Union Lake Wildlife Management Area	39º34’17.7”	75º03’33.3”	FW2-NT	3.4	none	8/24/16	A73

[a] Young-of-the-year trout not present, however trout from older year classes present.
[b] New boundaries suggested in Memo titled Recommended Changes to Individual Surface Water Quality Classifications (March, 11 2013).
[c] Stocked trout

Table 5. Electrofishing surveys conducted in 2016 by NJ Division of Fish & Wildlife that *neither confirm an existing use (classification), nor warrant a change to the existing use*, as classifications are not downgraded unless proven the existing use can not be re-established. Reproducing trout species is determined by the presence of young-of-the-year trout. Data are found in report titled "2016 Investigation & Management of NJ's Freshwater Fisheries Resources."

Waterbody	Waterbody section	Midpoint of survey		Current surface water classification	I.O. value	Reproducing Trout Species	Date	Page
		Lat. (N)	Long. (W)					
Upper Delaware (North) & Wallkill Region (Shimmers Brook to Paulins Kill and Wallkill River watersheds)								
Big Flat Brook (Sandyston)	Confluence with Parker Brook, through the Blewitt Tract, to the confluence with Flat Brook, except tributaries described under the listing for Flat Brook, below	41°12'23.5"	74°48'22.3"	FW2-TP(C1)	30.2	Brook [a] & Rainbow [b]	8/2/16	A2
Big Flat Brook (Sandyston)	Confluence with Parker Brook, through the Blewitt Tract, to the confluence with Flat Brook, except tributaries described under the listing for Flat Brook, below	41°11'54.9"	74°49'05.1"	FW2-TP(C1)	33.1	none	7/19/16	A3
Big Flat Brook (Sandyston)	Confluence with Parker Brook, through the Blewitt Tract, to the confluence with Flat Brook, except tributaries described under the listing for Flat Brook, below	41°11'30.6"	74°50'34.6"	FW2-TP(C1)	27.9	Brook [a]	8/2/16	A4
Black Creek (trib) (McAfee)	Entire length	41°11'14.7"	74°32'2.3"	FW2-TP(C1)	100	Brown [a]	8/22/16	A6
Black Creek (trib) (McAfee)	Entire length	41°11'14.9"	74°32'14.7"	FW2-TP(C1)	100	Brown [a]	8/25/16	A7
Little Flat Brook (Layton)	State park boundary to, but not including, tributary described below, to confluence with Big Flat Brook	41°14'24.3"	74°48'11.1"	FW2-TP(C1)	19.4	Brook [a]	8/9/16	A11
Little Flat Brook (Layton)	State park boundary to, but not including, tributary described below, to confluence with Big Flat Brook	41°11'24.1"	74°50'48.7"	FW2-TP(C1)	27.5	Rainbow [b]	8/9/16	A12
Shawanni Creek (Stokes State Forest)	Headwaters and tributaries downstream to, but not including, Shawanni Lake	41°10'8.3"	74°50'25.5"	FW1-TP	NA	No fish found	8/22/16	A17
Shawanni Creek (Stokes State Forest)	Outlet of Shawanni Lake downstream to confluence with Flat Brook	41°9'50.4"	74°51'52.9"	FW2-TP(C1)	48.7	Brown [a]	7/29/16	A18
Sparta Glen Brook (Sparta)	Entire length	41°2'19.2"	74°36'6.7"	FW2-TP(C1)	41.1	Brook [a]	7/15/16	A19

Table 5. (continued)

Lower Passaic & Upper Atlantic Region (Lower Passaic, Saddle, Hackensack, Pascack & Elizabeth to Toms River watersheds)								
Cresskill Brook (Alpine)	Source to Duck Pond Rd. bridge, Demarest	40º56'41.5"	73º56'27.3"	FW2-TP(C1)	31.5	none	7/18/16	A44
Raritan Region (Raritan River watershed)								
Black Brook (Polktown)	Entire length	40º39'39.0"	74º56'54.6"	FW2-TP(C1)	50.1	Brown [a]	7/1/16	A46
Rockaway Creek S/Br (Whitehouse)	Lake Cushetunk to its confluence with main stem Rockaway Creek	40º37'11.6"	74º46'28.3"	FW2-TM	7.6	none	8/3/16	A59
Rockaway Creek S/Br (Whitehouse)	Lake Cushetunk to its confluence with main stem Rockaway Creek	40º37'27.3"	74º45'58.0"	FW2-TM	9.4	none	8/3/16	A60
Sun Valley Brook (Mt. Olive)	Entire length	40º51'17.3"	74º44'34.1"	FW2-TP(C1)	45.5	Brook [a]	7/15/16	A63
Sun Valley Brook (Mt. Olive)	Entire length	40º51'6.5"	74º44'59.6"	FW2-TP(C1)	45.5	Brook [a]	7/14/16	A64
Sun Valley Brook (Mt. Olive)	Entire length	40º51'1.8"	74º45'24.0"	FW2-TP(C1)	26.6	none	7/14/16	A65
Lower Delaware Region (Assunpink Creek to Maurice River watersheds)								
*Masons Run (trib) (Pine Hill)	Source to Little Mill Road	39º47'28.5"	75º00'29.6"	[FW2-TP(C1)]	7.5	none	8/26/16	A71

[a] Young-of-the-year trout not present, however trout from older year classes present.

[b] Stocked trout

* Indicates unnamed tributary as recognized by SWQS. Name given is recommended by NJDFW.

Lake Assessments for Surface Water Classification

As part of the continued assessment of New Jersey waters dissolved oxygen and temperature profiles are performed to determine a lake's ability to support trout throughout the harsh summer months. During the summer, most New Jersey lakes deeper than 3 m (10 ft) thermally stratify. The epilimnion (surface waters) become too warm to support coldwater fishes (trout), and the metalimnion and hypolimnion (middle and bottom waters), while often cold enough for trout, often have dissolved oxygen levels too low to support trout (and other fish species). Only deep lakes (generally at least 15 m (50 ft) deep), that are not overly eutrophic, maintain sufficient levels of dissolved oxygen in some portion of the strata below the epilimnion during the summer and early fall. A water temperature and dissolved oxygen profile is conducted in the deepest part of a lake using a YSI meter with cable marked in one-foot increments. Measurements are generally taken at 5 to 10 foot intervals, but more frequently (1-ft increments) when marked changes are observed (typically in the metalimnion). A secchi disk (also marked in one-foot increments) is used to measure water transparency. The criteria used to determine trout-supporting water is water temperature $\leq$ 21ºC (69.8ºF) and dissolved oxygen $\geq$ 4 mg/L (Appendix B). If criteria are met, Lakes and reservoirs are classified as *Trout Maintenance* and they are classified as *Non-Trout* if they are not met. The presence and amount of trout supporting water can vary from year to year, depending on air temperature and rainfall. Shallow lakes, particularly those less than 50 feet deep, often have little or no trout supporting water during the summer due to anoxic conditions in their colder bottom waters and warm surface waters. (Federal Grant F-48-R, Project I)

Twelve water temperature and dissolved oxygen profiles were conducted on eight waterbodies during 2016. Eleven of the surveys were conducted during the summer months and can be used to use for classification purposes in the Surface Water Quality Standards (Table 6). All surveys conducted confirm existing classifications, therefore no additional surveys are necessary for classification purposes at this time.

Table 6.— Summary of temperature & dissolved oxygen profiles conducted during the summer months on eight lakes in 2016. Results page number references in *2016 Investigations & Management of NJ's Freshwater Fisheries Resources Report*.

Waterbody (County)	Current surface water classification	Depth (ft) of water capable of supporting trout [a]	Recommended classification change	Date	Page
Upper Delaware (North) & Wallkill Region (Shimmers Brook to Paulins Kill and Wallkill River watersheds)					
Columbia Lake (Warren)	FW2-NT	none	confirmed (2 locations)	7/27/16	69
Upper Delaware (South) Region (Delawanna Creek to Lockatong Creek watersheds)					
Allamuchy Pond (Warren)	FW2-NT(C1)	none	confirmed	8/8/16	80
Delaware Lake (Warren)	FW2-NT	none	confirmed	8/10/16	83
Mountain Lake (Warren)	FW2-TM	17	confirmed	7/27/16	75 & 80
Saffin Pond (Morris)	FW2-NT	none	confirmed	8/23/16	90
Twin Lakes (Sussex)	FW2-NT(C1)	none	confirmed	8/11/16 [b] & 9/1/16	92
Raritan Region (Raritan River watershed)					
Spruce Run Reservoir (Hunterdon)	FW2-TM(C1)	none	not confirmed	8/16/16	NA
Round Valley Reservoir (Hunterdon)	FW2-TM(C1)	30 - 135	confirmed	7/27/16	App I
Round Valley Reservoir (Hunterdon)	FW2-TM(C1)	30 - 130	confirmed	8/29/16	App I
Round Valley Reservoir (Hunterdon)	FW2-TM(C1)	0 - 120	NA (too late in season)	10/5/16	App I

[a] Depth measured from the surface; criteria for trout supporting water: water temperature $\leq$ 21ºC and dissolved oxygen $\geq$ 4 mg/L.

[b] Although this profile met criteria for trout supporting water (water temperature $\leq$ 21ºC and dissolved oxygen $\geq$ 4 mg/L), it should not be upgraded to *Trout Maintenance* due to the data obtained on 9/1/16 in which no trout supporting water was found.

ANGLER USE ASSESSMENT

Angler Surveys

Opening Day Trout Angler Survey

NJDFW's trout stocking programs provide Garden State anglers with many opportunities to fish for trout throughout the year. Under Fish and Wildlife's spring stocking program, nearly 200 streams, ponds, and lakes throughout the state are stocked with 570,000 trout annually. The opening day of the trout season each April is greatly anticipated by anglers, who flock to these waters to fish for trout on this eventful day. To assess angler turnout and success on this important recreational day, angler counts, and interviews are conducted on various trout-stocked waters. Information on angler participation and satisfaction is used to assess trout stocking and to make program changes. (Federal Grant F-48-R, Project III) (Shramko)

Since 2004 the NJDFW's Wildlife Conservation Corps (WCC) volunteers have provided a valuable service by assisting with the collection of angler data on *Opening Day*. Each volunteer is assigned a trout-stocked water and provided with written instructions on how to conduct the survey, data forms, and information about their assigned waterbody. Volunteers are also asked to submit digital pictures of anglers fishing, catching fish, and holding up their catch for display, as well as a panoramic view that would be indicative of the angler turnout. Not only do the volunteers obtain much needed information regarding trout angler activity, but their visible presence has also reaped several unexpected benefits. For many anglers, this is often their first contact with a NJDFW representative. Anglers are generally willing to provide information about their fishing experience, and many are pleased to see Fish and Wildlife taking an active role in managing the waterbody they are fishing. The WCC volunteers that participate also had positive experiences, with several commenting that this was their first opportunity to assist the NJDFW and they had fun doing it. In 2013 NJDFW began funding this survey under the Sport Fish Restoration Program (Federal Grant F-48-R, Project III) and the volunteer hours are used as state matching funds.

The Opening Day of the 2016 trout season was Saturday, April 9, 2016. The weather was cold with overcast skies and snow showers in many locations. Some parts of the state received upwards of 3 inches of snow by 12:00 p.m. Of the 37 surveys conducted, 18 were on lakes and ponds. On the 18 lakes and ponds surveyed, 664 anglers were observed fishing (an average of ~37 anglers per waterbody). This number is down from last year's opening day when 2,109 anglers were observed on 33 lakes and ponds surveyed (an average of ~64 anglers per waterbody). It is important to note, that the waterbodies selected to survey are not random. This year a number of waterbodies were selected due to consistent poor angler turnout in previous years which would affect the overall number of anglers recorded. The lower angler turnout could also be contributed to the effect of less than desirable weather. Also, as noted above, the counts do not account for turnover over the course of the day. For

Anglers this year braved harsh conditions in search of their share of the 360 trout stocked in Grenloch Lake.
Photo Credit: Ronald Mares, 04/09/2016

example, a volunteer survey clerk at a waterbody may record 100 anglers on any given hour, then, they count 100 anglers the next hour; this second count does not take into account anglers that may have left or arrived within that time interval. By making counts using these methods (number of anglers counted every hour and using the highest number) there is a potential for underestimating the number of anglers that actually fished on a given waterbody.

Trout-stocked Lakes and Ponds

In some locations trout fishing was fantastic. Several anglers proclaimed this was the best opening day ever while many more said they are happy to see the trout stocking program back to where it was prior to the disease issues at the Pequest Trout Hatchery in 2014. Mac's Pond (Monmouth), Manny's Pond (Hunterdon), Nomahegan Park Pond (Union) had the highest catch rates per angler at 1.78 fish per angler, 1.74 fish per angler and 0.93 fish per angler respectively. In fact, anglers at Mac's Pond caught an astonishing 72% of the total trout stocked in the pond before 12:00pm!

Unfortunately, trout were not as cooperative in other lakes and ponds. The cold air temperatures (lower 30's) and cold water temperatures (mid-30's to mid-40's) appeared to keep the fish from biting, frustrating anglers and sending them home early in multiple locations. Many clerks reported the number of anglers at a waterbody was highest at 8 a.m. or sometimes 9 a.m. but dropped heavily by 10 a.m. and throughout the rest of the day because of the weather, especially on the waterbodies where snow fell.

Jonathan Paterno holds one of the coveted broodstock from South Vineland Park Pond. Photo Credit: Tito Gonzalez, 04/09/2016.

The following waterbodies had a total of five or fewer trout reportedly caught by all anglers. The number of anglers ranged from 106 to 19.

- Amwell Lake – 19 anglers caught 4 trout
- Colonial Lake – 50 anglers caught 0 trout
- Grenloch Lake – 21 anglers caught 5 trout
- Mt. Hope Pond – 58 anglers caught 0 trout
- Pohatcong Lake – 27 anglers caught 0 trout
- Sylvan Lake – 106 anglers caught 5 trout
- Tuckahoe Lake – 24 anglers caught 0 trout

The following waterbodies also reportedly caught five trout or less, but had considerable fewer anglers (2-7 anglers total):

- Clinton Reservoir – 6 anglers caught 0 trout, but it is unknown how many of these anglers were targeting trout
- Green Turtle Pond – 5 angler caught 0 trout
- Heritage Park Pond – 7 anglers caught 0 trout
- Mountain Lake – 2 anglers caught 4 trout

Angler success rate data has been collected and calculated per waterbody starting in 2008. Since then, the division has had the ability to compare one year's opening day's success to another year's opening day success. Even with the waterbodies mentioned above that had very poor results, the overall success rate per anglers surveyed in 2016 was right on the average compared with previous opening days. 2016 had a success rate per angler of 0.57 fish per angler or just over 1 fish for every 2 anglers. The most successful opening day was in 2008 when 0.73 trout were caught per angler, while 2011 and 2015 are tied for the least successful with 0.46 trout per angler. See table below for more detail.

Yearly comparison of angler success rate

		2008	2009	2010	2011	2012	2013	2014	2015	2016	AVERAGE
Total	Anglers	1115	853	1095	1462	1675	1918	1830	2100	**664**	**1412**
	# Trout	814	485	551	669	1107	1354	996	960	**380**	**813**
	Trout/Angler	0.73	0.57	0.50	0.46	0.66	0.71	0.54	0.46	**0.57**	**0.58**

Some waterbodies have consistently poor opening day success rates. The following waterbodies in the table below will continue to be monitored, but if their success doesn't change, they could in the future be dropped from the trout stocking program.

Waterbodies with consistent poor angler success.

County	Waterbody	Acres		2010	2011	2012	2013	2014	2015	2016	AVERAGE
Mercer	Colonial Lake	10	Anglers	58			50	22	28	50	**41.6**
			# Trout	4			8	0	2	0	**2.8**
			Trout/Angler	0.07			0.16	0	0.07	0	**0.07**
Atlantic	Heritage Park Pond	6	Anglers					14	25	7	**15**
			# Trout					1	3	0	**1**
			Trout/Angler					0.07	0.12	0	0.09

A complete list of the 2016 Opening Day angler success on the lakes and ponds can be found in the table below along with trout catch information.

2016 Opening Day Angler Survey – Lakes and Ponds.

Waterbody	County	BB[1]	Total # of Anglers	Total # of Trout Caught	Trout Caught/ Angler	Allocated Trout Species	Allocated # of Trout	Percent of Allocation Caught
Amwell Lake	Hunterdon		19	4	0.21	RBT	370	1.08
Clinton Reservoir	Passaic		6	0	0.00	RBT	370	0.00
Colonial Lake	Mercer	X	50	0	0.00	RBT	370	0.00
Englishtown Mill Pond	Monmouth		18	8	0.44	RBT	430	1.86
Green Turtle Pond	Passaic		5	0	0.00	RBT	480	0.00
Grenloch Lake*	Gloucester	X	21	5	0.24	RBT	360	1.39
Heritage Park Pond	Atlantic		7	0	0.00	RBT	430	0.00
Lake Ocquittunk	Sussex	X	81	52	0.64	RBT	360	14.44
Lower Echo Park Pond	Union		50	35	0.70	RBT	390	8.97
Mac's Pond	Monmouth	X	73	130	1.78	RBT	180	72.22
Manny's Pond	Hunterdon	X	39	68	1.74	RBT	280	24.29
Mountain Lake	Warren		2	4	2.00	RBT	600	0.67
Mt. Hope Pond	Morris	X	58	0	0.00	RBT	410	0.00
Nomahegan Park Pond	Union	X	60	56	0.93	RBT	390	14.36
Pohatcong Lake	Ocean		27	0	0.00	RBT	610	0.00
South Vineland Park Pond	Cumberland	X	18	13	0.72	RBT	450	2.89
Sylvan Lake	Burlington		106	5	0.05	RBT	420	1.19
Tuckahoe Lake	Cape May		24	0	0.00	RBT	540	0.00
Total			**664**	**380**	**0.57**		**7440**	**5.11**

Trout-stocked Streams and Rivers

Typically, Opening Day Trout Angler Survey may only have a few streams or rivers as part of the survey because angler counts and success on streams and rivers is difficult to assess. The distance that has to be covered and the movement in and out of fishing spots by anglers makes it difficult to get accurate quantitative data from the survey. This year, fisheries staff focused on streams that have both wild and stocked trout, so more surveys on streams and rivers were done this year than in previous years. As such, streams selected were generally smaller and narrower, with shorter trout stocked sections helping offset limitations typically encountered when conducting angler surveys on streams.

Two young anglers show off their catch at Hakihohake Creek. Photo Credit: Heather Aupperle, 4/09/2016

Angler surveys and counts were conducted on 19 streams or stream sections. A total of 302 anglers were surveyed and 607 trout were caught. The catch rate was 2.01 trout per angler. This data shows that of the streams and stream sections surveyed, anglers did very well. Anglers had the highest catch rates on the following streams:

- Big Flat Brook – 67 trout caught by 31 anglers (2.16 trout per angler)
- Capoolong Creek – 25 trout caught by 11 anglers (2.27 trout per angler)
- Franklin Pond Creek – 76 trout caught by 31 anglers (2.45 trout per angler)
- Lopatcong Creek – 43 trout caught by 11 anglers (3.91 trout per angler)
- Mulhockaway Creek – 42 trout caught by 21 anglers (2.00 trout per angler)
- Spruce Run Creek – 42 trout caught by 20 anglers (2.20 trout per angler)
- S/Br Raritan R. (Upper Section) – 160 trout caught by 37 anglers (4.32 trout per angler)

Angler William Gunderman proudly holds his first trout of the season, caught at Franklin Pond Creek.
Photo Credit: Lisa Kisch, 04/09/2016

A complete list of Opening Day angler counts on streams and rivers is found in the table below.

2016 Opening Day Angler Survey – Streams and Rivers

Streams/Rivers						
Waterbody	**County**	**BB[1]**	**Total # of Anglers**	**Total # of Trout Caught**	**Trout Caught/ Angler**	**Allocated Trout Species**
Big Flat Brook	Sussex		31	67	2.16	RBT
Beaver Bk	Hunterdon		5	11	2.20	RBT
Capoolong Ck	Hunterdon		11	25	2.27	RBT
Franklin Pond Creek	Sussex		31	76	2.45	RBT
Furnace Brook	Warren		2	5	2.50	RBT
Hakihokake Ck	Hunterdon		14	25	1.79	RBT
India Bk	Morris		14	6	0.43	RBT
Jacksonburg Creek*	Warren		3	unk		RBT
Lopatcong Creek	Warren		11	43	3.91	RBT
Mulhockaway Creek	Hunterdon		21	42	2.00	RBT
Paulins Kill*	Sussex/Warren		43	71	1.65	RBT
Pequannock River TCA	Passaic		15	2	0.13	RBT
Pequest*	Warren		10	6	0.60	RBT
Pond Brook*	Sussex		15	11	0.73	RBT
S/br Raritan River (Upper S	Morris		37	160	4.32	RBT
S/br Rockaway Ck	Hunterdon		6	7	1.17	RBT
Spruce Run Ck	Hunterdon		20	42	2.10	RBT
Trout Brook (Middleville)	Sussex		3	0	0.00	RBT
Whippany River	Morris		10	8	0.80	RBT
Total	***incomplete surveys**		**302**	**607**	**2.01**	**RBT**

Interestingly, only 12 out of the 607 trout caught in this year's survey were Brook or Brown Trout. These 12 trout were likely wild trout as the Division has stocked only Rainbow Trout in these waterbodies over the last two years with few private stockings occurring on the surveyed waterbodies. This shows that the wild Brook Trout and Brown Trout are harder to catch than stocked Rainbow Trout and suggests that angler harvest of wild trout on opening day may not be as impactful to the wild trout population as one would anticipate based on sheer numbers of anglers fishing on opening day. Although it is acknowledged that there are a few instances where private landowners or private clubs stock Brown Trout or Brook Trout and that the Brown Trout and Brook Trout caught were possibly misidentified as wild trout.

In Summary

Opening Day success in 2016 was varied. The cold weather and up to three inches of snow in areas definitely had a negative effect on the number of anglers and the success rate at many waterbodies. However, some waterbodies still showed a strong angler contingent, and many waterbodies produced a much higher than average angler success rate. Anglers fishing streams were far more successful than anglers fishing lakes and ponds. The average angler's catch rate on streams was 2.01 fish per angler compared to 0.57 fish per angler fishing ponds and lakes. Streams flows were lower than average for this time of year, but still had plenty of water for anglers to enjoy.

The overall number of opening day anglers counted in this year's survey was down from recent years. No doubt the cold weather and snowy forecast kept many anglers indoors, but numbers were also lower due to division biologists focusing more on lakes and ponds with historically poor turnout and success rates, and more on streams and rivers which can be difficult to assess good angler numbers. For those who braved the elements, Sylvan Lake had the largest showing of anglers with 107 individuals fishing. But the place to be was Mac's Pond in Monmouth County as nearly 75% of the trout stocked in the pond were caught in the first 4 hours of the season.

Despite the overall average to slow start to the spring trout fishing season on many waterbodies, anglers will be more successful as the season progresses, when warmer waters and mild days prevail.

Detailed results noted by volunteer survey clerks for each waterbody surveyed can be found in Appendix F of this report.

Warmwater/Coolwater Angler Survey

In the Fall 2015, the Bureau initiated an online angler survey to obtain anglers opinions and experiences concerning their warmwater and coolwater fishing experiences in New Jersey. The survey specifically focused on opinions concerning Muskellunge, Northern Pike, Walleye, Hybrid Striped Bass, Channel Catfish, and bass. The questions focused on angling success, waterbodies fished, and views on regulations pertaining to these fisheries. The survey was concluded on April 25, 2016 with 1,013 anglers participating. 95.4% of participating anglers were residents and 4.6% were non-residents. It should be noted that non-residents account for 8.4% of overall fishing license sales. Responding anglers represented all 21 counties, with Morris with the highest representation of 10% and Cape May the lowest of 1%. The majority of non-resident anglers were from Pennsylvania. More than half of the anglers participating (both resident and non-resident) ranged in age from 51 to 69 years of age.

60.3% of the anglers spend the majority of their time fishing waters open to the general public. When asked to rank their favorite species to target while fishing, bass, trout, pickerel and Striped Bass (in order of preference) were the top ranked. 37.4% of anglers (980) fished more for other types of fish than trout while 21.7% fished more for trout than other types of fish (see chart).

When freshwater fishing in New Jersey do you fish		
Answer Options	**Response Percent**	**Response Count**
ONLY for other types of fish - NO TROUT	15.7%	154
MORE FOR OTHER TYPES OF FISH than trout	37.4%	367
EQUALLY for other types of fish and trout	20.0%	196
MORE FOR TROUT than other types of fish	21.7%	213
ONLY for trout	4.4%	43
Not Sure	0.7%	7
	answered question	**980**

With the exception of bass, targeted by the vast majority of responding anglers (88%), anglers targeting the other species were almost equally represented in the survey, 24.7% to 29.5%. Although catch and release was prevalent with most species, Muskellunge had the highest percentage of anglers always practicing catch and release with 93%. Not surprisingly, anglers fishing for Channel Catfish and Walleye were less apt (56.4%) to practice strict catch and release.

When asked about current regulations, the majority of anglers were satisfied with current regulations governing these fisheries. However, regardless of species, a percentage of anglers did indicate that although they are catching larger and larger fish, they believe the minimum size should be increased to force others to release their catch more often.

The survey also includes angler opinions and success on specific waterbodies, regulations, opinions on bass tournaments, and how anglers obtain information about fishing in New Jersey. (Federal Grant F-48-R, Project III) (Barno and Smith)

Wild Trout Angler Survey – A survey of wild trout anglers was designed to obtain angler feedback concerning New Jersey's wild trout fishing opportunities. The Wild Trout Survey, which was released to the public on March 2, 2016, had a total of 291 anglers participate in the 25 question survey. Anglers were asked if they supported or opposed the current Wild Trout Stream Regulations and how they felt about several possible new Wild Trout Stream Regulations. The following bullets are highlights from the survey. For more information on the Wild Trout Stream Regulation Assessment see page 52. (Federal Grant F-48-R, Project III) (Barno and Shramko)

- 90% of participating anglers felt that the most important attribute to having a good day of fishing for wild trout is not based on the number of trout caught or even the size of the trout caught, but just seeing evidence of wild trout in their stream.
- 87% said catching just one wild trout is important to having a good day fishing.
- 95% of the anglers said that a scenic location without a lot of other anglers was important to having that good day of fishing.
- In contrast, 60% of participants stated that catching big fish was NOT important to them when it comes to having a good day on the water.
- 61% are not in support of the current *2 fish per day creel limit* while only 26% support it.
- 75% answered that they want a *Catch & Release* Regulation on all wild trout streams (only 14% opposed this).
- 74% would like *Catch & Release* Regulations on Brook Trout streams, while 60% answered that they would support *Catch & Release* Regulations on wild Brook Trout, but allow harvest on wild Brown Trout and wild Rainbow Trout (19% oppose this).
- 78% of anglers were not in support of the current hook point regulation that allows up to 3 treble hooks or 9 hook points (8% supported).
- Anglers were asked about all different hook point combinations, but the most unified responses were: 65% of anglers support *single hook only* (15% oppose this) and 69% want *barbless hooks only* (13% oppose).
- 70% of participating anglers stated that they support the current *Artificials Only (No bait or scents)* gear restriction while only 19% oppose the current regulation.

Trout Angler Logbook Program

NJDFW utilizes a logbook (diary) program to obtain current information regarding trout angler catch and effort on special regulation areas on trout streams. Initially launched as a pilot program in 2012 on three special regulation trout fishing areas, the program was expanded in 2013 to include all seven areas. Logbooks are distributed annually to experienced anglers who indicate they regularly fish one or more of the areas in the study. Anglers record information about fish harvested or released during each trip, as well as time spent fishing and gear used. At the end of the calendar year anglers return their logbooks to NJDFW and the data is then compiled and analyzed during the following calendar year. Compared to other survey methods, angler logbooks are one of the least expensive ways to collect information on a fishery. Data collected through angler logbooks supplement other data collected by NJDFW (such as Opening Day angler surveys, telephone and internet-based surveys, on-site angler creel surveys, fish population surveys using electrofishing gear, and water temperature monitoring). Collectively, this data aids in evaluating the fishery and guides managers and stakeholders in making informed decisions that benefit both the resource users and the resource. (Federal Grant F-48-R, Project III) (Sedor)

In 2015 seven special regulation areas were included in the logbook program and the logbooks results were compiled (see table below). A total of 85 anglers volunteered for the program, receiving a total of 110 logbooks (some anglers needed more than one logbook to record all their trips). Despite efforts to encourage logbook returns only 16 anglers (19%) returned their logbooks. Collectively the 16 logbook anglers logged 309 trips to 6 of the 7 special regulation trout fishing areas. The Big Flat Brook / Flat Brook *Catch and Release (C&R)* area was the most commonly visited site with 119 trips (38%), followed by the Musconetcong River *YTCA* (81 trips, 26%), and the Ken Lockwood Gorge *C&R* section of the South Branch Raritan River (71 trips, 23%). The remaining 38 trips (13% of total) were to the Pequest River *STCA* (29 trips, 9%), S/Br. Raritan River – Claremont Stretch *YTCA* (6 trips, 2%), and Pequannock River *STCA* (3 trip, <1%). No fishing trips were recorded for the Toms River *YTCA.* Anglers fished an average of 2.9 to 4.0 hours per trip; the highest average trip lengths were on the Ken Lockwood Gorge (4.0 hrs/trip), the Musconetcong River (4.0 hrs/trip), and Pequest River (3.9 hrs/trip). The logbook data includes trips that were taken to the *STCA*'s at times when the special regulations were not in effect. Interestingly, fly fishing gear was used by anglers for the majority of trips; only 11 trips (3%) used spin fishing gear, including trips where both techniques were used.

Logbook anglers recorded a total catch of 2,206 trout. Catch and release fishing was practiced all the time, or nearly so; anglers recorded 2,167 trout released (99%), no trout kept, and failed to indicate if 39 other trout were kept or released. The catch rate averaged 2.0 trout/hr, and ranged (by special regulation area) from 0.5 – 2.9 trout/hour. The average number of trout caught per trip was 7.1, and by special regulation area ranged from 1.3 – 8.0 trout/trip. These catch rates are very much in line with previous year's logbook reports (2013 – avg. 7.0/trip, 1.8/hr., 2014 – avg. 5.2/trip, 1.9/hr.), despite the effects of 2014's truncated stocking season and the subsequent shift to stocking only rainbow trout. The highest catch rates (per hour and per trip) occurred in the Flat Brook / Big Flat Brook *C&R* (2.9/hr, 8.0/trip). The lowest catch rate was on the Pequannock River *STCA* (0.5 trout/hr and 1.3 trout/trip). Most trip reports were reasonably close to these averages, though three trips to the Flat Brook / Big Flat Brook *C&R* logged over 50 trout per trip. Two of the three 50+ trips were on stocking days (Flat Brook remains open to fishing

year round, including stocking days), and the third was the day after stocking. This may contradict the conventional wisdom that fish are less likely to feed immediately after stocking.

Of the total trout caught, anglers recorded the species for 95% (2,088 trout). Overall Rainbow Trout were caught most frequently 96%), followed by Brown Trout (3%), and Brook Trout (1%). Two Tiger trout (Brook X Brown hybrid) were recorded in the Ken Lockwood Gorge; one of unrecorded size and the other 16 inches in length.

Anglers were also asked to note if the origin of each trout they caught was wild, stocked, or unknown. This assessment can be very subjective and difficult since a decision is based primarily upon fin wear and also influenced by fish coloration. Anglers reported catching 54 (2%) wild trout and 1,969 (89%) stocked trout. 183 (9%) trout were recorded as species origin unknown, indicating that most anglers were reasonably confident in their ability to distinguish wild from stocked fish, though less so than in previous years (5% in 2014).

The average size of trout caught (results not provided in the table) was 294 mm (11.6 in) and they ranged in size from 76 mm (3 in) (Pequannock River) to 711 mm (28 in) (in the Pequest River *STCA*). 72% (1,582) of trout recorded fell within the 9 to 11-inch range stocked by Pequest Trout Hatchery. 85% (1,857) were between 8 and 12 inches, a range which allows for some variation in length estimates (anglers are asked only to estimate trout length, not required to carry a measuring device) and slight differences in stocking length.

Summary of fishing trip and catch statistics for 24 logbooks returned by 16 anglers who participated in the 2015 Trout Angler Logbook Program which targeted 7 special regulation trout fishing areas.

Total number of trips	Hours Per Trip	Number of trout caught by species1				Total trout caught	Number of trout caught by origin			% wild caught	Number of trout caught per	
		BKT	BNT	RBT	UNK		Wild	Stocked	UNK1		Hour	Trip
Big Flat Brook / Flat Brook (Catch & Release)												
119	2.8	7	2	929	15	953	10	865	78	1%	2.9	8
Musconetcong River – Point Mtn. (Year Round Trout Conservation Area)												
81	4	1	3	534	56	594	5	531	58	<1%	1.8	7.3
S/Br. Raritan River – Ken Lockwood Gorge (Catch & Release)												
71	4	0	47	345	40*	432	13	379	40	3%	1.5	6
Pequest River (Seasonal Trout Conservation Area)												
29	3.9	1	4	194	9	208	10	190	8	4%	1.8	7.2
S/Br. Raritan River – Claremont Stretch (Year Round Trout Conservation Area)												
6	3.3	5	4	5	1	15	9	4	2	60%	0.8	2.5
Pequannock River (Seasonal Trout Conservation Area)												
3	2.9	0	3	1	0	4	4	0	0	100%	0.5	1.3
Toms River (Year Round Trout Conservation Area)												
0	0	0	0	0	0	0	0	0	0	0	0	0

[1] BKT = Brook Trout; BNT = Brown Trout; RBT = Rainbow Trout; UNK = unknown (trout species or origin). * = One angler reported two Tiger Trout, Brook X Brown Trout hybrids. These trout included in UNK Count.

In 2015, 97 logbooks were prepared and distributed to anglers who indicated they regularly fish the seven stream sections described above. The data from these logbooks (that are returned by anglers) will be compiled and the results summarized in the 2016 annual field report titled: Investigations and Management of New Jersey's Freshwater Fisheries Resources.

INFORMATION AND EDUCATION

In addition to a multitude of research and management activities, the Bureau of Freshwater Fisheries actively participates in a number of Information and Education activities each year. Several such as two annual Fisheries Forums, a Public Trout Meeting, and biennial Public Hearing are directly tied to research and management activities and promulgation of regulations governing the state's freshwater aquatic resources. In addition, Bureau staff actively participates in the preparation of the Freshwater Fishing Digest. For the 2017 edition, the first of two feature articles is titled, "Restoring Free-flowing Rivers, Bringing Down the Dams" and explains the benefits of removing on-stream dams to improve water quality and to restore natural river functions and historic fisheries. The second feature article is titled "The Truth about Hooks and Lures", which aims to clarify the debate among anglers as to the impacts that various hook and lure types have on fish. The Freshwater issue of the Digest is perhaps the most widely distributed publication throughout the Department.

Professional Meetings/Conferences

New Jersey participates in a number of regional initiatives geared towards the protection of the nation's freshwater fisheries resources. As such, state fisheries biologists participate in a number of regional panels and workshops to share information and experiences with biologists in other states on a variety of topics in the realm of fisheries management.

Eastern Brook Trout Joint Venture (EBTJV) Meeting - Bureau staff attended two EBTJV meetings in 2016 (2/19/16 and 12/5-12/7/16). At the first meeting the partners were updated on the catchment assessment results for wild Brook Trout and discussed how to incorporate these results into the EBTJV Brook Trout Conservation Strategy. At the second meeting EBTJV's mapping of Brook Trout occurrence at the catchment scale (using data supplied by state fisheries agencies) and its incorporation into a new patch designation was explained. These patches and catchments were discussed at the state level and summarized for the Eastern Brook Trout range. This approach will allow states to view Brook Trout catchment data as collected patches, not only to identify key strongholds, but also to help prioritize catchments for restoration to connect patches to create larger strongholds. Since its inception in 2005, the EBTJV has coordinated range wide Brook Trout conservation and habitat restoration efforts through a collaborative, multi-agency approach. EBTJV partners (17 states, federal agencies, and NGO's) periodically meet to work, both collectively and in workgroups, on strategies and on-the-ground actions to improve water quality and restore Brook Trout habitat and populations. (Federal Grant F-48-R, Project I and II)

Merrill Creek Reservoir - The annual fisheries management meeting with staff and their consultant held on March 4 to review and discuss the fisheries data collected in 2015 and future management of the recreational fisheries. The data collected on Lake Trout continues to indicate this species is reproducing successfully in the reservoir (stocking was discontinued in 2013). The results from the night electrofishing survey indicate the Smallmouth and Largemouth Bass population is thriving and may be a good candidate for Lunker Bass fishing regulations.

Public Presentations

Each year state fisheries biologists attend meetings of a variety of organizations which may include angling clubs, watershed groups, local planning boards, and sportsmen shows. (Hunter and Angler Fund)

In 2016, presentations on the fisheries resources within the state were presented to:

North Jersey Freshwater Fisheries Forum – Thirty-seven anglers attended the annual North Jersey Freshwater Fisheries Forum held on January 30. The purpose of the forum is to disseminate information pertaining to Bureau research and management activities and provide attendees the opportunity to comment on our fisheries programs and interact with Bureau staff. Highlights of 2015 field sampling efforts were presented by Principal Biologist Shawn Crouse, Coolwater Fisheries Assessment work was presented by Fisheries Biologist Scott Collenburg, and discussion on potential Wild Trout Stream Regulations was presented by Principal Biologist Pat Hamilton. All Bureau of Freshwater Fisheries staff attended the meeting and answered questions from anglers.

South Jersey Freshwater Fisheries Forum - Twenty-five anglers attended the annual South Jersey Fisheries Forum held on February 20, 2016 at the Batsto Visitor's Center. Principal Biologist, Christopher Smith presented highlights of warmwater lake electrofishing surveys, and Fisheries Biologist, Eric Boehm presented fisheries data collected from bass tournaments held on Wildlife Management Area Lakes. A question and answer period and open discussion followed the presentations.

Trout Meeting – Ninety-seven anglers attended the annual Trout Meeting held on February 27, 2016 at the Pequest Trout Hatchery. Jeff Matthews, Fish Production Chief, presented hatchery production numbers for the upcoming spring trout stocking. Senior Fisheries Biologist, Ross Shramko, presented information on allocation and waterbody changes for the spring stocking as well as presented a new allocation methodology for Fall and Winter Trout Stocking Programs. Principal Biologist, Pat Hamilton, presented information concerning the development of potential Wild Trout Regulations. An extensive question and answer period, and open discussion followed the presentations.

Outdoor Writer's Workshop – Fisheries Biologist Chris Smith prepared and presented a PowerPoint presentation on various Bureau of Freshwater Fisheries activities, including highlights from the Bureau's 2015 Field Sampling Season, including a fisheries inventory completed at Union Lake.

Round Valley Trout Association – Biologist Shawn Crouse prepared and presented a PowerPoint presentation at Round Valley Trout Association's meeting held on March 17, 2016. Information provided included important dates, upcoming NJDFW events, current research and management of Round Valley Reservoir, with a focus on Lake Trout research and management.

South Jersey Bass Club Association – Biologist Chris Smith gave an informal presentation to the South Jersey Bass Club Association in January, 2016.

Public Events

The **New Jersey WILD Outdoor Expo** is an annual event celebrating the state's bountiful natural resources and rich outdoor heritage. The event was held on September 10 and 11, 2016, from 10 a.m. to 5 p.m. daily at the Colliers Mills Wildlife Management Area in Jackson Township, Ocean County. The Expo is an annual event which is free of charge and takes place rain or shine. The WILD Outdoor Expo is hosted by the NJDEP Division of Fish and Wildlife, Division of Parks and Forestry, the Green Acres Program and the Conserve Wildlife Foundation of New Jersey. The event also has several sponsors, and exhibitors and vendors from the field of outdoor recreation were on site. The Expo helps people connect with the natural world by providing a unique blend of conservation information, education and hands-on opportunities to learn outdoor skills and activities. Numerous environmental and conservation exhibits, demonstrations and seminars are planned for the weekend. Visitors can learn about, and try, a wide array of activities including fishing, hiking, shooting sports, kayaking, camping skills, rock climbing, wildlife watching and much more. (Hunter and Angler Fund)

Every year NJDFW holds an annual **Open House at the Pequest Trout Hatchery and Natural Resource Education Center**, prior to the opening of trout season. The event was held on April 2 and 3, 2016, from 10 a.m. to 5 p.m. Each year thousands of people of all ages come to the hatchery to see the trout that are raised, and participate in many activities including kids fishing, shooting sports, fisherman's flea market, and much more. Staff assist in a number of facets including assisting at the Fishing Education Pond, providing demonstrations on the stripping an fertilization of eggs, providing fish for the kiddie pool, and answering questions from the general public. (Hunter and& Angler Fund)

Attended the **Pequest Teen Angler Event (13th Annual)** held on July 23, 2016 at the Pequest Fish Hatchery's Fishing Education Pond. There were 56 anglers, 12 – 20 years old, with 16 of them licensed anglers. There were also 28 adults accompanying them, with 18 of which had fishing licenses. Fishing was excellent with lots of fish caught, in fact there were too many to count. The action kept up right to the end. Every angler caught multiple fish, with one young angler claiming she caught 30 fish. 138 trout from 18-28 inches and 11 under 18 inches were kept. A few of the fish in the 18 to 28-inch range were over 8 lbs. The 14th Annual Pequest Teen Angler Event is scheduled for July 22, 2017. (Hunter and Angler Fund) (Boriek)

NJDEP's Youth Fishing Derby was held at Stacy Pond in Trenton on May 22, 2016. An estimated 80 youth participated in the fishing derby (the largest number of competitors, to date) and an estimated crowd of 160 participants and volunteers experienced the event. (Boriek)

Union County's BioBlitz-

The 2016 BioBlitz was held at Kawameeh Park, Black Brook Park, and Galloping Hills Golf Course on June 11, 2016. The fish team, led by New Jersey Department of Environmental Protection, Division of Fish and Wildlife, sampled the West Branch of the Elizabeth River, Shallcross Pond, and several ponds within NJ American Water property near Kawameeh Park. The team used a variety of sampling methods including electro-fishing (using mild electrical currents to temporarily stun the fish for easy capture and identification) and seining. Thirteen fish species were collected. Native species include Pumpkinseed, Brown Bullhead, Golden Shiner, Banded Killifish, Mummichog, and American Eel. Non-native species include Largemouth Bass, Bluegill, Green Sunfish, Black Crappie, Common Carp, Goldfish, and Western Mosquitofish. The fish assemblage in the West Branch of the Elizabeth River is typical for a degraded watershed, consisting almost exclusively of Green Sunfish, Mummichogs, and Western Mosquitofish. The warmwater fish assemblage encountered at Shallcross Pond provides recreational opportunities for anglers. The fish team also conducted one waterfront public presentation, consisting of a fish collection demonstration by means of the use of a 20-ft. seine. The presentation also touched upon the job of a fisheries biologist, a summary of fishes encountered, and field identification. (Hunter and Angler Fund) (Crouse)

Common Name	Comments	Elizabeth River	NJ American Water Ponds	Shallcross Pond
American Eel	native	x		
Common Carp	non-native	x	x	
Goldfish	non-native	x		
Golden Shiner	native			x
Western Mosquitofish	non-native	x	x	
Largemouth Bass	non-native			x
Black Crappie	non-native			x
Pumpkinseed	native	x	x	x
Bluegill	non-native			x
Green Sunfish	non-native	x	x	x
Brown Bullhead	native	x	x	x
Banded Killifish	native	x		
Mummichog	native	x		

OTHER FISHERIES RELATED ACTIVITIES

Permits

The Bureau of Freshwater Fisheries reviewed and issued 425 permits in 2016 to provide for the effective management and protection of the state's aquatic resources (see table below). These permits encompass 9 specific permits which include commercial harvest of aquatic species, water level management (for the protection of aquatic species), the introduction of aquatic species into waters of the state, as well as the collecting of aquatic species for scientific purposes, and special use permits. The review and approval of these permits not only include protection for freshwater fish, but also protection for other aquatic species such as frogs and turtles during critical spawning and hibernating periods. In addition to permits directly issued by the Bureau, the BFF also reviews Aquatic Use Permit Applications issued by the Department's Pesticide Control Program for the use of copper in waters known to be stocked or inhabited with trout. Trout are particularly sensitive to copper which is a basic agent for algal control treatments (copper sulfate) throughout the state. (Hunter and Angler Fund) (Barno)

Permits issued by the Bureau of Freshwater Fisheries in 2016

Permit Type	Number
Baitfish - Commercial	6
Fish Stocking	169
Trout in the Classroom	4 new
Fish Stocking	202 existing
Gill Net – Staked - Commercial	0
Gill Net – Drifting -	0
Haul Seine - Commercial	1
Miniature Fyke/pot	0
Scientific Collecting	60
Special Use Limited License	28
Water Lowering	157
Total	**425**

Wildlife Management Area Fishing Tournament Permits

The popularity of recreational and tournament bass fishing was elevated to a new level during the 1960's. In an effort to unite bass anglers nationwide Ray Scott created the Bass Anglers Sportsmen Society (B.A.S.S). The goal of BASS was to emphasize conservation, education, and sportsmanship. Since 1996 the Division of Fish and Wildlife has required a permit to hold fishing tournaments on Wildlife Management Area Lakes. Permits are necessary to regulate the number of tournaments held on WMA Lakes, due to an increasing demand on our public waterbodies. NJDFW collects valuable information from tournament reports to supplement existing fisheries data. (Hunter and Angler Fund) (Smith)

In 2016 there were 185 WMA Tournament Permits issued by the NJDFW. Anglers are required to submit a summary report within two weeks following the event. The return rate had been rather poor until 2015 when the South Jersey Bass Club Association diligently pursued members of the organization reminding them of the reporting requirement. Their campaign was successful resulting in 64% return rate in 2015. In comparison only 24% of reports were received in 2014. This year was another successful year with a return rate 67%. The four most popular waters in 2016 were Salem Canal (46 tournaments), Union Lake (32 tournaments), Lake Assunpink (25 tournaments) and DOD Lake (16 tournaments). The largest bass reported to date was a 6.74-poind Largemouth Bass from DOD followed closely by a 6.71-pound Largemouth Bass from Assunpink Lake. Assunpink Lake has shown a significant increase in the number of five-pound bass with 10 bass over five pounds caught. DOD was second in the five pounder category with four caught, of which three were caught in the same tournament.

The tournament report forms are a vital component of the tournament permit process. A summary of tournament results will be prepared and available later in 2017.

Database Management - FishTrack

FishTrack is an Access database which houses New Jersey's Bureau of Freshwater Fisheries stocking information and field survey data collected by NJDFW throughout the state, historically through present day. In 2016, the *FishTrack* database was updated in a few key areas.

The young-of-the-year category was updated for all historical and present trout data. A determination was made that any trout collected and measured 100mm or less that the trout was born the year that it was collected. The database was updated to represent this determination.

In addition to the young-of-the-year category update, a stocked trout or wild trout label was applied to all individual trout where it could be determined for all surveys where trout were found. These two updates will assist the NJDFW with its management of stocked and wild trout.

Also, all 2016 field survey data has been inputted and validated for accuracy. Maintaining an accurate and consistent database is critical as this gives staff biologists the ability to access accurate historical data to assist with appropriate management of the state's fisheries resources. (Federal Grant F-48-R, Project I) (Shramko)

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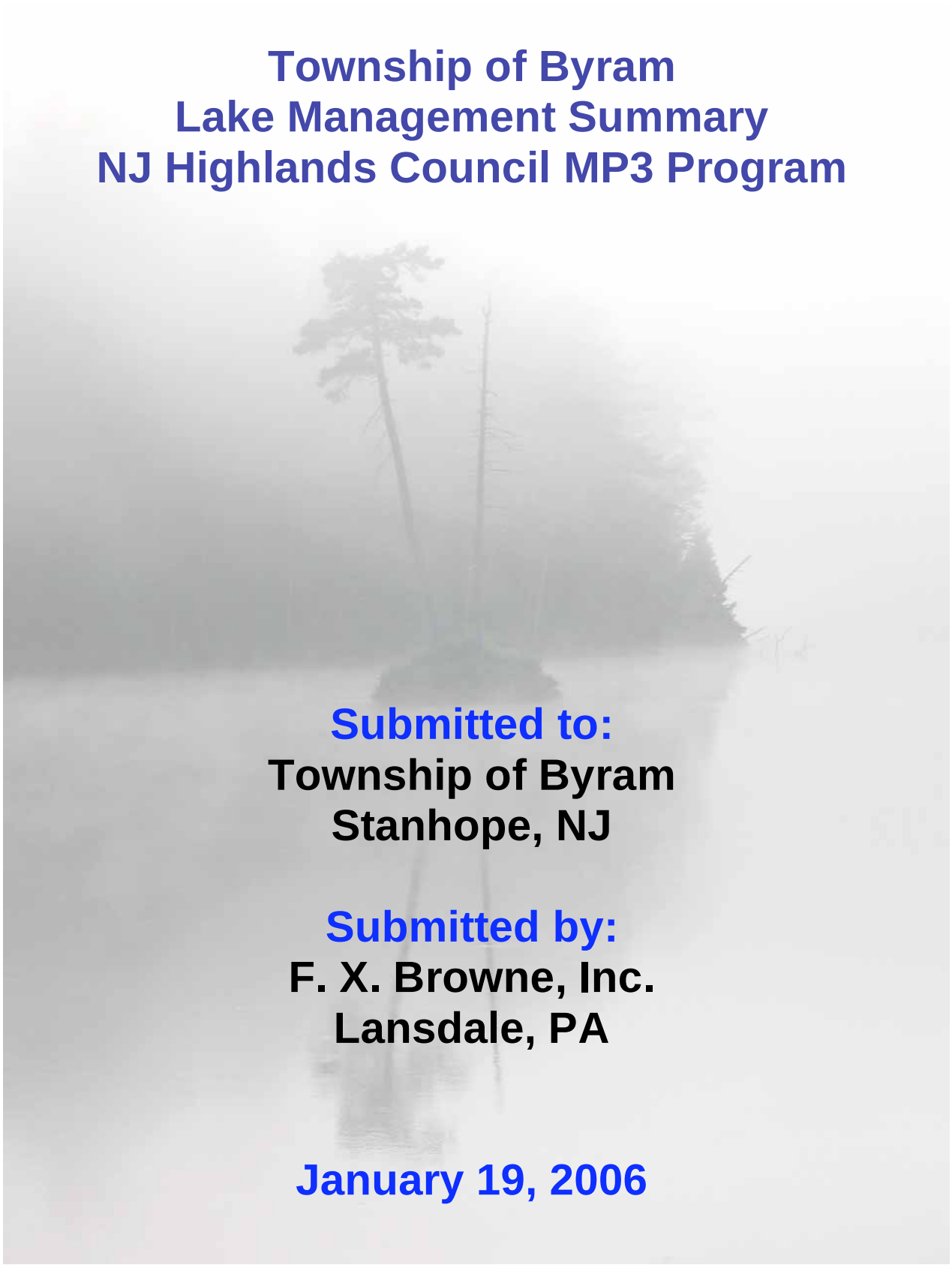
Township of Byram
Lake Management Summary
NJ Highlands Council MP3 Program



Submitted to:
Township of Byram
Stanhope, NJ

Submitted by:
F. X. Browne, Inc.
Lansdale, PA

January 19, 2006

Township of Byram
Lake Management Summary
NJ Highlands Council MP3 Program

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FXB Project No. NJ1725-01

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Executive Summary

This summary report is being undertaken by Byram Township as part of the New Jersey Highlands Council Municipal Partnership Pilot Projects (MP3) program. The MP3 program provided grants for seven case studies to investigate key areas of concern in coordination with Highlands region municipalities. The information gathered during the Pilot Projects will assist in the development of the Highlands Regional Master Plan. Byram Township is one of eight municipalities participating in the MP3 program.

The key issues of concern for Byram Township are lake management and center development. The lakes in Byram Township serve as headwaters for important drinking water sources in northern New Jersey. Protecting these source waters and the watershed areas within Byram Township are a high priority for both the Township and the Highlands Council.

Byram Township has long been proactive in its watershed protection efforts. Byram Township has already come a long way in commissioning studies, implementing lake management measures, and enacting regulations for the protection of the natural resources in the Township. The following Action Plan is designed to further the lake management efforts in Byram Township. The items in the Action Plan are organized with the most readily implemented items listed first. It is important to note that certain items lower down in the list, for example, the soil suitability mapping, are high priority items, but may require more funding and planning than items at the top of the list. The Action Plan consists of the following elements:

1. Require septic system inspections whenever a house is sold, planning board approval is sought, or a building permit is issued. Also require a 200-foot notification prerequisite for applications to install, replace, or repair a septic system or well.

2. Develop and adopt a Stormwater Management Ordinance.

3. Enact other municipal ordinances that would help enhance the quality of Byram Township's lakes, including a tree ordinance, riparian buffer ordinance, natural landscaping/noxious weed ordinance, pet waste ordinance, phosphate ban ordinance, and wildlife feeding ordinance.

4. Broaden the scope of the existing Septic System Management Program to encompass the entire Township.

5. Approve legislation banning PWCs on Byram Township lakes and ponds. If this is not possible, implement a noise or vehicle use ordinance to restrict PWC access in sensitive areas and reduce the disturbance of lakeshore property owners.

6. Post signs at public access points to the lakes within Byram Township warning users to avoid spreading invasive aquatic plants and providing tips on reducing the negative impacts of boats and vehicles to the lakes.

7. Develop a Public Education and Outreach Program to encourage property owners, business owners, government officials, and developers to become active partners in the conservation of the natural features of the Highlands Region.

8. Organize a “Lake Awareness Day,” or include workshops at the annual Byram Day to educate Township residents about lake management efforts. Educational programs should also be developed for the local schools.

9. Initiate watershed investigations to identify stormwater management opportunities, streambank erosion problems, riparian buffer restoration opportunities, and other potential sources of water quality problems.

10. Perform a Township Soil Suitability Mapping Project to help guide on-site wastewater management efforts within the Township.

11. Based on the Soil Suitability Mapping, evaluate decentralized wastewater management for those areas that are not suitable for conventional septic systems.

12. Create a Township-wide lake monitoring program. The Township should develop a volunteer monitoring manual and should purchase a set of water quality monitoring equipment for use by lake associations.

13. Develop a “weed watch” program with volunteers to help prevent the spread of invasive plant species in Byram Township.

14. Develop Lake Management Plans for each of the Township’s lakes.

15. Implement watershed Best Management Practices to address the nonpoint source problem areas documented during the watershed investigations.

The Byram Township Environmental Committee should work together with members of the Township’s Lake Associations and other stakeholders to form a Watershed Watch group. The group should coordinate their efforts to implement the recommendations of this report, seeking funding from such sources as EPA's 319 Nonpoint Source Program, the Environmental Infrastructure Financing Program (EIFP), the Water Quality

Management Planning Pass-Through Grant Program, and the Conservation Reserve Enhancement Program (CREP).

1.0 Introduction

Byram Township covers more than 22.48 square miles of Sussex County in Northern New Jersey. Byram is known as "The Township of Lakes", having more than two dozen lakes and ponds, as shown in Figure 1. The lakes and ponds in Byram Township constitute the headwaters of three important watersheds: the Musconetcong, the Pequest and the Wallkill watersheds. Several of these lakes and ponds are surrounded by established lakeside communities, each with their own unique character. The largest of these communities include Cranberry Lake, Lake Lackawanna, Forest Lake, Johnson Lake, Panther Lake, and Lake Mohawk.

1.1 Byram Township Objectives

Byram Township has long been proactive in its watershed protection efforts. The Township has undertaken several comprehensive planning initiatives, including the Byram Township Master Plan, Smart Growth Plan, and Natural Resource Inventory, in efforts to characterize the Township's natural resources and guide the Township's growth so that its natural resources are adequately protected.

The key issues of concern for Byram Township are lake management and center development. The lakes in Byram Township serve as headwaters for important drinking water sources in northern New Jersey. Protecting those source waters and the watershed areas within Byram Township are a high priority for both the Township and the Highlands Council.

1.2 Highlands Council Objectives

On August 10, 2004, the Highlands Water Protection and Planning Act went into effect. The law is implemented by the Highlands Water Protection and Planning Council, a public body charged with developing a regional master plan, performing land use functions and protecting the region's critical environmental areas and high resource lands.

The goals of the Highlands Act are to:

- Protect and conserve drinking water - quality/quantity
- Protect natural and cultural resources
- Preserve land in its natural state including farmland and historic sites
- Promote compatible agricultural, horticultural, recreational, and cultural uses
- Discourage incompatible and inappropriate development
- Promote a sound and balanced transportation system
- Encourage appropriate patterns of development and economic growth

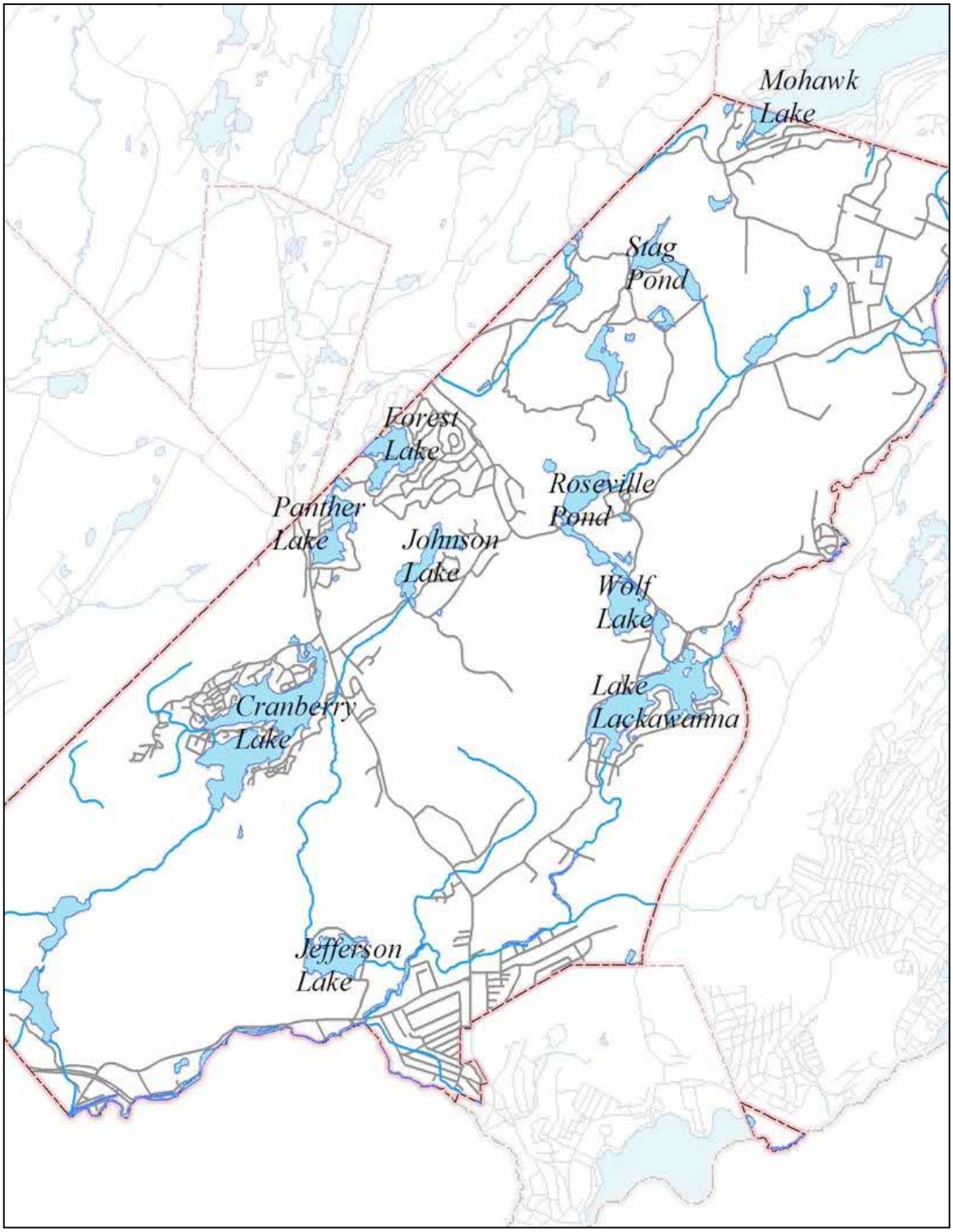


Figure 1: The Lakes of Byram Township

This summary report is being undertaken by Byram Township as part of the New Jersey Highlands Council Municipal Partnership Pilot Projects (MP3) program. The MP3 program provided grants for seven case studies to investigate key areas of concern in coordination with Highlands region municipalities. The information gathered during the Pilot Projects will assist in the development of the Highlands Regional Master Plan. Byram Township is one of eight municipalities participating in the MP3 program.

Byram Township was included in the case study because of the importance of its lakes to the Highlands region and because the Township has the simplest and most thorough Septic Management Program in the region. The goal of this summary report is to analyze the existing lake management programs within Byram Township (including lake monitoring, in-lake management, and Township ordinances and regulations), and to put forth recommendations for improving lake management within Byram Township and the Highlands Region as a whole.

2.0 Existing Lake Management Programs

2.1 Lake Management Programs in Byram Township

2.1.1 Lake Monitoring

Several of the Township's lakes have been the subject of water testing or other monitoring. The following is a summary of some of the major studies:

1976 Pytlar Thesis: A Study of Six of Byram's Lakes, by a Rutgers graduate student. The study concluded that all six lakes (Cranberry, Lackawanna, Forest, Roseville, Stag, and Panther) were mildly eutrophic and that any further decline will depend largely upon human activity in the lake and watershed.

1982 Lake Study, by the Byram Township Environmental Commission, measured various chemical and physical properties of Cranberry, Lackawanna, Forest, and Mohawk, the most heavily developed lakes. The study found that Forest Lake was the most impacted of the four study lakes by stormwater runoff. Lake Mohawk was found to act as a nutrient "sink" with the aquatic vegetation trapping many of the nutrients in the lake. Cranberry Lake and Lake Lackawanna were less eutrophic than the other two. These conclusions were contradictory to other studies that showed Cranberry Lake and Lackawanna Lake as being typically more eutrophic than Forest Lake. All of the lakes appeared to be impacted by road salt runoff.

1992 Study of Cranberry Lake, by Coastal Environmental Services, was an EPA 314 Clean Lakes Program Diagnostic Feasibility Study. Byram Township Environmental Commission members performed testing and helped administer the study, which was the basis for obtaining a three-year $200,000 USEPA lake management grant for drainage improvements, weed harvesting, community education, and a sensitive land use plan. Nutrient loadings were calculated and a septic leachate detector study was conducted as part of the study. The 1992 Study also resulted in a second implementation grant of $350,000 for dredging a small cove.

Cranberry Lake Septic Management District Survey. Septic snooper tests conducted under the 1992 Feasibility Study showed three general areas where septic effluent was reaching the lake. Other in-lake water quality tests were performed for the feasibility study and later during lake management work to show the eutrophic quality of the lake. To help measure the effectiveness of the Septic Management Program, in the mid 1990s an informal survey was conducted of Township septic files for Cranberry Lake properties, which showed that a substantial number of the Lake's homeowners had either repaired or replaced their systems since the inception of the program. It was assumed that many of these repairs resulted from the educational materials sent out as part of the Septic Management Program and from the requirement that homeowners locate and map their systems.

MTBE testing at Cranberry Lake, 1998. The NJ Department of Environmental Protection and the NJ Geologic Survey conducted in-lake and well testing around Cranberry Lake, following a small spill in one of Cranberry's neighborhoods. While the concentrated area of contamination was remediated with filtration systems in affected homes, the study showed that the entire lake was characterized by low-level MTBE contamination, probably from motor boats and jet skis, and that connections between the lake and neighborhood wells—and the intensive pumping of groundwater for the community's 500 residents—resulted in similar low levels in the approximately 14 Cranberry wells where a series of readings were taken (readings ranged from 0.1 to 3 ug/l, with an average of 0.4). Records of this study are in Township Environmental Commission files. No follow-up measures were taken.

Lake Lackawanna Non-Point Source (NPS) Pollution Control Study, 1998. Byram Township received a Public Education and Outreach Grant from the NJDEP to fund a study to determine the costs and benefits of controlling NPS pollution at Lake Lackawanna by extending sewer service into the area or by implementing a septic management plan. The study by Thonet Associates involved a cost-benefit analysis of projected NPS pollution under current and build-out conditions, and investigating several options for sewer extensions. The study concluded that although implementation of a septic management plan and sewer extension would yield immediate and long-term water quality benefits, these measures would not significantly change the appearance of the lake and the need for active management would continue. The study also concluded that extension of sewers would increase the development potential of the lake area and the resulting increased development would increase nutrient inputs and off-set the water quality benefits of the sewer system. An alternative of extending limited sewers to serve only the existing homes and infill lots in the Lake Lackawanna area was ruled out since the ability of this option to be strictly limited was considered unlikely and could increase the development potential in the area.

Lake Mohawk Monitoring Report, 2002. The Lake Mohawk Country Club has initiated an annual Lake Mohawk Monitoring Program and contracted with Princeton Hydro, to manage the testing and reporting program. The master plan identified the primary cause of the lake's continuing eutrophication to be excessive phosphorus loading from stormwater runoff, internal recycling of lake sediments and loading from septic systems. The 2002 report presented results for a variety of water characteristics. In spite of the existing destratification aeration system that was installed in the lake, the lake still suffers from some anoxic conditions near the lake bottom, potentially allowing for internal phosphorus loading and deep-water algal blooms. The mean surface total phosphorus concentration was 0.04 mg/L, which is above the US EPA threshold of 0.03 mg/L for a eutrophic lake, but less than 0.06 mg/L threshold established in the Lake Mohawk Management Plan. The mean bottom water total phosphorus concentration was 0.055 mg/L, which is below the 0.10 mg/L threshold established in the Lake Mohawk Management Plan. Dissolved organic phosphorus concentrations were consistently low, less than 0.02 mg/L throughout the 2002 season. Water clarity

suffered somewhat in August 2002, with Secchi disc readings less than 1 foot in the coves and shoreline areas caused by a blue-green algae bloom; but for the rest of the summer, Secchi depths were 3 feet or more. The overall phytoplankton community dynamics of Lake Mohawk followed a pattern that is typical of eutrophic lakes. Blue-green algae, and to a lesser extent green algae, were responsible for the nuisance conditions in August. Overall water quality conditions were generally acceptable through the 2002 season.

Coliform testing at public swimming areas. For the last 15 years, Sussex County sanitarians have tested public swimming areas during the summer. These tests have shown occasional episodes of high coliform counts, typically the result of either nearby septic problems or Canada geese. Commercial recreational lakes do their own testing, with occasional spot-checks by the County.

Other Lake Studies: Other than the studies listed, there has been no formal, comprehensive monitoring of the lakes in Byram Township. The assumption is that they all remain in various stages of eutrophication, that septic management is a necessary and effective strategy, that better zoning and land-use practices will positively affect the lakes, and that improved stormwater systems should continue to be implemented

2.1.2 Existing In-Lake Management Programs

Lake Management Programs have been initiated at several of the lakes in Byram Township. These programs are described below:

Cranberry Lake: Cranberry Lake has obtained approximately $550,000 since the 1992 Feasibility Study to undertake a series of lake management strategies including retrofitting of all drainage basins, dredging, in-lake testing, and mechanical weed harvesting. The Cranberry Lake Community Club pays a private company for chemical weed control, which includes some water quality monitoring. One cove of Cranberry Lake with serious siltation and nuisance weed growth was dredged several years ago. Weed harvesting was also tried on Cranberry Lake; it was very successful but expensive. Byram Township is currently considering buying a harvester that could be used on all of the lakes, but they are trying to work out details such as who runs the harvester, scheduling, and other issues.

A small gasoline spill occurred on Cranberry Lake several years ago, which resulted in the contamination of several residential wells. Filtration systems were installed in the affected homes but in the course of examining this episode, low levels of MTBE (a gasoline additive) were detected throughout the lake itself and in a number of wells in various Cranberry Lake neighborhoods. The US Geological Survey and the NJ Department of Environmental Protection conducted a series of well tests and produced a pamphlet detailing the results.

Lake Lackawanna: Lake Lackawanna does not do its own water monitoring; however, their weed control vendor, Allied Biological, does some testing. Limited water quality analyses and a macrophyte survey are included in the monitoring program. LLIC is proposing a small weed harvesting/dredging program in one of its coves.

Lake Mohawk: The Lake Mohawk Country Club has an active lake management program and a Lake Master Plan. As part of the 2002 Phosphorus Management Program, the stormwater control system around the lake was updated, including nineteen siltation basins around the lake. An innovative, in-lake alum dosing system was also installed in the lake to bind alum with phosphorus, reducing the phosphorus levels available for algae. The dosing system is designed to release alum at a rate equal to the inflowing phosphorus loading. Additionally, an alum blanket was applied in two separate years in an effort to control nutrient recycling from the sediments. The lake has benefited from a five-fold decrease in phosphorus levels. A destratification aeration system was installed in the deepest parts of the lake to ensure complete mixing, thus maintaining dissolved oxygen levels and further facilitating the alum blanket functions. The Country Club has also engaged in a thorough public outreach and education program, coupled with restrictions on phosphorus fertilizers and household products and requests to the local golf course for integrated pest management practices. The Mohawk Lake Country Club entered into a septic management program in both Sparta Township and Byram Township, much like the Cranberry Lake program.

Township-Wide Programs: The Byram Township Environmental Commission is discussing ways to facilitate mechanical harvesting of weeds to diminish the quantities of chemical herbicides applied in the Township lakes.

Eurasian Milfoil Harvesting
Source: Cedar Eden, LLC

2.2 Municipal Planning in Byram Township

2.2.1 Township Ordinances and Regulations

Byram Township has a number of existing ordinances and regulations that are designed to preserve and protect the water quality and critical areas within the Township. Each ordinance or regulation is listed and summarized below.

Septic Management Program—Ordinance BH1-2005

This ordinance was originally passed by the Township Board of Health in 1990 to encompass 525 homeowners in the Cranberry Lake neighborhood. It was amended for minor issues in 1998, and amended in 2005 to also include the 312 homeowners in the Lake Lackawanna neighborhood.

The ordinance requires that all homeowners:

- submit to-scale plot plans of their parcels showing the location and nature of their septic systems;
- submit proof that they are pumping their systems on a 3-year cycle; and
- pay a $15 program fee to the Township each time they submit proof of pumping.

In addition, the ordinance requires that the Township provide homeowners with educational materials about septic system management at the start of the program and imposes possible penalties of $100 per violation plus $25 per day of the violation after the Township issues a notice of violation. The ordinance provides a waiver process based on annual certifications by a licensed pumper that the system does not need pumping, but no pumping schedule shall exceed once every six years unless there are proven extenuating circumstances.

Lake Mohawk Septic Management District—Ordinance BH1-1999

This ordinance was adopted by the Townships of Byram and Sparta on the recommendations of the Lake Mohawk Country Club (LMCC), which governs this lake neighborhood lying mostly in Sparta Township. LMCC administers the program and the Townships enforce it.

The ordinance requires that all homeowners:

- apply for licenses to operate their septic systems;
- submit to-scale plot plans of their parcels showing septic location; and
- submit proof that they are pumping their systems on a 3-year cycle.

In addition, the ordinance requires that the Township provide homeowners with educational materials about septic management and imposes possible penalties of up

to $100 for each violation plus $25 per day of the violation after the Township issues a notice of violation. The ordinance provides a waiver process based on annual certifications by a licensed pumper that the system does not need pumping.

Lawn Fertilizer—Ordinance BH2-1999

This ordinance was passed on the recommendation of the Lake Mohawk Country Club (LMCC) to ban the use of fertilizers containing phosphorus (new turf is exempted for the first growing season).

In addition:

- lawn fertilizers may not be applied when the ground is frozen;
- fertilizers may not be applied within 10 feet of any wetland or body of water; and
- leaves and other vegetative materials are not to be deposited on roads or in stormwater drainage systems in the lake.

The ordinance provides possible penalties of $200.

Tract Disturbance Ordinance—Ordinance 27-2004

This ordinance provides for “reasonable control of development” within critical areas, which are defined as surface water, wetlands, steep slopes, ridgelines and hillcrests, and floodplains. It applies to all applications for development and approval, including subdivisions, site plans, and building permits. Roadway or utility projects undertaken by a government entity, farming as defined in the State Right to Farm Act, and forestry activities related to an approve State Forest Service Forest Management Plan are exempt.

Conservation easements/deed restrictions are required for all critical areas inside or outside the area of tract disturbance. All subdivision plats shall reference such easements.

Proximity to Waterways—Ordinance 240-25

This ordinance requires that all parcels having frontage on a lake shall meet the minimum lot area requirements of at least the R-2 zone (minimum 40,000 square foot lot size plus greater setbacks), rather than the R-3 (20,000 square foot) or R-4 (10,000 square foot) zones historically typical of the lake communities.

This ordinance also requires that all structures (except docks, etc.) be at least one foot above the 100-year floodplain and otherwise not obstruct water flow. In addition, erosion and sedimentation control plans must be in place before any structure is constructed within 75 feet of any lake, stream, or natural watercourse.

Conduct—Article II, adopted 12/19/79

This regulation prohibits the placement of anything in any water bodies, storm sewers, or adjacent to any park that could pollute those waters.

Smart Growth Regulations and Standards—Ordinance 22-2003

The goals of this ordinance include preserving lake communities and rural environs.

Residential schedule of space regulations—240 Attachment 1

These regulations require a minimum setback of building envelopes from surface waters, including wetlands of 100 feet in the R-1 zone, 75 feet in the R-1A zone, 50 feet in the R-2 zone, 35 feet in the R-3 zone, and 40 feet in the R-4 zone. The setback is measured from the 100-year flood line.

Open space requirements for subdivisions in all residential zones—various ordinances

The open space regulations that are included in various Township regulations require that developers must show that the open space provisions are expected to promote one or more objectives, including conservation of natural features such as streambeds, lakes, ponds, protection of floodplains, and preservation of significant/sensitive views.

Byram Township Stormwater Management Ordinance

The Township is currently developing a Stormwater Management Ordinance. The ordinance is expected to be adopted in the spring of 2006.

Byram Township Tree Protection Ordinance

The Byram Township Environmental Commission has drafted a Tree Protection ordinance for Planning Board and Council review that aims at controlling excessive lot-clearing in new subdivisions and existing residential lots, especially around the Township's lakes.

2.2.2 Township Planning Documents

Over the past decade or more the Township has produced several major environmental and planning documents that address, among other issues, the protection and management of the Township's many lakes, with particular concern for sustaining the half dozen lakes that are heavily developed.

The most recent of these, the 2004 Master Plan, draws together many of the recommendations in the prior documents and calls for major zoning changes through

ordinances that emphasize environmental protection and the preservation of Township and neighborhood character.

Each of the Township's planning documents are listed and described briefly below.

Natural Resources Inventory, 1994

This document, prepared by the Byram Township Environmental Commission, gathered substantial information about existing and potential sources for contamination of surface waters and groundwater, including water testing and lake management studies from the early 1980s. Chapter 5, Water Resources, emphasizes the importance of protecting surface water and groundwater quantity and quality in Byram Township. Chapter 7 contains recommended planning practices and ordinances from the Township Planner and the Environmental Commission.

These include:

- requiring 100-foot buffers around all water bodies;
- prohibiting development within 100-year floodplains;
- installing better stormwater controls that emphasize natural structures and pollution control;
- minimizing tree removal, in particular around lakes;
- establishing more cautious zoning and planning procedures for the lake communities, including restrictions on house size on small lots or on inadequate septic systems; and
- prohibiting disturbance on steep slopes and ridgelines.

Lubbers Run Greenway Project: A Stream Corridor Study, 1997 with 2000 update

This document, prepared under a grant obtained by the Byram Township Environmental Commission, discusses land use and environmental protection within the watershed of the Township's most important stream, Lubbers Run. Many of the recommendations in this Study also pertain to lakeshore and lake watershed land use. Specifically included in the Study is Lake Lackawanna, a dammed portion of Lubbers Run, its Wolf Lake tributaries, and Jefferson Lake, which drains directly to Lubbers Run. (Two other smaller lakes in Byram Township—Tomahawk and Dallis— were also created by damming Lubbers Run.)

Major emphases of the Study include:

- emphasis on the beauty of the stream corridor and its viewsheds;
- protection of sensitive ecological communities;
- best management practices; and
- improved land use practices.

Open Space Plan, 2000

The Open Space and Recreation Plan compiled by the Morris Land Conservancy and the Byram Township Open Space Committee establishes project areas that aim to preserve the large undeveloped forested tracts between Byram Township's compact neighborhoods. The Plan also aims to establish trailways and greenways that protect important corridors and connect all of Byram Township's residential, commercial, and civic areas by foot or bicycle.

The goals of the plan include:

- preserving the character and special sense of place of the Township's historic areas;
- preserving the character and special sense of place of the Township's 'lakeside' communities;
- maintaining the essential rural character and amenity of the Township by guarding against degradation and destruction of woodlands, steep slopes, lakes and waterways, areas of natural beauty, sensitive environmental areas, productive agricultural areas, and important historic places; and
- protecting stream corridors, wetlands, woodlands, steep slopes, groundwater recharge, lakes, and other environmentally sensitive lands and waters through the development of local ordinances.

The Plan also points out the need to "decrease and restrict new impervious surface surrounding the lakes…to minimize the amount of stormwater runoff entering the ecosystem and protect the lakes from further degradation."

Smart Growth Plan, 2002

Prepared by Township Planners from Heyer, Gruel & Associates under a State Smart Growth Grant, this Plan emphasized a new approach for the Township and was the basis for the new Master Plan. In accordance with the NJ State Development and Redevelopment Plan, the Township's Smart Growth Plan established a Village Center land use plan (along a portion of Route 206) and a preservation plan for the Environs (the Township's lakes and lake communities and broad expanses of undeveloped land between them). The Smart Growth Plan supports the designation of Byram Township as PA 4 and 5 and the location of the Township within the Highlands project area.

The Township's Village Center was officially designated by the State Planning Commission on May 19, 2004. The Center is approximately 600 acres and occupies about 2 percent of Byram' Townships land mass. The remainder of the Township is now officially within the Highlands Preservation Area. The Smart Growth Plan notes that the Township will prepare a separate Lake Development Plan, under a Smart Growth grant from the Association of New Jersey Environmental Commissions.

Lakefront Development Plan, September 2003

Prepared by Township Planners from Heyer, Gruel & Associates under an ANJEC Smart Growth grant, this document describes and maps existing conditions, including zoning, at the Township's six most heavily developed lakes—Cranberry, Lackawanna, Mohawk, Forest, Johnson, and Panther. It identifies environmental constraints and critical planning issues, relates the Lakefront Development Plan to the Township's Smart Growth Plan, Open Space Plan, and Lubbers Run Greenway Project, reviews State regulations for lake districts, and makes specific recommendations, including:

- zoning changes and design standards to protect the lakes and maintain neighborhood character;
- septic management for all lake neighborhoods;
- open space preservation strategies;
- public education; and
- lake management plans for each lake.

The Lakefront Development Plan also discusses the importance of protecting the Township's Environs, which are characterized by large expanses of undeveloped land, mostly forested, lying between the compact lake neighborhoods. The Lakefront Development Plan, like the Township's other planning documents, aims at sustaining and improving the lake neighborhoods while limiting development in the environs.

Byram Township Master Plan, 2004

Prepared by Township Planners from Heyer, Gruel & Associates under an ANJEC Smart Growth Grant, this document establishes Smart Growth goals and strategies for Byram Township and encompasses the recommendations from the earlier planning documents described above. The introduction and vision emphasize the Township's natural beauty and tight-knit neighborhoods, most of which are settled around the largest of it two dozen lakes and ponds, and the importance of maintaining neighborhood character and water quality.

The 'Goals and Objectives' of the Master Plan are to:

- Maintain the traditional character of each lake community, including preserving the environmentally sensitive areas and undeveloped forests surrounding these communities, which together establish Byram's distinct land use pattern.
- Minimize the impact of development on Byram's extensive forestlands, waterways, and wildlife.
- Encourage the preservation of the Township's historic and cultural resources, including scenic views, forests, ridges, waterways, and rural roadways.
- Support the State Development and Redevelopment Plan and the Highlands Act, which direct carefully planned growth to Byram's designated Village Center and

call for very limited development in the remaining Environs and the Highlands Preservation Core.
- Protect stream corridors, wetlands, woodlands, steep slopes, groundwater recharge areas, lakes, ponds and other critical areas through the enforcement of local ordinances.
- Protect and upgrade water quality in Byram's lakes and ponds and groundwater through enhanced land use controls, open space acquisitions, better stormwater management, and septic-management programs.
- Minimize the visual impact of residential, commercial, and public development projects on the natural environment.

The 'Land Use and Zoning Plan' of the Master Plan calls for increasing most residential lot sizes in the Environs to 5- or 10-acre and establishes an Open Space Zone for preserved parcels. It leaves in place small-lot zoning in already-built neighborhoods, including the lakes, but requires one acre lots whenever new lots are created that depend on septic systems and wells and requires that lakeside lots meet the standards of the 40,000 square-foot zone (even when the neighborhood zoning is 20,000 or 10,000 square feet).

The 'Revised Residential Bulk Standards' of the Master Plan establishes more restrictive lot disturbances and building coverages, establishes minimum setbacks from all surface waters (including wetlands) ranging from 50 to 100 feet from the 100-year flood line, and calls for a 10-foot-wide vegetated buffer along at least 80% of the water's edge.

The 'Conservation Recommendations' of the Master Plan cites the Byram Lakefront Development Plan for its recommendations to protect water quality and lake health, as well as neighborhood character and notes that it "should be considered Township planning policy." It specifically cites the Lakefront Development Plan's recommendation for septic management at all lake communities and calls for each lake to prepare and adopt a lake management plan.

Other conservation recommendations in the Master Plan call for:

- an improved, cohesive stormwater management plan;
- a reduction in the sewer service area coinciding with the Designated Village Center to help contain sprawl (including major expansions of the lake community boundaries or increases in the density of housing there);
- a dam safety program (all Township lakes are dammed);
- an expanded water quality monitoring program in the lakes (currently Sussex County sanitarians do regular summer beach water testing);
- a comprehensive Township woodland management plan; and
- protection of groundwater and well water (citing an October 2004 report prepared under a grant obtained by the Byram Township Environmental Commission that

assesses groundwater and aquifers in Byram Township, calls for a wellhead protection program, and proposes a supply well evaluation ordinance).

Under 'Utility Services,' the Master Plan discusses non-point source impacts on the lakes and discusses:

- retrofitting catch basins (completed at Cranberry Lake under a State lake management grant);
- harvesting weeds to reduce pesticide use (also used in a Cranberry Lake pilot management strategy and under discussion by the Environmental Commission for all lakes);
- spot dredging (conducted at Cranberry Lake and proposed at Lake Lackawanna);
- community outreach and education; and
- septic system management.

Municipal Stormwater Management Plan for Byram Township, 2005

The Municipal Stormwater Management Plan for Byram Township was adopted according to the requirements of the New Jersey Department of Environmental Protection (NJ DEP) Municipal Stormwater Regulation Program, under USEPA's Phase II NPDES stormwater rules. The plan contains all of the required elements described in N.J.A.C. 7:8 Stormwater Management Rules including how to address groundwater recharge, stormwater quantity, and stormwater quality impacts by incorporating stormwater design and performance standards for new major developments.

Stormwater Pollution Prevention Plan, 2005

The Stormwater Pollution Prevention Plan prepared by Harold E. Pellow & Associates was also developed to meet the requirements under the USEPA's Phase II NPDES Stormwater regulations. The Plan describes the measures that the Township is planning to use to meet the six Minimum Control Measures (MCMs) required of regulated small MS4 municipalities.

The MCMs include:

1. Public education and outreach on stormwater impacts.
2. Public involvement/participation.
3. Illicit discharge detection and elimination.
4. Construction site stormwater runoff control.
5. Post-construction stormwater management in new development and redevelopment.
6. Pollution prevention/good housekeeping for municipal operations

2.2.3 Highlands Council Planning

In 2004, the New Jersey State Legislature determined that a coordinated regional effort is necessary to safeguard the Highlands Region from the detrimental effects of overdevelopment, and thus created the Highlands Council. The major planning documents that have been developed by the Highlands Council to enhance local land use planning efforts include the Highlands Water Protection and Planning Act and the Highlands Regional Master Plan (in development).

Highlands Water Protection and Planning Act, 2004

The Highlands Water Protection and Planning Act, or Highlands Act, created the Highlands Water Protection and Planning Council. The Highlands Act requires that a portion of state realty transfer fee revenue be dedicated annually for conservation purposes in the Highlands Region and the Pinelands Area. The goal of the Highlands Council is to protect drinking water sources, preserve open space, and provide effective regional planning for the Highlands region.

Highlands Regional Master Plan, to be completed in 2006

The Highlands Council is charged with the creation of a Regional Master Plan by the spring of 2006, which will include, at a minimum, the following elements: a resource assessment; financial component; government and public input component; coordination and consistency component; transportation component; smart growth component; and a preservation area land use capability component. Included in the Master Plan will be a Land Capability Map that will be the result of a carrying capacity analysis of the Highlands Region.

Suburban sprawl, left unchecked, can get out of hand
Source: NRCS

3.0 Lake Management Recommendations

A number of lake water quality protection and improvement measures are currently being employed in Byram Township, including lake monitoring programs, municipal planning, Smart Growth initiatives, and in-lake management practices. However, it is clear that more can be done to protect and enhance the lakes, streams, and wetlands in Byram Township that remain so critical to wellhead protection, health, recreation, aesthetics, and natural habitat. This section discusses these additional lake management recommendations in detail.

3.1 Lake Monitoring Programs

Existing lake monitoring programs in Byram Township are discussed in Section 2.1. Further recommendations for monitoring the water quality in Byram Township's lakes and ponds are discussed below.

3.1.1 Changes to Existing Programs

Although Lake Mohawk, Cranberry Lake, and Lake Lackawanna have conducted water quality monitoring programs, only Lake Mohawk's program is comprehensive enough to provide long-term data of a quality to reveal trends in water quality, either improving or deteriorating, over time. In particular, the trophic state parameters, including total phosphorus, Secchi disc transparency, and chlorophyll a, should be monitored regularly in order to not only determine the trophic status of the lakes, but also to compare the lakes to EPA standards for these parameters. Biological parameters, such as chlorophyll a, phytoplankton counts, and zooplankton counts, are important measurements to determine how the lake's biological community is responding to the nutrient levels in the lake.

In addition, because algae blooms have been a problem at some lakes in Byram Township in the past, we recommend that each lake that is used for swimming be monitored for phytoplankton populations during the growing season. This is due to the fact that some species of blue-green algae produce toxins when the algae are present in large numbers that can be dangerous for humans and animals that ingest or come in contact with the lake water. In particular, Lackawanna Lake's monitoring program should be expanded to include the trophic state parameters.

3.1.2 Model Township-Wide Monitoring Program

Lake monitoring helps lake managers and residents to develop an understanding of key interactions within a lake and its watershed, particularly those related to land use. Data from regular monitoring enables a lake management program to be designed to reduce or minimize those activities within a watershed that may negatively impact water quality. It is recommended that a Township-wide lake and pond monitoring program be established for Byram Township in order to fully evaluate the quality of lake waters that

have not been monitored, and to compare waters that have been monitored in the past in order to detect changes or problems over time. The monitoring program can be conducted by volunteers that have been trained by professional lake scientists. With a well-organized program, coordination of sample collection and laboratory analyses, as well as data evaluation, can be relatively simple and effective.

A lake monitoring manual should be developed that outlines the program, describes each monitoring parameter and why it is used, explains general lake ecology concepts, and provides a set of step-by-step instructions for lake water sample collection. Volunteers could collect lake samples as part of an annual "Lake Awareness Day" or Byram Day celebration, or on their own throughout the summer. The Township should purchase a set of lake monitoring equipment for volunteer use. An annual training should be held to instruct the volunteers in the use of the equipment. It is critical for the volunteers to perform their analyses under the guidance of a professional lake scientist. Lake data are only as good as the quality of the sampling regime, and poorly collected data are not useful to provide meaningful results. Well-trained volunteers, however, can be highly successful and can significantly lower the cost of a water quality monitoring program.

Several different program options could be employed, depending on the desires of the individual lake associations. For simplicity, two monitoring options are described below: a Minimum Monitoring Program and a Comprehensive Monitoring Program.

Minimum Monitoring Program

At a minimum, each lake or pond in Byram Township should be monitored once per year during the height of the growing season in July or August for the three basic trophic state parameters. These three parameters are:

- **Chlorophyll a**: Chlorophyll a is the green photosynthetic pigment found in the cells of all algae. By taking a measured sample of lake water and extracting the chlorophyll a from the algae cells contained in that sample, a good estimate of the biomass of the algal population can be made. The ease of sampling and relatively low cost of analysis makes chlorophyll a an attractive parameter for characterizing the algal population in lakes. However, it is important to understand that chlorophyll a analysis does not provide any information about the species of algae present, which can be important information if one is concerned about the potential negative impacts of algae toxins on human health.

- **Total phosphorus**: Phosphorus is one of several essential nutrients that algae and vascular plants need to grow and reproduce. In many lakes, phosphorus is in short supply; therefore, it often serves as a limiting factor for algal growth. The majority of phosphorus enters lake water from human sources. Lakes with developed watersheds often receive human-generated phosphorus through stormwater runoff, septic leachate, and

other sources. This runoff fertilizes the water and can stimulate increased algal and plant growth.

- **Secchi disk transparency**: Secchi disk transparency is commonly used in lake management as a general indicator of water clarity. Water transparency is affected by a number of factors, including algae, microscopic organisms other than algae, natural or unnatural dissolved materials that color or stain the water, and suspended sediments. Although somewhat simplistic, this testing method probably best represents the conditions which are most readily visible to the common lake user.

By analyzing the three trophic state parameters, Carlson's Trophic State Index can be calculated. Trophic state is a term used in limnology (lake science) to describe the amount of productivity (algae and weeds) found in a lake. Oligotrophic lakes have few algae and other plants and appear clean and clear, while eutrophic lakes show an overabundance of growth and often have a pronounced green color due to algae. Knowing a lake's trophic state provides information about what lake management techniques are applicable to the given lake.

Comprehensive Monitoring Program

A more comprehensive lake monitoring program should be designed for each of the five most developed lakes in Byram Township: Cranberry Lake, Lake Lackawanna, Forest Lake, Johnson Lake, Panther Lake and Lake Mohawk. This program should include monthly monitoring during the growing season (May or June through September) for total phosphorus, dissolved orthophosphate, nitrate/nitrite, ammonia, organic nitrogen, alkalinity, pH, total suspended solids, Secchi disc transparency, chlorophyll a and phytoplankton and zooplankton populations. In addition, dissolved oxygen and temperature profiles should be measured at each lake. This more comprehensive program would provide more detailed information about the sources of any nutrient loading, as well as critical information about potential algae blooms and toxins.

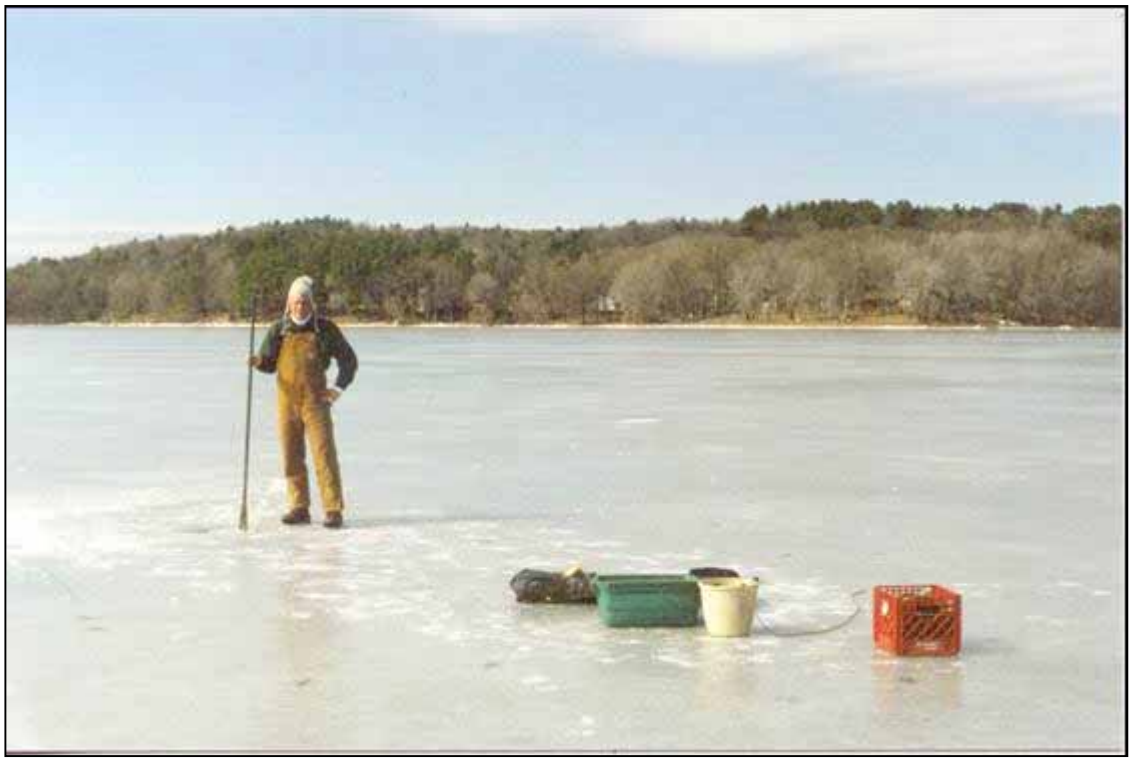
Once a year, preferably in July or August, an aquatic plant survey should be performed to identify the type and distribution of macrophytes (aquatic plants). This should be performed to identify the presence of excessive aquatic plants and/or invasive aquatic species and to document aquatic plant growth patterns in each lake. A bathymetric (lake depth) survey should be performed to determine the amount of sediment accumulation in the lakes and the need for dredging. Wet and dry weather stream monitoring should be performed to estimate the amount of nutrients and sediment entering each lake. Dry weather stream samples generally detect septic system problems and wet weather samples are indicators of stormwater runoff.

In addition to the lake monitoring programs, a Township-wide watershed monitoring program is recommended to look for nonpoint source pollution problem areas such as roadside erosion, streambank or shoreline erosion, culvert damage, swale sediment

clogging, and other sources of stormwater runoff and sedimentation. The investigations could be carried out by volunteers under the guidance of a professional. Retired Senior Volunteers, Americorp workers, or college students would be good sources for volunteers.

3.1.3 Lake Management Plans

As indicated in several of Byram Township's existing planning documents, each of the developed lakes in Byram Township should have a lake management plan. The plans should include a thorough watershed delineation for the lake, a description of point and nonpoint sources of pollution in the lake's watershed, lake monitoring schedules, existing and proposed in-lake management techniques, and recommended watershed best management practices for each lake. Each lake management plan should be developed with sufficient input from the lake community members. A public meeting should be held upon plan completion in order to educate the community about the plan recommendations and to encourage plan implementation.



Lakes can be monitored year round, but most lake monitoring programs focus on the summer growing season

3.2 Municipal Planning

Byram Township has been proactive in its development and implementation of municipal planning, ordinances, and regulations that help protect the quality of the Township's abundant natural resources. The following section describes some additional ordinances and planning documents that would further the goal of water quality preservation and improvement in the Township.

3.2.1 Stormwater Ordinance

Of all the municipal planning priorities for Byram Township, the adoption and implementation of a stormwater ordinance should top the list. Byram Township is in the process of developing a Stormwater Ordinance as part of the requirements for the New Jersey Department of Environmental Protection (NJ DEP) Municipal Stormwater Regulation Program, under USEPA's Phase II stormwater rules. The stormwater management ordinance should incorporate the Part II NPDES requirements for New Jersey.

3.2.2 Township Stormwater Management Plan

In addition to the Stormwater Ordinance, Byram Township should adopt and implement their Township Stormwater Management Plan and Stormwater Pollution Prevention Plan. The stormwater management plan incorporates the Design and Performance Standards in New Jersey's Stormwater Management Rules (N.J.A.C. 7:8-4.2). Whenever possible, low impact development concepts should be incorporated into all new development plans. Low impact development is an innovative, ecosystem-based approach to land development and stormwater management. The general goals of low impact development are to reduce the amount of impervious area on a site and to infiltrate and treat stormwater runoff. Low impact development mimics the pre-development hydrology and controls the peak flow, volume, and quality of stormwater runoff. It does this by minimizing the effective impervious area (the impervious area that produces stormwater runoff) and directing stormwater runoff onto vegetated areas that treat, infiltrate, and evaporate the runoff.

3.2.3 Tree Ordinance

A tree ordinance is currently in the development stages in Byram Township. Any tree ordinance should aim to preserve the mature trees in the township. In addition, the ordinance should include provisions to limit the size, type, and number of trees that can be cut within a buffer zone of any water body. This will help to preserve the riparian buffers along the lakes and streams in the Township that help to stabilize streambanks, filter nutrients in stormwater runoff, maintain proper water temperature, provide habitat, and contribute leaf litter to streams that many stream organisms require for food or shelter.

Examples of provisions that should be included in the tree ordinance are:

- Restrict the removal of 30 percent of the trees in excess of six inches in diameter at breast height within 50 feet of the 100-year floodplain of any water body or wetland.
- Within six feet of the 100-year floodplain, only 30 percent of any type of vegetation should be allowed to be removed from any individual lot. This would apply to areas outside of the lake communities. The new Master Plan calls for a 10-foot buffer to be maintained along 80 percent of the shoreline on all lots.
- The ordinance would not apply to diseased or rotten vegetation, or to trees posing a threat to structures or power lines. Nor would the ordinance apply to vegetation within road or power line right-of-ways.

3.2.4 Riparian Buffer Ordinance

A riparian buffer ordinance should be adopted to require vegetated buffers along wetlands, streams, and lake and pond shorelines for all new construction projects. A buffer of approximately 75 feet should be sufficient to protect water quality along wetlands and streams. A 50-foot buffer is more realistic for lake and pond shorelines. The purpose of the riparian buffer would be to (1) eliminate major earthmoving activities close to the waterbody, (2) filter and infiltrate stormwater runoff before it reaches the water, and (3) maintain stabilized streambanks and shorelines to prevent erosion.

3.2.5 Natural Landscaping/Noxious Weed Ordinance

A Natural Landscaping and Noxious Weed Ordinance should be adopted in order to promote the use of native vegetation, including native grasses and wildflowers, in managed yards and landscapes to preserve and restore natural plant communities and discourage the colonization of noxious (non-native, invasive) weeds. It is important to include provisions for maintaining buffers in riparian and drainage areas so that the ordinance is not misinterpreted, resulting in removal of vegetation in such areas.

3.2.6 Pet Waste Ordinance

Pet waste can be a significant source of nutrient loading to water bodies when it is washed into surface waters from residential areas with stormwater runoff. In order to reduce the amount of improperly disposed pet waste for both water quality and aesthetic reasons, Byram Township should adopt a pet waste ordinance that would require pet owners to clean up after their pets and dispose of the waste in a proper trash receptacle. A model pet waste ordinance can be found on the NJ DEP's stormwater website. Sparta Township, in which most of Lake Mohawk lies, currently has a draft pet waste ordinance.

3.2.7 Wildlife Feeding Ordinance

As with pet waste, droppings from wildlife such as Canada Geese can be a significant source of nutrient and bacteria loading to water bodies. Feeding waterfowl and other wildlife encourages resident populations. In order to reduce the amount of wildlife waste in surface waters, Byram Township should adopt a wildlife feeding ordinance that would ban residents or visitors from feeding or otherwise encouraging nuisance wildlife congregation. A model wildlife feeding ordinance can be found on the NJ DEP's stormwater website.

3.2.8 Phosphate Ban Ordinance

Phosphorus is often the limiting nutrient that controls algae growth in lakes. Reducing the amount of phosphorus entering stormwater runoff within Byram Township would lead to less phosphorus entering the lakes, and a subsequent reduction in excess algae and weed growth. Sources of phosphorus in the lake community include lawn and garden fertilizers, and phosphate-containing cleaning products used in the home that enter the groundwater via septic systems. The Lake Mohawk community currently has a regulation banning the use of fertilizers and cleaning products that contain phosphates. A similar phosphate ban ordinance should be adopted for all of Byram Township. The ordinance should include a provision that newly established turf areas may be exempt from the ordinance for the first growing season.

3.2.9 Land Carrying Capacity Planning

The Highlands Council is in the process of undertaking a land carrying capacity analysis of the Highlands Region as part of the Highlands Region Master Plan. Regional carrying capacity can be generally defined as the maximum amount of growth or development that can be supported indefinitely in a defined region without permanently impairing the sustainability of the region. The Highlands Council is preparing a Land Capability Map of the Highlands that will:

- identify existing developed areas capable of sustaining redevelopment,
- identify undeveloped areas that could be developed (i.e. areas not significantly constrained by environmental limitations such as steep slopes, wetlands, or dense forests, that are not prime agricultural areas, and that are located near or adjacent to existing development and infrastructure),
- identify infrastructure that would support or limit development and redevelopment,
- identify special critical environmental areas and other critical natural resource lands where development should be limited; and
- identify areas appropriate for redevelopment. [Highlands Act, N.J.S.A. 13:20-11.a(6)]

Figure 2 shows a schematic diagram of the preliminary plan for the Highlands Land Capability Map. Byram Township should amend its Master Plan to include references to the Highlands Council Land Capability Map, and the Byram Planning Board should refer to the map when making decisions regarding growth and development in Byram Township. Byram Township should set appropriate density standards for redevelopment in areas that are appropriate for redevelopment.

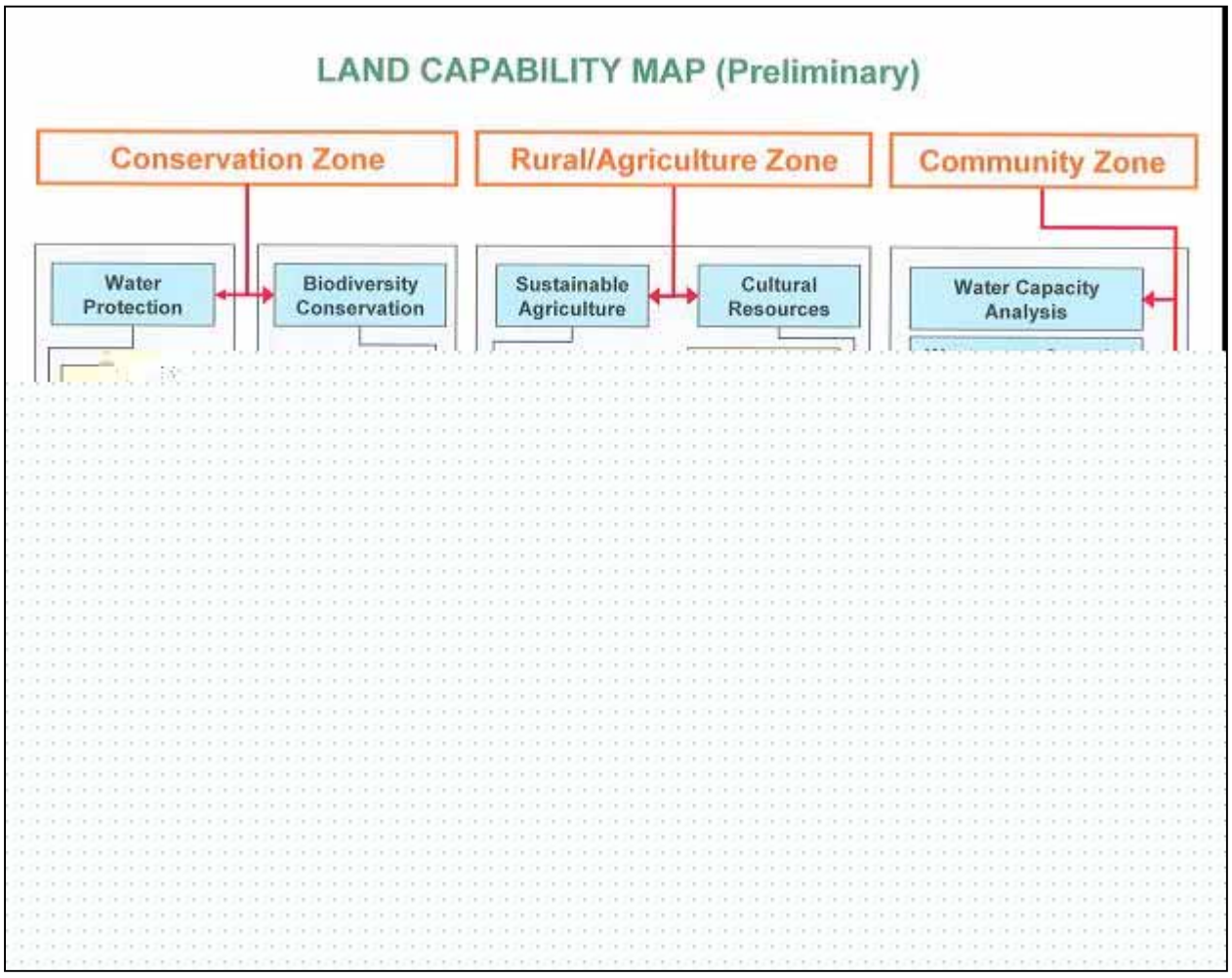


Figure 2: Preliminary Plan for Highlands Land Capability Map
Source: Highlands Regional Master Plan Update, January 2006

3.3 In-Lake Management

Lake Mohawk and Cranberry Lake are currently implementing various in-lake water quality management strategies, most of which are highly successful. However, the other lakes in the Township may also benefit from in-lake management. The following sections provide general information about potentially applicable in-lake management techniques. At this time, these strategies are not being specifically recommended for individual lakes. Although these techniques can be highly successful when properly applied, careful feasibility investigations should be conducted for each lake before determining the applicability of in-lake management techniques.

3.3.1 Aquatic Weed Control

Nuisance levels of aquatic vegetation can create major problems for lake users. Overabundant macrophytes (aquatic weeds) can interfere with recreation (fishing, boating and swimming) and can adversely affect aesthetics. However, it is important to remember that a certain amount of aquatic weeds are beneficial. Macrophytes protect the shoreline from erosion by dampening the force of waves and stabilizing soils. They provide animal habitat, cover, food, and spawning sites, and are critical to the ecology of a healthy lake. Lake management strategies must strike a balance between preserving a certain amount of macrophyte growth while allowing traditional lake uses to continue unimpeded.

Macrophyte removal can be accomplished by various means, including physical, biological, and chemical methods. The following is a brief summary of each general macrophyte management technique. The applicability of each technique to any individual lake is determined by the type of aquatic vegetation present, the ecology and the use of that lake and must be considered on a case-by-case basis after careful study of the lake's ecology.

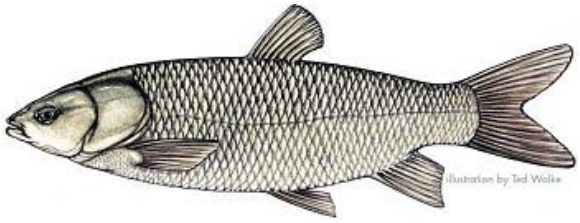
Lake Drawdown

Lake drawdown is a physical means of macrophyte management, involving partially draining the lake during the winter months and allowing the aquatic plants and the substrate around the lake edges to freeze. This method is not always effective as it depends upon the weather and the types of plants in the lake, but it is a relatively simple and very inexpensive management technique. A lake drawdown permit is required from the NJ Department of Environmental Protection Division of Fish and Wildlife. The main disadvantage to this technique is that all vegetation, even beneficial vegetation, may be killed. Ideally the native vegetation will re-colonize the affected area over time, but sometimes invasive or non-native species will take advantage of the disturbance and more rapidly colonize the areas to nuisance levels.

Grass Carp

Grass Carp (*Ctenopharyngodon idella*), or white amur, are voracious feeders on aquatic vegetation, eating many pounds in a single day. Stocking a lake with grass carp is a

chemical-free weed control option. Reproductively sterile forms of the fish, called "triploid" grass carp, are allowed under a tightly regulated permit, available through the NJ Department of Environmental Protection Division of Fish and Wildlife. There are a number of factors that affect the rate and the amount of vegetation consumed by grass carp, such as water temperature, water quality, size of the fish and very importantly the species of vegetation available. A detailed macrophyte survey is recommended for any lake where grass carp stocking is being considered to ensure that the types of vegetation desired to be removed are compatible with the preferred diet of the carp.



Grass Carp
Source: PA Fish & Boat

The following conditions are required by the Division of Fish and Wildlife for a grass carp stocking permit:

- The water body must be 10 acres or less in size,
- The lake's outlet structure must be such that the fish can be reasonably expected to be prevented from escaping,
- A minimum of 40 percent of the lake surface must be covered with a vegetation that is palatable to the species, and
- Stocking of grass carp will not be approved in areas identified as sites of endangered or threatened species, plant or animal.

Benthic Mats

Benthic mats, or bottom barriers, are a very effective physical method for controlling rooted aquatic plant growth in small areas. The mats are large sheets of fabric anchored to the lake bottom that prevent sunlight from reaching rooted aquatic plants. Plants trapped below the fabric are not able to grow up through the material or photosynthesize, and they eventually die. Benthic mats are non-toxic to the environment, and have limited impact on bottom-dwelling organisms or the surrounding habitats. The main disadvantage of benthic mats is that, compared to other control methods, benthic mats are expensive. The method is most economically feasible for isolated areas (e.g. around docks) or small stands of invasive plant species. Unlike other aquatic plant management techniques such as harvesting, the fragmentation and spread of invasive species is avoided with benthic matting. Areas with uneven bottoms, steep slopes, large rocks, embedded stumps, or large submerged logs are not good candidates for this control method, nor are areas with strong wave action or shallow waters with heavy boat traffic.

Weed Harvesting

Weed harvesting is a physical aquatic plant control method that offers lake managers a means of reducing nuisance aquatic plant growth without the environmental concerns often associated with chemical methods. Several commonly used weed harvesting

practices exist, including mechanical weed harvesting, hydroraking and rototilling. Each of these practices involves using a machine to cut, rake, or till the weeds from the sediments and then remove the weeds from the lake for off-site disposal. When considering the use of weed harvesting in a lake, a thorough macrophyte survey is recommended in order to detect the presence of certain invasive species such as Eurasian watermilfoil in the lake. The harvesting process tends to chop the plants into pieces. Invasive species such as milfoil that multiply via fragmentation can actually be spread by harvesting, creating a greater aquatic plant problem than existed originally. A better treatment for Eurasian milfoil would be benthic matting, suction harvesting (see below), or chemical herbicides (for small stands).

Mechanical Harvester
Source: VT ANR

In small areas, weeds can be pulled by hand or by a hand-held suction harvester using divers. Hand-pulling and suction harvesting reduces fragmentation and spread of invasive species, although the method is very time-consuming.

Chemical Herbicides

Chemical herbicides can be an effective way to control undesirable algae and macrophyte growth in lakes and ponds. However, they are not the preferred method of weed control for Highlands waters. Chemical treatments are costly, must be continuously added to the lake, and can cause a buildup of undesirable chemical compounds in the lake. Chemical treatments usually require lake use restrictions for a period of time after application. In addition, when aquatic weeds are killed, they sink to the bottom of the lake where they are broken down and serve as a nutrient source for additional plant growth.

Chemical herbicides are a band-aid, reactionary approach to controlling aquatic weeds and should be used as a last resort. Alternative long-term methods of improving water quality (i.e. weed harvesting, dredging, nonpoint source pollution BMPs such as riparian buffers, streambank stabilization, stormwater runoff management, and municipal ordinances) are environmentally responsible ways to avoid the use of potentially harmful chemicals. If chemical herbicides are deemed necessary, they should be applied judiciously in small, controlled areas, and at the proper time to reduce the impact on other plants and wildlife in the lake. Chemicals should never be applied to the

lakes by individual homeowners; a pesticide operator's license is required for herbicide application. Lastly, great care should be taken when considering the use of chemical herbicides in lakes and ponds around the Township's major aquifers in order to avoid groundwater contamination.

3.3.2 Alum Treatment

Phosphorus inactivation, or alum treatment, is a lake restoration process that inactivates phosphorus so that it is not available for biological uptake by the phytoplankton. There are two general types of phosphorus inactivation: batch alum treatment and continuous alum treatment.

Batch Alum Treatment

Batch alum treatment consists of applying high doses of alum (aluminum sulfate) to the surface of a lake. The alum falls to the bottom of the lake where it reacts with phosphorus to form an aluminum-phosphorus precipitate. The precipitate remains on the lake bottom and acts as a "blanket" to effectively seal the bottom sediments. The purpose of batch alum treatment is to seal the sediments so that phosphorus is not released from the lake sediments during anoxic (zero oxygen) conditions. Under the proper conditions, one alum treatment may last eight years or more. Batch alum treatment is appropriate for lakes with high internal phosphorus recycling and low external phosphorus loads.

Continuous Alum Treatment

Continuous alum treatment consists of adding alum directly to the major tributary (or tributaries) of a lake on a continuous basis. The purpose of continuous alum treatment is to remove phosphorus from the water entering a lake. Alum is added to the stream in proportion to the flow. A feasibility study involving alum jar tests should be performed in order to determine the dose needed to reduce the phosphorus concentration to a sufficient level. An alternative method is to apply alum through a lake aeration system; such a system is presently being successfully used in Lake Mohawk. Alum treatment should be considered for other Township lakes that may have internal and external phosphorus loading problems.

3.3.3 Chemical Algae Treatment

Chemical algaecides are often used as a band-aid approach to control undesirable algae growth in lakes and ponds. Chemical treatments are costly, must be continuously added to the lake, and can cause a buildup of undesirable chemical compounds in the lake. In addition, when the algae are killed, they sink to the bottom of the lake where they are broken down and serve as a nutrient source for additional algae growth. Algaecides are not the preferred method of algae control in Highlands lakes and should only be used as a last resort. Alternative long-term methods of improving water quality (i.e. dredging, nonpoint source pollution BMPs, shoreline stabilization) are environmentally responsible ways to avoid the use of potentially harmful chemicals.

For small ponds with low flushing rates, a nontoxic water colorant such as Aquashade may be useful in blocking sunlight and deterring algae and aquatic plant growth. Aquashade is an EPA-registered non-toxic organic water dye for algae and weed control that filters sunlight to reduce the growth of aquatic weeds and algae. It is also useful for coloring controlled waterways an attractive blue to enhance their aesthetic quality. Aquashade is fairly inexpensive; one gallon treats one acre of water with an average depth of four feet. Applications begin in the spring before aquatic plants begin to grow, and may significantly reduce the extent of algae blooms in small water bodies.

3.3.4 Lake Aeration

Dissolved oxygen depletion is a major problem in many eutrophic lakes. Dissolved oxygen depletion adversely affects the lake by (1) significantly reducing the habitat for fish, most of which need about 5 mg/l of dissolved oxygen to survive, (2) eliminating the benthic macroinvertebrates (bottom aquatic insects), which are food for many fish, and (3) releasing dissolved orthophosphorus from the sediments under anoxic conditions.

There are two types of lake aeration: total lake aeration and hypolimnetic aeration. Total lake aeration consists of installing aerator tubing in the bottom of the lake, as shown in Figure 3. Air is pumped through the tubing and enters the lake via small holes in the tubing. This type of aeration breaks up the stratified lake layers, if present, and allows the nutrient-laden bottom waters to mix with the top waters of the lake. Mixing of the nutrient-rich bottom waters with the surface waters can sometimes increase the eutrophication of the lake. In Lake Mohawk, destratifying aeration is being used successfully in conjunction with alum treatment to reduce the internal and external phosphorus loading in the lake.

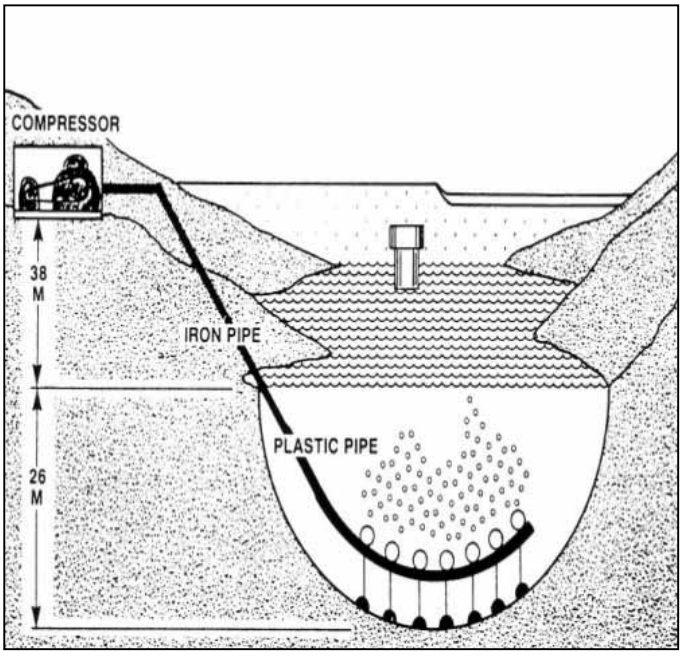


Figure 3: Total Lake Aeration
Source: Jones and Taggart, 2001

The second type of lake aeration is hypolimnetic aeration. Hypolimnetic aeration consists of adding air or oxygen to only the hypolimnion (bottom water below the thermocline) of the lake. The purpose is to aerate only the bottom water where dissolved oxygen depletion occurs. Hypolimnetic aeration, unlike total lake aeration, does not destratify the lake.

Aeration as an in-lake management strategy should be investigated via a feasibility study. Water quality studies should be performed before and after the installation of an aeration system in order to evaluate the improvement in water quality.

3.3.5 Lake Dredging

Dredging involves the removal of accumulated sediments from lakes, ponds, and reservoirs. Dredging can be an appropriate and highly effective in-lake treatment strategy when sediment accumulation is a significant management concern. There are several potential undesirable consequences of excessive sedimentation in freshwater lakes and reservoirs. Sediment accumulation contributes to lake eutrophication by aggravating internal phosphorus loading and resuspension under anoxic conditions, and by providing nutrient resources for rooted vascular aquatic plants. By reducing water depth and increasing light availability, sediment accumulation may also dramatically increase the available habitat for rooted vascular aquatic plants. Sedimentation may reduce water depth to levels that significantly impair recreational activities such as swimming and boating.

Mechanical Dredging
Source: F. X. Browne, Inc.

Two commonly-used methods exist for dredging freshwater lakes and reservoirs. These include mechanical dredging, during which material is manually removed with heavy equipment such as bulldozers and clamshell diggers, and hydraulic dredging, during which dredged material is "sucked" out of the lake using a device called a cutterhead.

Once the sediment is removed, it must be disposed of either in a dewatering basin onshore or a nearby disposal site. If the sediments are contaminated with any hazardous materials such as heavy metals or pesticides, regulatory agencies may require that the sediment be "capped" with clean fill or taken to a hazardous waste landfill. Nutrient-rich dredged soils can sometimes be used as agricultural fertilizer or as a soil amendment for restoring brownfield areas.

Dredging design and permitting usually takes at least a year to complete. The first step in the design process involves conducting a dredging feasibility study. The dredging feasibility study includes a bathymetric survey, which measures unconsolidated sediment and water depth. This information is used to then calculate sediment volume. In addition to the bathymetric survey, sediment testing may be required by regulatory agencies to determine suitable disposal alternatives. Finally, sediment disposal and lake drawdown options as well as permitting feasibility considerations are investigated. Once all the information is collected, a dredging design plan is developed that includes the

recommended type of dredging (hydraulic or mechanical), equipment needed, and recommended disposal site, as well as potential permits, funding, and timelines for the project.

Although dredging can be very effective, it is also very expensive. Often times, sediment accumulation problems can be addressed on a smaller scale by spot dredging at strategic points in the lake, such as inlet or beach areas. Spot dredging benefits lake uses such as swimming, boating, and aesthetics more than it benefits water quality.

3.3.6 Invasive Species Management

Invasive, non-native, or "exotic," weeds can be a major problem in lakes, streams, and wetlands. If left unchecked, these weeds can out-compete more desirable, native plant species. This upsets the balance of the entire ecosystem as it affects the insects and other animals that depend on the native plants for food. The term "invasive" plant refers to a plant species that has become a weed pest, growing aggressively and displacing other plants. Invasive plants tend to appear first on disturbed areas, but many will invade existing ecosystems over time.

Mats of Eurasian watermilfoil in Cayuga Lake, NY
Source: Robert L. Johnson, Cornell University

Common aquatic invasive species include Eurasian watermilfoil, curly-leaf pondweed, and water chestnut. Common terrestrial and wetland invasive species include Purple loosestrife, Japanese knotweed, and common reed. Existing stands of invasive species should be immediately eradicated before they become more dominant and such eradication becomes very costly and difficult. Information about invasive species can be found in various online resources, including an excellent site called "Plant Invaders of Mid-Atlantic Natural Areas" (Swearingen, et. Al, 2002) http://www.nps.gov/plants/alien/pubs/midatlantic/index.htm .

Community "Weed Watcher" groups consisting of residents who are trained to recognize certain invasive species should be organized in each of the lake communities. Detecting small stands of invasive plants early allows for much easier removal. In addition, all lake community members should be educated about the importance of boat washing and other invasive species prevention measures. An ounce of prevention truly is worth a pound of cure when it comes to invasive plants. Signs

should be posted at all public lake access points to educate visitors about avoiding the spread of invasive species.

3.3.7 Watercraft and Vehicle Use

The use of motor boats, Personal Water Craft (PWC) aka jet skis, snowmobiles, ATVs, and other vehicles on the lakes within Byram Township can have a negative impact on lake water quality. Boats that are transported from one lake to another can spread invasive weeds between the lakes if not properly cleaned between uses. Boats and PWCs driven at high speeds along the lakes cause large wakes that splash against and erode shorelines. Noise and waves from watercraft can disturb wildlife and disrupt habitat, not to mention diminish the quality of life for property owners living around the lakes. Gas and oil from watercraft can leak into the lakes, contaminating the water. Cranberry Lake has already been found to contain constant low levels of MTBE, a gasoline additive, throughout its waters and in surrounding water wells. Similarly, snowmobiles, ATVs, and other vehicles driven over frozen lakes during the winter months can leak petroleum products onto the ice, which end up in the lakes come spring.

PWCs and ATVs are particularly problematic and do not fit the character of the Highlands that the Highlands Council and many others are striving to protect. The very manner in which these vehicles are often marketed and used creates environmental problems. PWCs are marketed as “thrillcraft”. ATV riders often purposely seek out environmentally-sensitive areas such as wetlands and streams for riding in order to maximize the mud factor. For example, Byram Township spent $350,000 on a bicycle trail, which featured barriers designed to restrict ATV access. Within days of the installation of the barriers, they were broken and ATV tracks marred the trail.

PWCs are often ridden by inexperienced riders, leading to safety issues. Nationwide, PWCs constitute 9 percent of all motorboats but account for 36 percent of all accidents and are responsible for 46% of all injuries (RCPA 2001). PWCs are designed to go anywhere, and consequently they do. Often PWC riders enter shallow, near-shore areas that traditional motorboats cannot access and that provide habitat for wading birds, juvenile fish, and other sensitive animal species. The oil and gasoline emitted by the engines of motorboats, PWCs, snowmobiles, and ATVS follow the old adage and the laws of

physics – oil and water don't mix. The petroleum products form a thin film on the surface of the water, coating anything emerging from or floating on the surface of the water. The negative impacts for phytoplankton and zooplankton (microscopic plant and animal species that live at the water's surface and are ecologically important as the base of the food chain) led to banning PWCs (and 2-stroke engines) on Lake Tahoe.

Some lakes within Byram Township already ban PWCs from their waters, and a similar ban has been considered for other lakes. The Township has also discussed township-wide regulations banning or limiting PWC use. The Township attorney has been asked to review a draft PWC ordinance all lakes within the Township prepared by the Environmental Commission. The lakes within Byram Township are intensely settled. Regardless of whether or not banning the use of PWCs or vehicles on the lakes proves impractical, Byram Township should institute an ordinance that disallows PWCs, snowmobiles, and anything but human-powered vehicles or vehicles with small trolling motors on the Township's lakes at certain times of day, including early morning or late evening, so as to reduce the disruption to lakeshore homeowners and allow quiet use of the lakes. Enforcement methods should be specifically spelled out in any regulations.

In addition to the PWC ban, boat and snowmobile owners in Byram Township should be encouraged to retire their older, two-stroke engines in favor of four-stroke engines. Up to 30% of the fuel in a two-stroke engine (found in most motorboats, ATVs, snowmobiles, and PWCs) passes through the combustion chamber unburned or partially unburned and is released directly into the water and air as pollution. Therefore, a four-stroke engine is not only cleaner, but is also more fuel efficient. Byram Township should negotiate with a local four-stroke engine retailer to provide discounted rates on the engines for Township residents, perhaps by offering coupons at an educational booth held during the annual Byram Day or coordinating a "swap" program for both boats and snowmobiles.

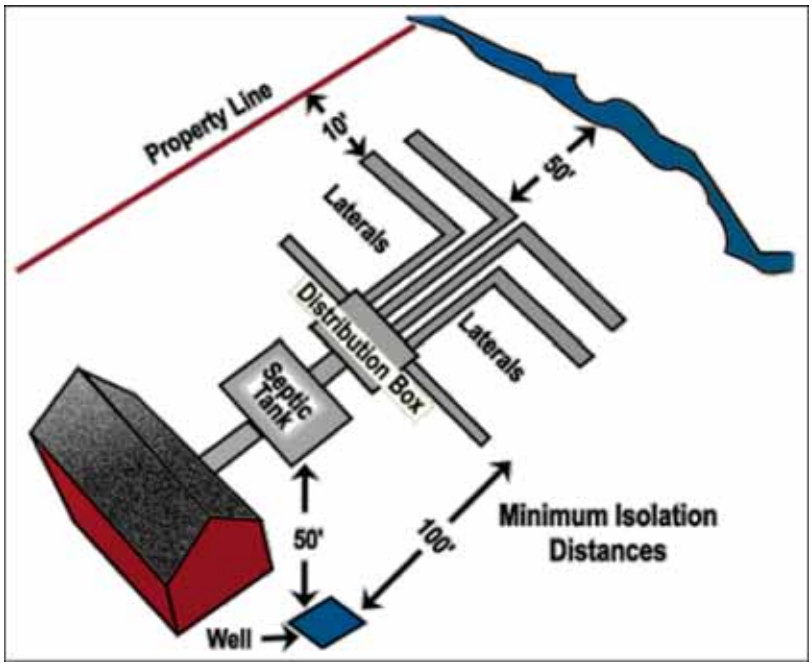
The residents and lake users come to enjoy Byram Township's lakes because they truly love to be on or near the water. Most of these users care about protecting the health of the lakes and are willing to cooperate to keep the lakes clean. For this reason, a public education campaign can go a long way toward improving lake water quality. Even if boaters or snowmobilers cannot replace their existing two-stroke engines, they can actively participate in controlling pollution from these engines by adopting a few simple practices. These practices include: operating only well maintained engines, limiting full throttle operation, eliminating unnecessary idling, following recommended maintenance schedules, eliminating spillage when refueling, properly measuring fuel and oil if required for a particular engine, washing their boats and PWCs before transporting them to another water body so as not to spread invasive plants, and avoiding the creation of large wakes close to shorelines or in shallow waters in order to reduce shoreline erosion. Signs listing these environmentally-friendly practices should be posted at marinas and boat accesses throughout the Township and flyers should be handed out during Byram Day, and in the local schools. Articles addressing these issues should be published each spring in the local paper.

3.4 Wastewater Management

Most of Byram Township is served by onsite septic systems, many of which are very old and many of which probably do not meet current standards. The vast majority of the soils in the Township are not suitable for conventional on-lot septic systems. Therefore, attention to wastewater planning in the Township is critical. Byram Township has already developed septic system management programs for its three largest lake communities. The following sections describe ways to build on this solid foundation to further improve wastewater management in the Township.

3.4.1 Septic System Management Programs

Currently, Byram Township has a very good septic system management program for the Cranberry Lake, Lake Lackawanna, and Lake Mohawk neighborhoods. The program has been very successful in educating residents about the importance of septic system management and requiring regular pumping schedules. This program should be extended (via municipal ordinance) to the entire township. Even homes that are not located directly around the lakes can contribute nutrient loads to lakes via streams when their septic systems fail, and groundwater contamination is a concern throughout the Township.



The Septic System Management Program should be expanded
Source: Tobyhanna/Tunkhannock Creek WA

The existing septic system management program requires residents to identify and map their system and to pump their systems regularly. The program works very well as a means of maintaining systems that are designed and constructed properly, located in suitable soils, and that have not yet failed. However, it does not provide a means of detecting failing septic systems, especially systems that have failed prior to the initiation of the program. It is common practice in many lake communities around the country for homeowners to convert what was once a weekend cabin to a year-round primary residence upon retirement or purchase of the property. Often times this leads to the house being enlarged or simply occupied significantly more frequently than originally intended, leading to increased pressure on the septic system. Many systems were not designed to handle such use and thus they

fail. Most people assume that failing systems are obvious due to odors or visible seepage, but this is not always true. In fact, the majority of septic system leakage flows directly into the groundwater via seasonal high water tables or other pathways, and the homeowner is completely unaware of the problem.

It is important for Byram Township to enhance its existing septic system management program by requiring septic system inspections by certified engineers upon the transfer or sale of property, with the application for planning approval or a building permit to enlarge the existing structure, or upon any change in the use of the property (i.e. conversion of a residence to a home occupation). These situations provide opportunities for investigating septic systems when residents are applying for permits and are more likely to comply with the regulations. In addition, the septic management program should include a requirement that the owners of any property within 200 feet of a septic system or well that is being installed, repaired, or replaced must be notified in advance of the construction. This would allow neighboring property owners to notify the Township of any unforeseen conflicts with the installations. The Township is not always aware of the locations or conditions of individual wastewater systems within the Township, and this regulation would provide an additional means of gathering information and protecting property owners from potential health risks from failing or improperly installed septic systems.

3.4.2 Township Soil Suitability Mapping

The Natural Resources Inventory (1994) included a septic suitability map and discussion. However, this map only referred to soil suitability for conventional septic system construction. Many areas that are not suitable for conventional on-lot septic systems are adequate for alternative systems, including raised sand mound, drip irrigation, and spray irrigation systems. These alternative designs are sanctioned by the NJ Department of Environmental Protection and typically require less soil depth for installation than conventional systems.

A more thorough soil suitability mapping of on-site soil-based disposal system suitability in Byram Township should be conducted using Geographic Information Systems (GIS) to compare data layers. The soils, slopes, geology, and groundwater resources in the Township should be analyzed and compared to the current New Jersey Department of Environmental Protection on-site disposal system design standards. Care must be taken during the analysis to protect the natural aquifer recharge areas as documented in the Natural Resources Inventory. Groundwater sources are relatively scarce in Byram Township and existing recharge areas must be protected from groundwater contamination. Figure 4 shows an example of a soil suitability map for steep slopes.
The end result of the suitability mapping study will be a set of maps depicting specific areas within the township where conventional septic fields, raised sand mounds, drip irrigation systems, or spray irrigation systems could be used. Areas where no soil-based wastewater disposal facilities should be constructed would also be identified. These maps can then be compared to the known septic system uses in each area to determine

likely failures. When failing systems are found, the proper type of replacement system can be recommended based on the suitability mapping. Field site visits may be required in order to confirm the assumptions of the mapping project. The soil suitability mapping would be an extremely useful addition to the septic system management program for Byram Township. A septic system replacement program should be developed in order to assist residents in addressing their septic system problems.

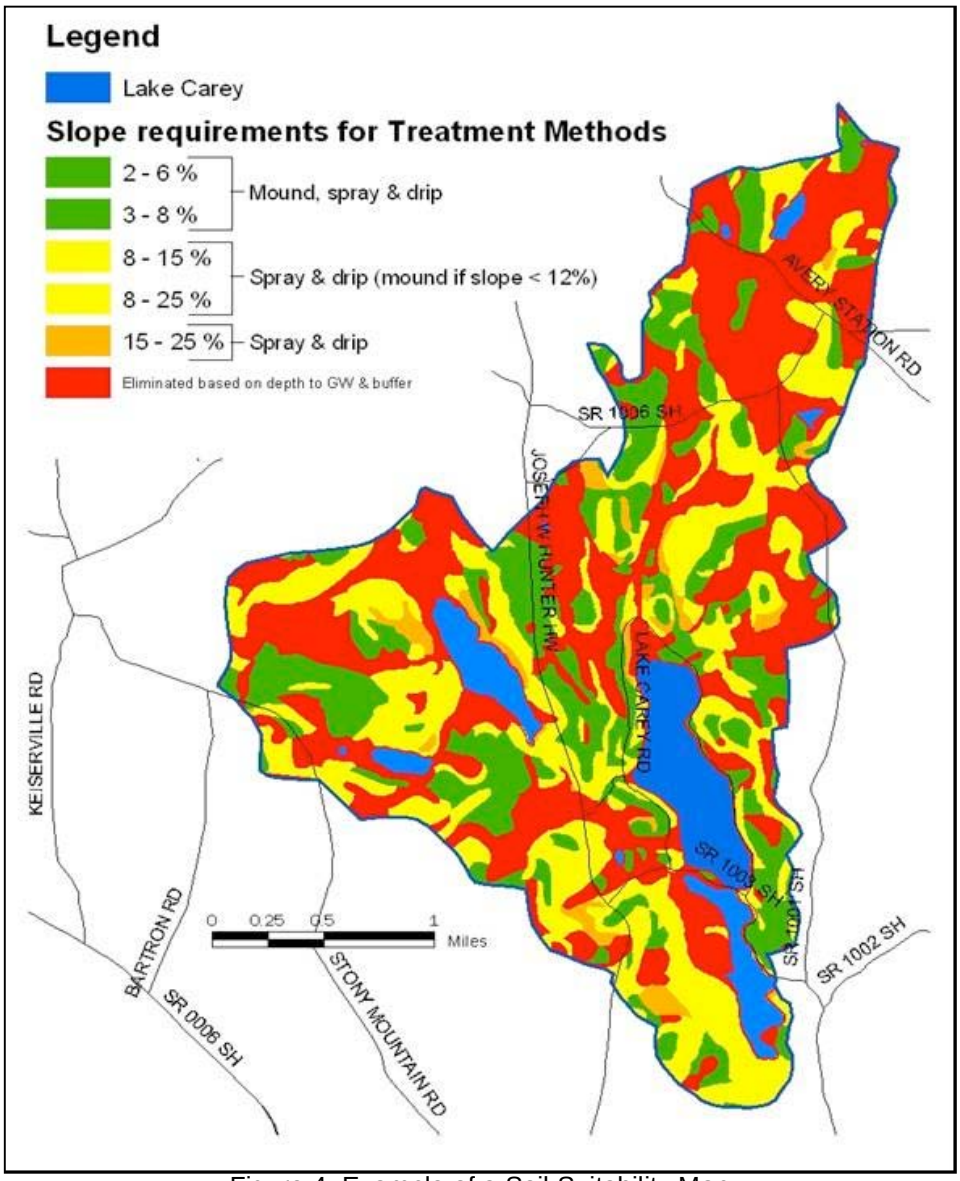


Figure 4: Example of a Soil Suitability Map
Source: F. X. Browne, Inc.

3.4.3 Decentralized Wastewater Systems

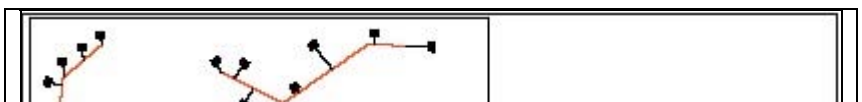


Figure 5: Comparison of a centralized and decentralized wastewater system. Source: F. X. Browne, Inc

Based on the present soils suitability map, the soils in the Township are not generally suitable for conventional septic systems. This means that the existing septic systems, whether they meet present code or not, are probably contributing nutrients and other pollutants to the streams and lakes in the Township. There are two potential solutions for correcting this problem. One is to construct a centralized sewer system and one or more large wastewater treatment facilities to treat the wastewater and discharge the effluent to a stream. This approach has several disadvantages. It is expensive; it depletes the groundwater; and it encourages new development. Another approach is to install decentralized wastewater management systems where they are needed to treat and dispose of wastewater. This approach has several advantages, which are discussed below.

A decentralized wastewater system is defined by the US EPA as “An onsite or cluster wastewater system that is used to treat and dispose of relatively small volumes of wastewater, generally from individual or groups of dwellings and businesses.” A comparison of a centralized vs. decentralized system is presented in Figure 5. A centralized wastewater system uses gravity or pressure sewers to transport all of the wastewater in the area to one location for treatment and disposal, usually to a stream discharge.

Decentralized wastewater disposal consists of a system of clusters. Wastewater from each cluster is transported to a smaller wastewater system for treatment and disposal. A decentralized wastewater system breaks up the service area into smaller clusters. Instead of one centralized treatment facility, there are two or more smaller, decentralized wastewater treatment facilities. The cluster treatment systems, being smaller due to the reduced cluster wastewater flow, may be on-site systems such as a mound, drip system, or spray irrigation system. They could also be small package treatment plants that discharge to streams.

There are several advantages to a decentralized wastewater system:

1. Decentralized systems usually do not promote uncontrolled growth as centralized systems often do.

2. Decentralized systems often are less expensive to construct and operate. They reduce the length of sewers needed and do not sewer unpopulated areas.

3. Decentralized systems, consisting of a series of smaller wastewater flows, have a greater potential for on-site disposal. Most centralized wastewater

systems require a wastewater treatment plant with stream discharge because of the larger wastewater flows being treated.

4. If on-site treatment and disposal is feasible, decentralized systems, by using on-site soil disposal, provide better treatment, better meet EPA and DEP water quality antidegradation requirements, and recharge groundwater.

In existing lakeshore communities, decentralized systems can offer distinct benefits. Lakeshore communities often run into lake water quality problems when seasonal residences that were originally built on soils unsuitable for on-lot wastewater treatment begin to age and have septic system failures. In addition, lakeshore homes are increasingly being converted to year-round residences whose wastewater systems are insufficient to treat the increased usage. Since lakefront real estate is usually at a premium, very little land and money may exist for the construction of a centralized treatment facility, so a series of smaller, decentralized systems may be the best option. Decentralized systems can be targeted toward clusters of homes with the most serious problems, leaving newer, well-functioning septic systems out of the loop.

There are, however, several disadvantages to decentralized wastewater systems. They usually require more up-front soils testing to locate suitable sites. They may also require slightly higher engineering design fees. Although system maintenance is typically lower than a centralized system, it could be more complicated for multiple cluster systems.

EPA recently released a Program Strategy for decentralized wastewater treatment systems. This strategy presents EPA's vision, mission, and actions to improve the performance of decentralized wastewater treatment systems, thereby providing better protection of public health and water resources. The Strategy can be downloaded at http://www.epa.gov/owm/septic/pubs/septic_program_strategy.pdf

In 1999, Thonet Associates, Inc. completed a Septic Management vs. Sewers Study for the Lake Lackawanna district. The study concluded that although implementation of a septic management plan and sewer extension would yield immediate and long-term water quality benefits to Lake Lackawanna, these measures would not significantly change the appearance of the lake and the need for active management would continue. The study also concluded that extension of sewers would increase the development potential of the lake area and the resulting increased development would increase nutrient inputs and off-set the water quality benefits of the sewer system. A consideration of extending limited sewers to serve only the existing homes and infill lots in the Lake Lackawanna area was ruled out since the ability of this option to be strictly limited was considered unlikely and could increase the development potential in the area.

The findings of this study confirm the assertion that decentralized wastewater systems would be more beneficial to the lake communities in Byram Township than centralized

sewers. However, because the water quality portion of the study was only based on limited water quality data, it is questionable whether improving sewage facilities at Lackawanna Lake, or any of the other lakes in Byram Township, would not benefit the lakes. Byram Township should consider replacing clusters of failed septic systems with decentralized systems within the Township, especially in the lakeshore communities or other areas near sensitive environmental habitats. The soil suitability mapping described in Section 3.4.2 above would help to identify areas that would benefit most from decentralized wastewater planning. Care should be taken when planning decentralized systems to avoid encouraging an increase in development in certain areas.

3.4.4 Alternative Wastewater Systems

As previously stated, the vast majority of the soils in Byram Township are not suitable for conventional on-lot septic systems. However, in some areas, alternative on-lot wastewater systems may be feasible. As with any conventional septic system installation, soil testing is critical to determining the practicality of installing a specific wastewater system. Depending on the site conditions, alternative designs such as elevated sand mounds, infiltration chamber systems, drip irrigation systems, low-pressure pipe systems, spray irrigation systems, or constructed wastewater treatment wetland systems may be used. Refer to N.J.A.C. 7:9A for information about wastewater system design criteria. In addition, several technologies exist that may help accelerate the wastewater treatment process and result in better pretreatment, including septic tank effluent filters and aerobic treatment units. These alternatives to conventional septic systems are discussed below.

<u>Elevated Sand Mounds</u>

Raised (elevated) sand mounds may be installed where soil depths are insufficient for a conventional on-lot septic system, or where conventional septic leach fields have failed and are in need of replacement. Elevated sand mound systems consist of distribution pipes in gravel trenches situated within a mound of sand and topsoil that is placed on top of the original soil, as shown in Figure 6. A properly designed and maintained sand mound has a design life of over 20 years; therefore, raised sand mounds are considered an adequate long-term wastewater disposal method.

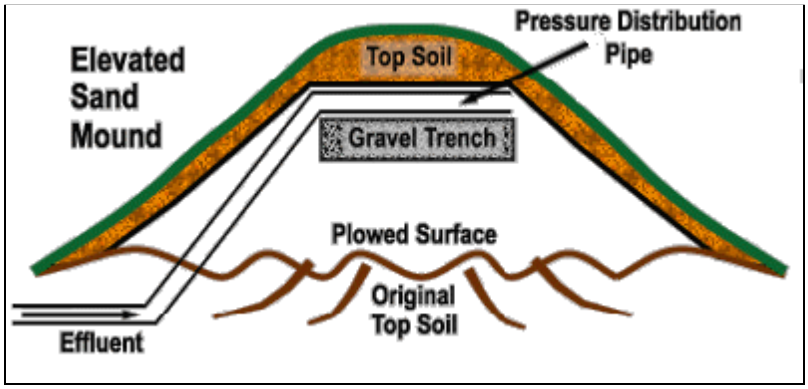


Figure 6: Typical Cross Section of an Elevated Sand Mound System
Source: Tobyhanna/Tunkhannock Creek Watershed Assoc.

Infiltration Chamber Distribution Systems

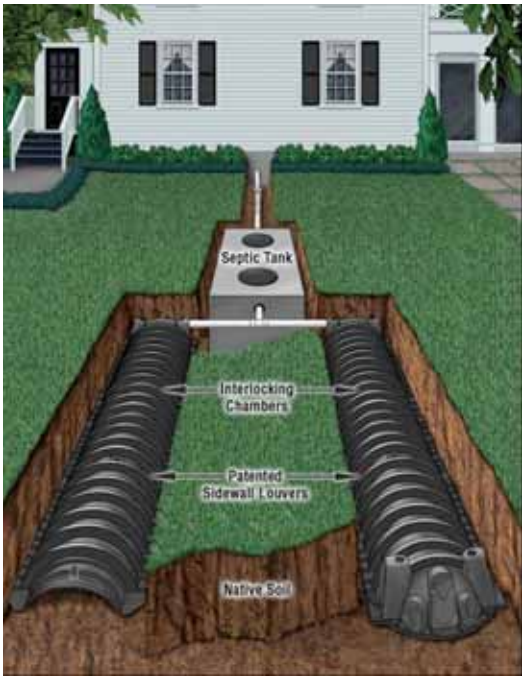


Figure 7: Infiltrator Chamber Distribution System Source: Company Website

Infiltration Chamber Distribution Systems are similar to conventional systems in that pretreated effluent flows from a septic tank into the leach field and eventually percolates into the ground. The difference is that instead of perforated pipe and gravel, the leach field consists of specialized chambers that are designed to increase the surface area for wastewater treatment. Therefore, these systems typically afford greater design flexibility due to the smaller footprint required (up to a 50 percent smaller leach field area). A number of U.S. manufacturers and suppliers of proprietary leaching chamber distribution systems exist. In New Jersey, Infiltrator® Chamber Distribution Systems are approved for general use with certain conditions. The infiltration chambers are typically placed over either native soil or specified fill soil in the disposal trench(es) as shown in Figure 7.

Drip Irrigation Systems

Drip irrigation systems apply treated wastewater to soil absorption fields slowly and uniformly from a network of narrow plastic, polyethylene or polyvinylchloride (pvc) tubing, as shown in Figure 8. The tubing is placed at shallow depths of usually six to 12 inches, in the plant root zone. The wastewater is pumped through the drip lines under pressure but drips slowly from a series of evenly spaced openings called "emitters." Wastewater must be pretreated and filtered prior to subsurface drip irrigation dispersal. One advantage to these systems is the minimal site disturbance required due to the flexible tubing that can be placed around trees and shrubs. The principal difference between drip irrigation systems and conventional on-lot wastewater systems is that irrigation systems are specifically designed to allow the water and nutrients to be used by plants.

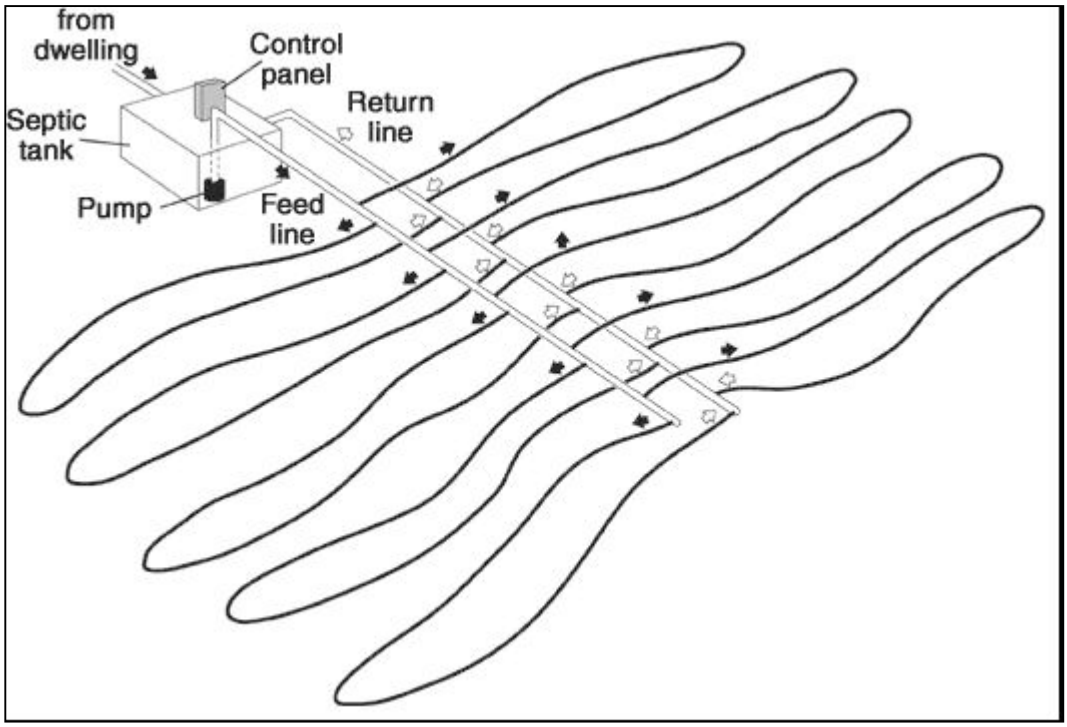


Figure 8: Typical Drip Irrigation System Layout
Source: University of Minnesota Cooperative Extension

Low Pressure Pipe Systems

Low pressure pipe (LPP) wastewater systems use one to two inch diameter plastic pipes with orifices (small spray holes) spaced 2.5 to 7.5 feet apart to deliver wastewater to the soil. A pump delivers effluent throughout the system on a regular basis as determined by a timer or the pump tank capacity. With this technology, absorption fields can be located upslope of the septic tank, or on uneven terrain that would otherwise be unsuitable for gravity flow systems.

Spray Irrigation Systems

Spray irrigation involves pumping pretreated effluent at 80 to 100 psi through nozzles and spraying it directly onto the land. Spray irrigation for wastewater disposal requires

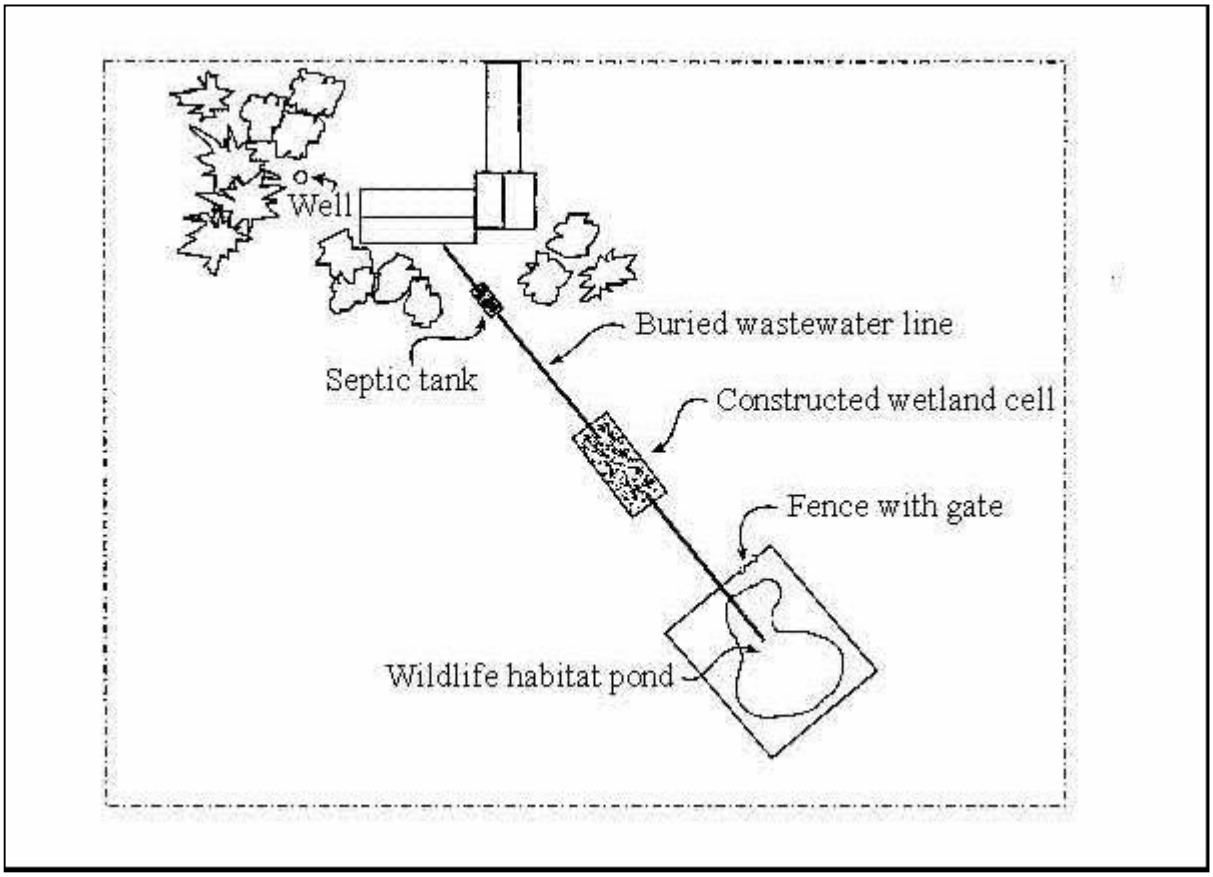
the availability of a relatively large parcel of suitable land for wastewater storage (lagoons) and disposal (spray field). However, spray irrigation systems require less usable soil depth beneath the spray field than conventional systems. Properly designed, maintained, and operated spray irrigation systems provide highly effective treatment of residential wastewater and allow for maximum recharge of groundwater, a benefit that is completely lost by small package and large community wastewater treatment facilities that use stream discharge for treated effluent. Many New Jersey public facilities such as golf courses and parks are finding the beneficial reuse of treated wastewater to be a win-win situation: wastewater disposal, grounds fertilization, and drought relief are accomplished in one step.

Wastewater Treatment Wetlands

Constructed wastewater treatment wetlands utilize the nutrient-absorbing abilities of natural vegetation to treat wastewater. When properly constructed, wastewater wetlands are both attractive and effective. Constructed wetlands can offer an affordable solution to wastewater disposal in sites with failed conventional absorption fields, narrow or oddly-shaped lots, high water tables, and/or low soil percolation rates.

Two types of constructed wetlands exist: "free water surface" (FWS) wetlands, where wastewater runs through dense vegetation over a generally impervious soil surface, and "subsurface flow" (SSF) wetlands, in which the effluent runs beneath a coarse substrate such as a gravel bed matrix. Wastewater treatment wetlands can be less costly to construct and are usually less costly to maintain than traditional wastewater treatment systems. In addition, the wastewater treatment wetland recharges groundwater while providing habitat for wetland species.

The wetland system consists of a septic tank that discharges to the wetland bed. Vegetation that is adapted to saturated conditions is grown in the wetland bed, removing nutrients, organic matter, suspended solids, and pathogens from the effluent. The pretreated effluent from the wetland bed can then discharge to a land application system, as shown in Figure 9, or can be designed to be absorbed completely by the system.



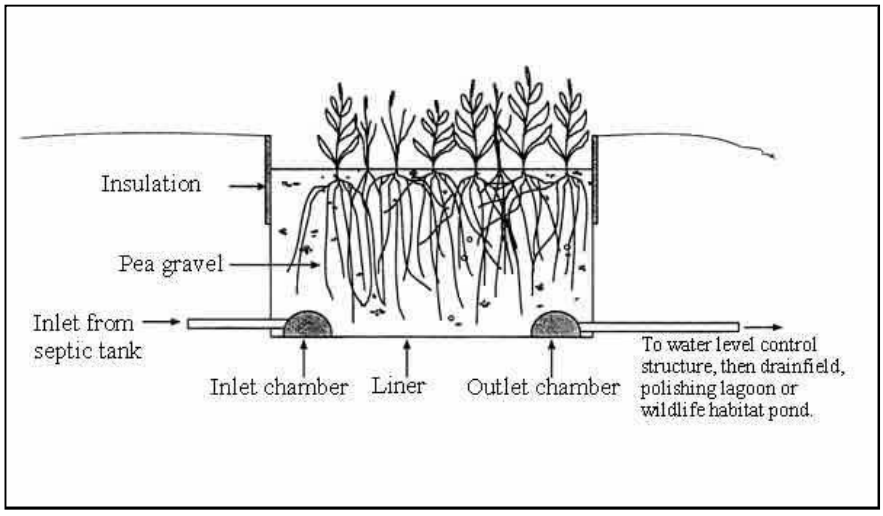


Figure 9: Typical Constructed Wastewater Treatment System
Source: University of Nebraska Cooperative Extension

Alternative On-Lot Pretreatment Technologies

In New Jersey, septic tank effluent filters and aerobic treatment units are approved for general use with certain conditions. Aerobic treatment units (ATUs) pretreat wastewater by adding air to break down organic matter, reduce pathogens, and transform nutrients. Compared to conventional septic tanks, ATUs break down organic matter more efficiently, achieve quicker decomposition of organic solids, and reduce the concentration of pathogens in the wastewater.

Various septic tank effluent filter types and designs have been extensively tested and used in the United States. Some wastewater treatment filters use peat, pea gravel, crushed glass, shredded recycled tires, or other experimental media, but sand is the best understood and the most predictable media. A peat system is currently in use at Cranberry Lake. The peat filter pretreats septic tank effluent by filtering it through a two-foot-thick layer of sphagnum peat before sending it to the soil treatment system. Peat is partially decomposed organic material with a high water-holding capacity, large surface area, and chemical and biological properties that make it very effective in treating wastewater. Unsterilized peat is also home to a number of different microorganisms, including bacteria, fungi, and tiny plants. All of these characteristics make peat a reactive and effective filter.

Many other pretreatment technologies exist for wastewater systems. Denitrification devices such as Recirculating Sand Filters (RSF) utilize an additional treatment chamber between the septic tank and the leach field as a means of discharging cleaner effluent with a lower nitrogen concentration. Effluent from the septic tank is pressurized and sprayed on a volume of sand in the filter chamber, as shown in Figure 10. Microorganisms in the sand break down organic matter and convert ammonia into nitrate as the effluent filters through the filter. When the effluent reaches the underdrain, a portion of the water enters the leach field and the rest re-circulates through the septic tank, where the nitrates are converted into nitrogen gas, an inert gas that can be vented to the atmosphere (Obropta and Berry, 2005).

Alternative on-lot wastewater alternatives may require special approvals. Alternative wastewater systems require maintenance just like conventional septic systems, and they tend to have a higher failure rate due to improper maintenance and installation. Composting toilets and low-flow fixtures can be used to reduce the amount of wastewater entering a septic system, but should not be used in lieu of a functioning wastewater treatment system.

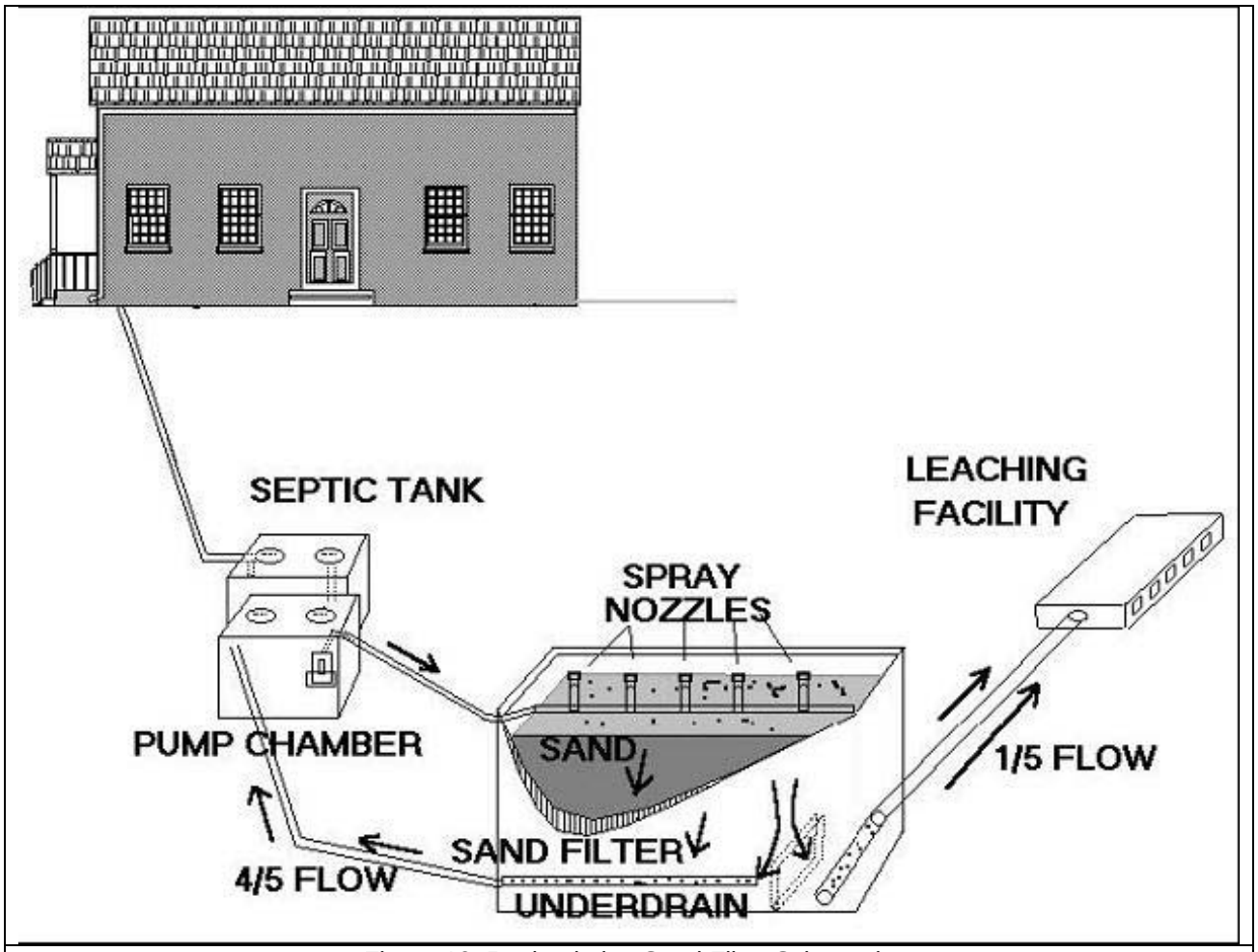


Figure 10: Recirculating Sand Filter Schematic
Source: Massachusetts DEP

3.5 Stormwater Management

Stormwater control measures serve two distinct functions: (1) to reproduce pre-development hydrologic conditions and (2) to provide pollutant removal capabilities. Historically, stormwater management has focused on reducing the frequency and severity of downstream flooding by reducing the peak discharge from post-developed sites. More recently, stormwater management has been redefined to include the removal of pollutants, thereby improving and protecting the quality of downstream waters.

Stormwater runoff carries nutrients and sediments
Source: F. X. Browne, Inc.

Byram Township should continue to implement their Stormwater Management Plan. In developed areas, stormwater management should primarily focus on retrofitting existing stormwater facilities or adding new stormwater facilities. Retrofit approaches include adding urban stormwater controls such as sand filters, water quality inlets, bioretention areas, and infiltration facilities. These stormwater controls do not require large areas of land, and therefore can be integrated into existing urban and suburban settings. Byram Township should target any large parking lots that do not currently have stormwater facilities to implement these BMPs. The goal of these BMPs is to capture and treat the water quality design storm.

In areas of future development or redevelopment, stormwater management controls such as infiltration basins, extended naturalized detention basins, constructed wetlands, bioretention areas, and buffer strips should be constructed or implemented. These stormwater control measures typically require larger tracts of land and therefore should be incorporated or designed as part of the land development planning process.

In addition, existing older stormwater detention basins should be retrofitted wherever possible to a naturalized detention basin or constructed wetland that utilize natural

vegetation to filter and treat stormwater runoff. Older stormwater designs often detain, but fail to treat stormwater, and can be a breeding ground for mosquitoes. More naturalized stormwater systems such as bioretention areas and constructed wetlands provide habitat for insects and other animals that eat mosquito larvae, which help to keep mosquito breeding to a minimum.

Byram Township should continue to implement strategies outlined in their existing Stormwater Pollution Prevention Plan, including:

- Maintaining monthly street sweeping schedules,
- Storm drain stenciling, and
- Leaf management programs.

Changes or additions to the existing Stormwater Pollution Prevention Plan should include:

- Existing homeowners and business owners should be encouraged to direct roof runoff to dry pits, rain barrels, or buffer areas to reduce the amount of stormwater that enters the storm sewer system. Using a rain barrel or cistern gives the homeowner the advantage of water use reduction by storing rain water for watering gardens or lawns during dry periods. B.t.i mosquito larvicide (sometimes called B.t.i. donuts) can be used to ensure that the rain barrels do not turn into mosquito breeding areas. These “donuts” are EPA-approved and readily available in hardware and gardening stores.

- Increase the Township’s stormwater catch basin cleaning program frequency from once per year to after major storm events or once every three months.

- Homeowners should be encouraged to wash cars and trucks on grassy areas, if possible, or use a commercial car wash. This practice will reduce the amount of phosphorus and detergent that runs down the driveway into a nearby storm sewer and eventually into the lakes.

- Organize annual educational workshops for developers, engineers, contractors, and Township officials describing stormwater management practices and Low-Impact Design techniques that can and should be used in all new developments, including residential and commercial sites. Present a similar workshop or demonstration at the annual Byram Day in addition to the table providing educational brochures.

- Conduct annual Township-wide watershed investigations to look for roadside erosion, streambank or shoreline erosion, culvert damage, swale sediment clogging, and other sources of stormwater runoff and sedimentation. The investigations could be carried out by volunteers under the guidance of a

professional. Retired Senior Volunteers, Americorp workers, or college students would be good sources for volunteers.

Public Education Programs can help avoid common homeowner nonpoint source pollution problems.
Source: NRCS

3.6 Other Watershed Management Practices

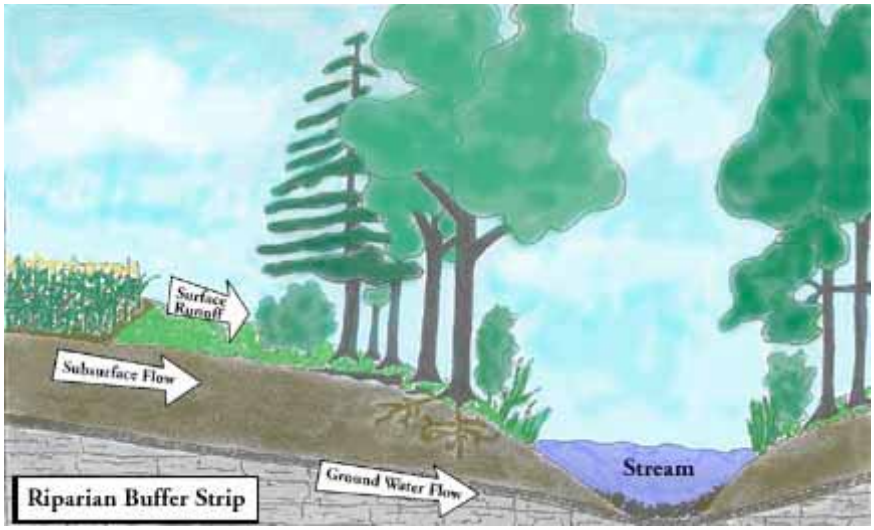
3.6.1 Streambank and Shoreline Stabilization

Restoring and stabilizing eroded streambanks and shorelines is a highly cost-effective way to reduce nonpoint source pollution and improve the water quality in lakes and ponds. Soil erosion along streambanks is a major source of nonpoint pollution in many watersheds. Nutrients and other pollutants adhere to eroded soil particles and are transported to the streams and lakes. Lakes are particularly affected by nutrients associated with sediment loads. Large, still bodies of water serve as settling basins for the particulate matter that is transported by their contributory streams. Improperly sized or damaged culverts at road crossings are a common source of downstream scouring and erosion in developed watersheds. Excessive stormwater runoff causes streambank erosion.

The use of bioengineering (vegetative) or a combination of bioengineering and structural engineering techniques is an effective way to stabilize eroded streambanks and shorelines at low cost. With bioengineering, the erosion problem is corrected while the stabilized streambank serves as a vegetative buffer and in many cases, a restored riparian corridor. The buffer along the stream reduces the quantities of sediments and nutrients that enter the stream via stormwater runoff.

3.6.2 Riparian Corridor Restoration

Adequately vegetated or buffered streams remove pollutants from stormwater runoff. In addition to pollutant removal, stream buffers reduce water temperature, maintain stream flow during dry seasons, stabilize streambanks, decrease erosion potential, provide valuable wildlife habitat, provide improved in-stream aquatic habitat, provide flood control, and enhance the natural landscape by providing visually appealing “green belts.”



Riparian Buffer
Source: F. X. Browne, Inc.

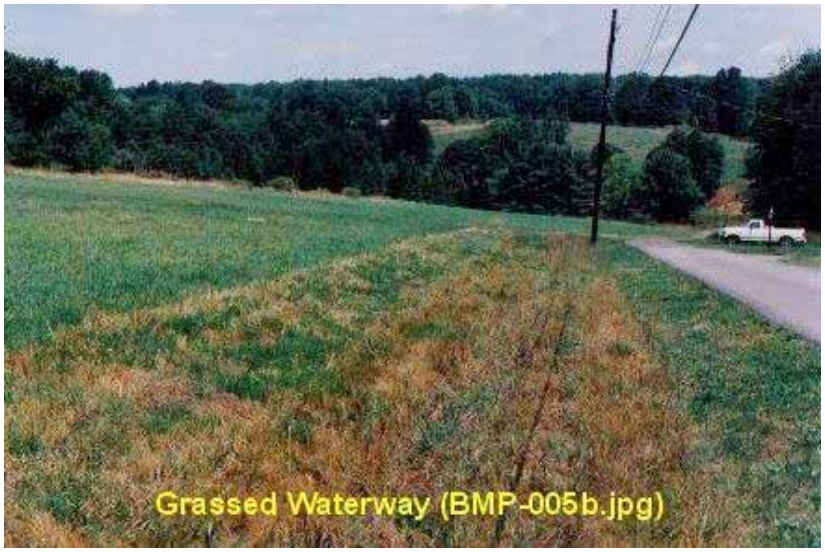
Riparian buffers should be enhanced wherever necessary in Byram Township. A Township-wide River Corridor Field Survey should be conducted to determine stream

reaches in need of riparian buffer restoration. The survey could be carried out by volunteers under the guidance of a professional. Retired Senior Volunteers, Americorp students, or college students would be good sources for volunteers.

Once identified, eroded areas of the streambanks should be stabilized, and a 50- to 75-foot buffer should be maintained along the entire stream channel. A multi-zone buffer provides the best protection, including a zone of native trees next to the water's edge, a zone of shrubs and “disturbed forest” beyond that where recreational activities can occur, and a third zone composed of dense grasses, broad-leaved herbaceous plants, and wildflowers extending outward from the stream. A more extensive riparian buffer will have the additional benefit of reducing nuisance waterfowl congregation. The buffer should be maintained by replacing poor growing vegetation, removing invasive plant species, and protecting the area from game animals such as whitetail deer.

3.6.3 Agricultural Management

Although only a small percentage of Byram Township is involved in active farming, nonpoint source pollution from agricultural sites can be significant. Runoff from agricultural land uses can contribute significant amounts of nutrients (phosphorus and nitrogen) and sediment to lakes and streams. Pollutant loadings from agricultural land uses can be reduced by the implementation of both traditional and innovative agricultural best management practices including pasture and hayland management, conservation tillage, integrated pest management, agricultural waste management, contour farming, cover cropping, critical area planting, terracing, strip cropping, crop rotation, sediment retention, streambank and shoreline stabilization, as well as through the implementation of grassed waterways, grade stabilization structures, nutrient management plans, streamside fencing, agricultural waste storage structures, buffer strips, erosion or water control structures, stormwater diversions, drainage facilities, livestock watering and feed facilities, planned grazing systems, and optimum fertilization practices.



Agricultural Best Management Practice – Grassed Waterway
Source: F. X. Browne, Inc.

The Sussex County Conservation District, Delaware Riverkeeper and other conservation organizations such as the NRCS should pursue funding to educate and encourage farmers within the watershed to adopt nutrient management plans and install BMPs on their land. Nutrient management and conservation management plans should be developed for all farms within the watershed. Nutrient management plans and conservation management plans are especially important on farms that produce or receive manure.

3.6.4 Nuisance Waterfowl Control

"Nuisance" waterfowl is a term frequently used to describe such flocks of birds that congregate on the shores of lakes and other water bodies year-round, eroding shorelines by frequently entering and exiting the water and contributing large amounts of nutrients to the water through their feces. Although most people enjoy seeing the birds, and many even feed them, the potential harm to lake water quality can be serious. The excessive bird feces can lead to algae blooms, accelerated eutrophication, depleted dissolved oxygen levels, and high bacteria levels in downstream waterbodies. These problems have a negative impact on the ecological balance of the water body, and can threaten other native species.

A range of options is available to discourage nuisance resident waterfowl populations, some more palatable to bird lovers than others. Geese can be chased away by dogs, loud noises, or visual deterrents. Geese can be excluded from congregating in certain areas via fencing or other barriers. Breeding can be minimized via egg addling. Geese can be gathered up and moved during the molting period. Some park and municipal managers have been known to scare off geese by shining lasers into their eyes at night. Many managers have resorted to gassing or shooting the geese. Other than the barriers and visual or audio deterrents, NJ DEP permits are usually required for nuisance waterfowl management.

One of the most effective ways to discourage geese from congregating is to allow vegetation to grow up around the edge of a lake or stream. Geese prefer not to walk through long grasses or sedges to enter the water, so by maintaining a buffer area around the edge, the geese will look for another home. Vegetative buffers have the additional water quality benefit of filtering runoff from entering the water. Byram Township officials should work together with individual lake communities to develop an acceptable and effective nuisance waterfowl management plan.

3.6.5 Golf Course Management

Golf courses can be significant contributors to nonpoint source pollution in lakes and streams due to the excessive amounts of fertilizers sometimes used. However, with proper management, the amount of nutrients entering lakes and streams from golf courses can be kept to a minimum. Golf courses within Byram Township should be

encouraged to minimize the use of fertilizers by turf monitoring and proper timing, water greens only when necessary as a means to reduce fertilizer usage, and implement stormwater management facilities such as constructed wetlands and bioretention strips to reduce fertilizer runoff into nearby water bodies. In addition, a three to five foot unmowed buffer strip along lakeshores and streambanks should be maintained to ensure proper erosion control and to filter runoff. Aesthetically pleasing vegetation such as irises and rushes can be planted in these areas.

The Audubon Cooperative Sanctuary Program provides golf course members and superintendents with information about environmentally-friendly golf course management. Program members become certified after developing a management program that incorporates fertilizer management practices, integrated pest management plans, vegetative buffer installation, habitat enhancement, stormwater management, and other techniques. Becoming involved with the Audubon Cooperative Sanctuary Program is an excellent way for a golf course to show the community its commitment to protecting the local environment.

3.6.6 Road, Driveway, and Trail Maintenance

Sediment washing from roads and driveways is a significant nonpoint pollution source in certain areas of Byram Township, especially in the Forest Lakes vicinity where steep slopes lead to high runoff velocities during storms. Traditional thinking in road maintenance has been to get water off of the roads and into low-lying areas such as streams and wetlands by the quickest means possible. However, this results in excess sediment from eroded areas entering streams and depositing in larger water bodies. The roads in Byram Township should be properly maintained so that sediment does not enter waterways. All watershed roads should be maintained in good condition and the road edges well vegetated or otherwise stabilized. Properly sized culverts at stream crossings and under driveways and cross streets are imperative for conveying stormwater without causing downstream scouring of streambanks.

Road and highway maintenance is particularly significant in Byram Township since many roads run adjacent to area lakes and their tributaries. Watershed investigations should be conducted to document and repair areas of roadside erosion. Eroded areas should be repaired using methods such as grassed swales, riprap swales, bank stabilization, bioengineering techniques, level spreaders, and other methods. Roadside swales should be properly maintained and

should always be immediately stabilized if they are disturbed. Culverts and ditches should be cleaned of leaves and debris regularly in order to maintain water conveyance and reduce scouring. Whenever new driveways or roads are installed or whenever existing roads and driveways are repaired, care should be taken during the design process to make sure adequate culverts and drainage channels are included. This is especially important in areas with steep slopes.

Emergency procedures should be established in Byram Township to handle accidental spills such as cargo fuel or other materials. The use of ice melting materials, such as calcium chloride and magnesium chloride, is necessary on occasion to ensure safe driving conditions. These chemicals should be used only when necessary and only in amounts required to provide effective results.

Many of the same principles that apply to road maintenance also apply to trail maintenance. The lakeside trails within the Byram Township parks and Allamuchy Mountain State Park should be maintained and inspected annually for erosion problems. Eroded soils and pet waste on lakeside trails can contribute significant amounts of nutrients and sediments to area lakes. Trail users should be educated via signage or information on trail maps about ways to protect trails from erosion. American Trails, a nonprofit organization working on behalf of all trail interests, has some excellent trail maintenance information on their website. The information can be accessed at http://www.americantrails.org/resources/ManageMaintain/. Recreation groups (i.e. Appalachian Mountain Club, New York-New Jersey Trail Conference, Northern New Jersey Geocachers, and other outdoor sports groups), scout groups, and local trail users should be encouraged to maintain and improve the trails within Bryram Township in order to improve access to scenic areas. Greater accessibility will likely breed increased interest in preserving and protecting the lakes.

3.6.7 Public Education and Outreach Program

Public outreach programs encourage property owners, business owners, government officials, and developers to become active partners in the conservation of the natural features of the Highlands Region. An environmental education program should be developed for Byram Township, focusing on lake management with particular emphasis on septic systems and watershed protection. The program should include the following elements:

1. Develop and distribute a nonpoint source pollution awareness brochure, articles for the Township's newsletter, and columns in the local newspapers.

2. Develop a watershed management program for presentation at local schools.

3. Develop and install educational kiosks at Riverside Park, Tomahawk Park, Neil Gylling Memorial Park, and Allamuchy Mountain State Park detailing

watershed protection efforts and things local citizens can do to protect the lakes and the watershed.

4. Write a fact sheet on watershed management for distribution at the kiosk and at local events such as Byram Day.

5. Conduct homeowner seminars and other environmental education programs to cover such topics as septic system maintenance, lakeshore and riparian buffer restoration and management, proper use of lawn and garden fertilizer, composting, leaf management, and the use of native vegetation in yards and gardens.

6. Form collaborative relationships with developers that encourage the use of new technologies to improve stormwater management, reduce ecological disturbance, and protect natural landscape features. To facilitate this process, Byram Township should periodically sponsor a developers' roundtable. The roundtable would be professionally facilitated and would allow a dialogue between area developers, planners, natural resource professionals, and other stakeholders concerning ways that these groups can work collaboratively to achieve common and individual goals.

7. Create a developers' certification program that would require developers to undergo a training program in low-impact development techniques and a commitment to protect and respect critical natural resources. The certification program could provide marketing and branding appeal to developers looking to distinguish themselves among consumers and municipalities.

8. Coordinate with local realtors to distribute educational "Welcome to the Highlands" materials to new home buyers and renters.

9. Include all educational materials developed under the Public Education and Outreach Program on Byram Township's web site so that current and future residents can refer to them whenever necessary.

The U.S. Environmental Protection Agency (EPA) actively encourages the development of environmental education programs by providing helpful literature, suggestions and funding sources. The U.S. EPA has funded education programs through the 319 Nonpoint Source Program and the Environmental Education Program.

4.0 Byram Township Action Plan

4.1 Action Plan

Byram Township has already come a long way in commissioning studies, implementing lake management measures and enacting regulations for the protection of the natural resources in the Township. The following Action Plan is designed to further the lake management efforts in Byram Township. The items in the Action Plan are organized with the most readily implemented items listed first. It is important to note that certain items lower down in the list, for example, the soil suitability mapping, are high priority items, but may require more funding and planning than items a the top of the list.

1. Require septic system inspections whenever a house is sold, planning board approval is sought, or a building permit is issued. Also require a 200-foot notification prerequisite for applications for permits to install, replace, or repair a septic system or well.

2. Develop and adopt a Stormwater Management Ordinance.

3. Enact other municipal ordinances that would help enhance the quality of Byram Township's lakes, including a tree ordinance, riparian buffer ordinance, natural landscaping/noxious weed ordinance, pet waste ordinance, phosphate ban ordinance, and wildlife feeding ordinance.

4. Broaden the scope of the existing Septic System Management Program to encompass the entire Township.

5. Approve legislation banning PWCs on Byram Township lakes and ponds. If this is not possible, implement a noise or vehicle use ordinance to restrict PWC access in sensitive areas and reduce the disturbance of lakeshore property owners.

6. Post signs at public access points to the lakes within Byram Township warning users to avoid spreading invasive aquatic plants and providing tips on reducing the negative impacts of boats and vehicles to the lakes.

7. Develop a Public Education and Outreach Program to encourage property owners, business owners, government officials, and developers to become active partners in the conservation of the natural features of the Highlands Region.

8. Organize a "Lake Awareness Day," or include workshops at the annual Byram Day to educate Township residents about lake management

efforts. Educational programs should also be developed for the local schools.

9. Initiate watershed investigations to detect stormwater management opportunities, streambank erosion problems, riparian buffer restoration opportunities, and other potential sources of water quality problems.

10. Perform a Township Soil Suitability Mapping Project to help guide on-site wastewater management efforts within the Township.

11. Based on the Soil Suitability Mapping, evaluate decentralized wastewater management for those areas that are not suitable for conventional septic systems.

12. Create a Township-wide lake monitoring program. The Township should develop a volunteer monitoring manual and should purchase a set of water quality monitoring equipment for use by lake associations.

13. Develop a "weed watch" program with volunteers to help prevent the spread of invasive plant species in Byram Township.

14. Develop Lake Management Plans for each of the Township's lakes.

15. Implement watershed Best Management Practices to address the nonpoint source problem areas documented during the watershed investigations.

4.2 Funding Options

The primary funding source for implementing items in the recommended Action Plan is the EPA's 319 Nonpoint Source Program. The 319 Nonpoint Source program is administered in New Jersey through the Department of Environmental Protection, and provides funds for watershed management projects and public education programs.

The Environmental Infrastructure Financing Program (EIFP) provides low-interest loans for the construction of a variety of water quality protection measures, including wastewater treatment facilities and stormwater and nonpoint source management facilities. Financing program eligibility is limited to municipal and county governing bodies; municipal, county and regional water, sewer and utility authorities; county improvement authorities; private water purveyors and certain state authorities. The projects eligible for financing from the EIFP include wastewater collection and conveyance facilities, combined sewer overflow abatement facilities, rehabilitation of existing sewer systems, pump stations, stormwater basins, sewer maintenance equipment, and lake restoration activities, including the purchase of mechanical weed harvesting equipment. In fact, Byram Township has already submitted an application to

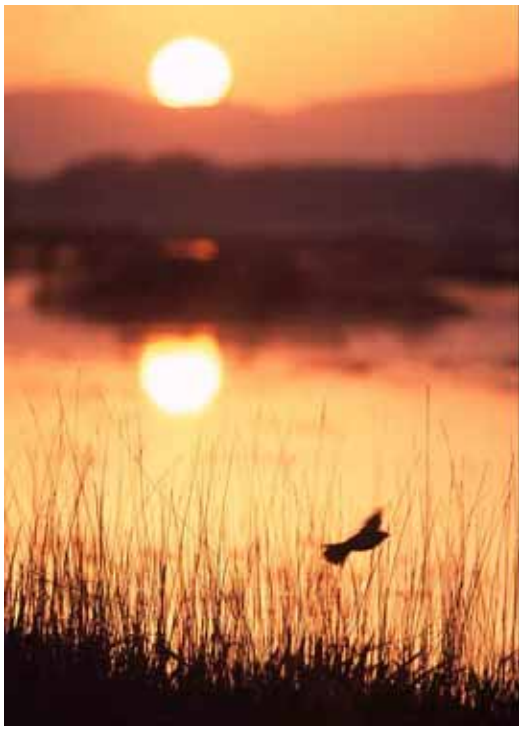
fund its weed harvesting program. Although the EIFP does not directly finance planning and design costs, an allowance (calculated as a percentage of the allowable building costs) to assist in defraying these costs is provided by the EIFP as part of the loan package.

Additional wastewater funding may be available through the Water Quality Management Planning Pass-Through Grant Program. The purpose of this program is to provide grants for conducting wastewater management planning activities and for developing management plans for onsite wastewater treatment systems.

Another funding source is the Conservation Reserve Enhancement Program (CREP), which helps to support the installation of conservation practices on farms. CREP is a federal program where the U.S. Department of Agriculture (USDA) partners with states to reduce sediment or nutrient runoff from agricultural land. The USDA provides 50 percent of the funds necessary to install conservation measures, such as filter strips, permanent vegetative cover or riparian buffers. The program is administered through the County Soil and Water Conservation Districts.

4.3 Watershed Management Organization/ Environmental Committee

The Byram Township Environmental Committee has done an excellent job in the past of initiating and guiding water quality improvement and protection efforts in the Township. The Environmental Committee should work together with members of the Township's Lake Associations and other stakeholders to form a Watershed Watch group. The group should coordinate their efforts to implement the recommendations of this report.



Source: NRCS

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A COMPREHENSIVE LIMNOLOGICAL ASSESSMENT OF JOHNSON LAKE BYRAM TOWNSHIP, SUSSEX COUNTY, NEW JERSEY

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1.0 Introduction

The New Jersey Conservation Foundation (NJCF) is well recognized for state-wide efforts in land conservation, stewardship, and community based conservation. Core to the mission of the NJCF is the preservation of New Jersey's environmental resources and the protection of drinking water sources. Currently, the NJCF owns and manages approximately 153 acres located on Tamarack Road, Byram Township, Sussex County. The property is part of Tamarack Park, owned and managed jointly by NJCF and Byram Township. A significant feature of the property is Johnson Lake, an approximate 38.4-acre waterbody. The Byram Township website notes that Johnson Lake "is open to residents for fishing and small, non-motorized boats". The adjoining park land includes a small launch site located along the lake's eastern shoreline. The Tamarack Park Trail System loops along the north side of the lake. The lake's long-term management is discussed in very general terms in a 2006 report prepared for the township by F.X. Browne (Lake Management Summary NJ Highlands Council MP3 Program). Other available reports highlight the multi-season recreational fishing opportunities provided by the lake. However, there is little information available pertaining to the lake's water quality, limnology or ecological status. To better assess the cause of the submerged aquatic vegetation (SAV) problems and formulate a long-term lake and watershed management strategy to control or mitigate these problems, the NJCF contracted Princeton Hydro to conduct a single day monitoring study, with a two-day bathymetric study, of the water quality of Johnson Lake, as well as a background records search. This report presents the results of this monitoring study, as well as the results of the background file searches.

Johnson Lake is an impoundment, located in the Township of Byram (Block 360, Lot 39), Sussex County, New Jersey. The surface area of the impoundment comprising Johnson Lake is 38.4 acres. The lake's watershed is relatively small (152.3 hectares) and is not extensively developed (Tables 1, 2 and 3). As per N.J.A.C. 7:8B, the lake is classified as an FW2-NT (freshwater, non-trout) by the New Jersey Department of Environmental Protection (NJDEP). Based on initial observations, and a review of historical aerial photographs, the lake has been prone to SAV problems (Eurasian watermilfoil), as well as emergent vegetation problems (yellow and white-water lily).

In developing this report Princeton Hydro conducted a review of various publicly available State, County and Local data sources. Those sources were reviewed to specifically obtain any data or information related to Johnson Lake's documented limnological attributes, surface water quality and other ecosystem characteristics. As part of this review, Princeton Hydro filed an electronic Open Public Records Act (OPRA) request with the NJDEP on September 20, 2017. Princeton Hydro received a response to the OPRA search request via e-mail on September 26, 2017 that stated the NJDEP indeed possesses responsive records related to the site. Copies of all the correspondence related to the NJDEP OPRA request (#215698) are presented in Appendix D. The file received from the NJDEP includes a screen shot of the publicly available records obtained from the Bureau of Dam Safety, and can be found in Appendix D. As per NJDEP records, the Johnson Lake dam was rehabilitated in 2005 and is currently up to code.

As part of this review, Princeton Hydro filed an electronic Open Public Records Act (OPRA) request with the Township of Byram on September 20, 2017. This OPRA request was specific to the inquiry of any pesticides or herbicides that may be utilized in the Lake and Park. Princeton Hydro received a response to the OPRA search request via e-mail on September 21, 2017 that stated the Township possessed no responsive records related to the site. Copies of all the correspondence for the Township OPRA request are presented in Appendix D.

As per the publicly available data contained on the New Jersey Department of Environmental Protection's (NJDEP) Geo-Web program, Johnson Lake is located in the Upper Delaware Watershed Management Area within the Musconetcong River watershed. This watershed includes along with Johnson Lake, Cranberry Lake and various tributaries (HUC 11 # 02040105150). The Lake currently has a Total Maximum Daily Load (TMDL) designation for mercury in fish tissue. It should be noted that the mercury in fish tissue TMDL applies to the majority of lakes in northern New Jersey and is the result of historical atmospheric deposition. This mercury in fish tissue TMDL dates back to 2010. Additionally, the Lake and its watershed are located within the Highlands Preservation Area. Finally, a community wellhead protection area is located to the immediate east of the Lake.

The actual 2017 sampling effort coincided with the seasonal decline (late summer) of the phytoplankton and SAV growing season. The monitoring program conducted by Princeton Hydro focused on the collection and assessment of several key lake and tributary water quality and ecological parameters. These data were then used to investigate and make recommendations concerning short-term (immediately implementable) and long-term management options designed to decrease/control the development of algae and SAV, improve long-term water quality and make recommendation with regards to the lakes bathymetry and sediment accumulation.

2.0 Bathymetric Survey

Methodology

A bathymetric survey is the mapping of water depth and the determining the volume of accumulated, unconsolidated sediment (top of sediment to bottom of sediment) in a lake or pond. The data from this study will produce both mapping and statistical analyses. Contours of top of sediment elevations and sediment thickness contours (in feet) are created, and quantitative data of mean and maximum top of sediment elevations, mean and maximum sediment thickness, and an estimated volume of water and unconsolidated sediment are calculated.

All elevations on the accompanying maps and discussed in this report are in North American Datum of 1988 (NAVD88) elevations. In order to produce the results in NAVD88, a bench mark was set on site to calculate the Water Surface Elevation (WSEL) at the time of the survey. The north, downstream corner of the dam spillway was chosen as the location on a permanent structure to utilize as a bench mark. The elevation of that corner was found using a Leica GS14 survey grade GPS unit. A point was taken at the location with the GPS that provided the Northing and Easting locations in NJ State plane NAD83 coordinates, as well as the NAVD88 elevation. This concrete corner was then used to calculate the WSEL of the lake with a site level and a Philadelphia rod. The WSEL at the time of survey was 834.2 NAVD88.

Field data was collected by Princeton Hydro on both September 14th and 18th, 2017. As you are aware, Johnson Lake is overrun with aquatic vegetation, which covers a large majority of the surface of the Lake. The presence of this vegetation dictated that the calibrated survey pole and not the echo-sounder be used to conduct the survey. The calibrated survey pole has graduated marks that are in half foot intervals. The pole is lowered into the water until it reaches the top of sediment. The location of the pole is marked with a Trimble ProXH GPS unit and the depth (in feet) is recorded with the point. The rod is the then pushed down into the sediment until the point of refusal. This depth is the bottom of unconsolidated sediment, and is also input into the GPS data. Data was collected along pre-determined transect lines that ran from shoreline to shoreline at 150-foot intervals. Data points were collected roughly every 30 to 40 feet along each transect.

All data collected on the lake was analyzed by Princeton Hydro using ESRI's ArcGIS Geographic Information System program. The data points were imported into GIS and inside the database, the water depths and bottom of sediment depths are converted from feet to NAVD88 elevations utilizing the WSEL calculated while on site. Models were created of top of sediment elevations and bottom of unconsolidated sediment elevations. Contours of the top of sediment were generated from the model and edited for modeling errors. A contrast analysis produced a model of the estimated sediment within the lake. This model produced sediment thickness contours (in feet). A volume analysis of the models calculated the volume of water within Johnson Lake, as well as the volume of estimated unconsolidated sediment.

Results

Generally speaking, a major contributor to overall aquatic vegetation growth in the Lake is exposure to sunlight and water depth. With a large portion of Johnson Lake so densely covered in aquatic vegetation, initial suspicions were the water depths would fall in the range of 2' to 3'. The exception would be near the dam, where depths are generally the greatest anywhere within a lake. This assumption held true at Johnson Lake – the deepest depths were discovered just upstream of the dam, where only a few sparse patches of aquatic vegetation resided. However, the rest of the lake was deeper than anticipated. Even in the upstream cove areas of the lake (North and Northeast areas), the water depths were 5' to 6' deep, and gradually getting deeper moving south towards the dam (see 'Top of Sediment Contours' map).

While water depths within the lake were a bit surprising, the sediment deposition patterns were not. One of the main water inputs into the impoundment is a tributary stream that enters at the North end of the lake. Sediment deposition is heavy here (reaching 8' of sediment) as it should be – stream flow carrying suspended solids enters the lake, thus slowing flow velocity and allowing suspended solids to settle to the bottom of the lake. An unnamed tributary enters Johnson Lake in the Northeast arm of the lake, and as expected, significant sediment deposition occurs here as well. Moving south down the lake, sediment deposition remains at 8' only in the middle of the lake: this is an indication of the historical stream channel that has filled in over the years since the dam was constructed. Another large pocket of sediment deposition occurs in the South West section of the lake where sediment thickness is 9 feet deep. Finally, only a small volume of sediment can be found directly adjacent and just upstream of the dam. This is not surprising as Ghost Pony Brook enters a small impoundment prior to entering Johnson Lake proper. This impoundment most likely serves to settle sediment from this tributary prior to entering Johnson Lake.

The following statistics were calculated and generated from the bathymetric data collected:

- Surveyed Area of Lake: 38.4 Acres
- WSEL at time of survey: 834.2 NAVD88
- Mean Elevation: 829.3 NAVD88
- Minimum Elevation: 824.7
- Mean water depth (in feet): 4.9 feet
- Maximum water depth (in feet): 9.5 feet
- Volume of water: 179.8 Acre-Feet
- Estimated volume of sediment: 258,224 cubic yards

BATHYMETRY STATISTICS

Area of Survey: 36.9 Acres

WSEL at time of survey: 834.2 NAVD88

Mean Elevation: 829.3 NAVD88

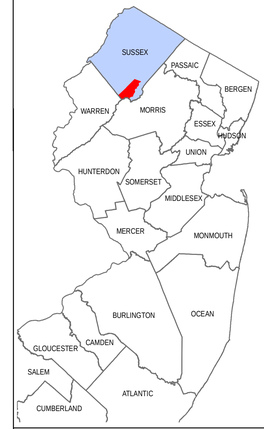
Minimum Elevation: 824.7 NAVD88

Mean Depth: 4.9 Feet

Maximum Depth: 9.5 Feet

Volume of Water: 179.8 Acre-Feet

NEW JERSEY COUNTY MAP



SOURCES:

1. Bathymetric data collected by Princeton Hydro personnel on September 14th and 18, 2017. Data collected utilizing a calibrated survey rod and a Trimble ProXH GPS unit.

2. All elevations are North American Vertical Datum of 1988 (NAVD88). A bench mark was set on site by Princeton Hydro with a Leica GS 14 survey grade GPS unit. Water Surface Elevation (WSEL) at time of survey was calculated with the bench mark, a site level and a Philadelphia rod. WSEL at time of survey was 834.2 NAVD88.

3. All modeling and contouring completed with ESRI's ArcGIS 10.2

Feet

0 50 100 200

1 inch = 100 feet

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PROJECT NAME/LOCATION:

BATHYMETRIC SURVEY OF JOHNSON LAKE
BYRAM TOWNSHIP, SUSSEX COUNTY, NJ

THE NEW JERSEY CONSERVATION FOUNDATION
170 LONGVIEW ROAD
FAR HILLS, NEW JERSEY

DRAWING NAME:

TOP OF SEDIMENT CONTOURS

Legend

Lake Boundary

Top of Sediment Contours

File: P:\1035\Projects\1035002\GIS\MXD\TOS.mxd

BATHYMETRY STATISTICS

Area of Survey: 36.9 Acres

WSEL at time of survey: 834.2 NAVD88

Mean Elevation: 829.3 NAVD88

Minimum Elevation: 824.7 NAVD88

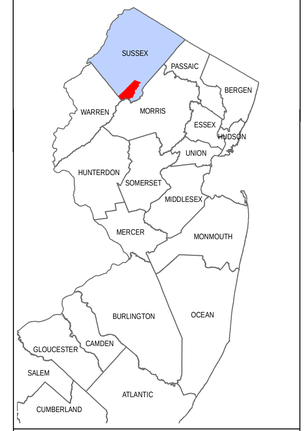
Mean Depth: 4.9 Feet

Maximum Depth: 9.5 Feet

Volume of Water: 179.8 Acre-Feet

Estimated Volume of Sediment: 258,224 cubic yards

NEW JERSEY COUNTY MAP



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Feet

0 50 100 200

1 inch = 100 feet

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THE NEW JERSEY CONSERVATION FOUNDATION
170 LONGVIEW ROAD
FAR HILLS, NEW JERSEY

DRAWING NAME:

SEDIMENT THICKNESS CONTOURS

Legend

Lake Boundary

Sediment Thickness Contours (in Feet)

File: P:\1035\Projects\1035002\GIS\MXD\Sediment.mxd

3.0 Water Quality Modeling

Every lake system drains a distinct area of land known as a watershed. Determined by the surrounding topography, Johnson Lake has its own unique watershed whereby every drop of rain that falls on this area either returns to the atmosphere via evapotranspiration or is conveyed through groundwater, tributary flow, or direct surface runoff flow into the lake.

The size, land uses, soils, and slopes of the Johnson Lake watershed are unique to that watershed and are the primary influencing factor on the water quality of the lake. Of all the different variables that may be analyzed when looking at a lakes watershed, the two most important ones are the watershed size and the land uses that comprise that watershed. The watershed size relative to the receiving waterbody is crucial in determining the magnitude of pollutant loads entering the receiving lake. Simply, larger watersheds transport more water, nutrients, and sediments to receiving lakes than do small watersheds. As such, high watershed to lake ratios generally impart a greater loading aspect to the receiving lake and are often correlated to increased rates of eutrophication.

The land uses comprising the watershed are the other critical component in determining the receiving lake's water quality. Watersheds with large Urban areas sees precipitation converted to surface water runoff as a result of increased impervious areas associated with these residential areas. This conversion serves to increase flow volume while concomitantly serving to decrease duration, leading to flashier storm events. This change in hydrology ultimately serves to increase nutrient loading to Johnson Lake as a result of increased stream bank and bed erosion and increased mobilization and transport of pollutants from residential land uses.

Methodology

For the purpose of this study Princeton Hydro utilized GIS data provided by the New Jersey Department of Environmental Protection, Bureau of GIS. Specifically, the 2012 Land Use/Land Cover data was utilized. A ten-meter Digital Elevation Model as also downloaded and modeled to delineate the watershed boundary of Johnson Lake. The modeling and delineation was completed with ESRI's ArcGIS 10.2 Geographic Information System program.

Results

Johnson Lake's watershed encompasses 376.4 acres (152.3 ha). Since Ghost Pony Brook is the largest tributary to Johnson Lake, a sub-watershed was cut for this tributary. The Ghost Pony Brook sub-watershed has a total area of 155.2 acres (62.8 ha)[1], while the Johnson Lake sub-watershed is 221.3 acres (89.5 ha)[1]. As based on NJDEP Land Use/Land Cover database,

[1] The discrepancy between the hectares listed here and those found in Tables 1, 2 and 3 are due to the fact the hectares for Johnson Lake were removed from the UAL model

Forested land accounts for 243 acres (98.4 ha); the majority of both the lake's total watershed area (65.1%), as well as for each sub-watershed. Although by area the second greatest land use is classified as Urban, developed land only accounts for 76.5 acres (31 ha) or 20.5% of the total watershed area. Urban Land Use plays a more significant role in the Johnson Lake sub-watershed with 24.5 hectares, while the Ghost Pony Brook sub-watershed only contains 6.5 hectares. Much of this developed land is adjacent to the lake or along Tamarack Road. Lands categorized by NJDEP as either Wetlands (10.7 acres /4.4 ha) or Agriculture (4.1 acres/1.7 ha) are present in the watershed, respectively accounting for 3.2% and 2.8% of the total watershed Area. Other than Johnson Lake, the other lands designated by the NJDEP as Open Water (ponds) accounts for only 1.7 acres (0.7 ha) or 0.5% of the watershed. All watershed land uses are presented on the attached map that depicts the watershed boundary and associated land uses.

Pollutant Loading

In order to properly analyze the management strategies of Johnson Lake, a comprehensive nutrient budget must first be developed. In this sense all pollutant inputs must be identified and quantified in order to assess those areas which contribute a disproportional amount of that load and their relative influence on pond productivity. The pollutants of concern are total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS). Phosphorus and nitrogen are those two nutrients most critical to plant and algal growth and as such, increases in these nutrients generally lead to increased lake/pond productivity. While both nutrients are modeled, the nutrient of primary concern is phosphorus. In most temperate freshwater ecosystems this is the limiting nutrient, that is, the nutrient that is least available in relation to biological demand, and as such, small increases in phosphorus loading may result in exponential increases in algal and weed growth. There are several sources, both external and internal, of phosphorus loading to freshwater systems and each of these potential sources must be evaluated to develop a proper loading estimate. Total suspended solids represent the total amount of inorganic and organic particles within the water column and are the prime determinant of water clarity. High TSS concentrations may be associated with "muddy" water clarity and are generally the result of excessive sediment loading and suspensions of algal particles. Primary sources of sediment loading to the lake are generally derived through erosion of watershed soils and stream banks. These erosional processes may be even more pronounced in those watersheds predominated by urban and residential land uses as increased impervious coverage associated with these areas serves to alter hydrologic loading in a way that increases flow volume while decreasing duration therefore leading to increased stream bank and bed erosion. This increased sediment loading generally results in the formation of sediment deltas and infilling of near shore areas thereby increasing SAV habitat and providing the fertile substrate for benthic, filamentous algae. In addition, as phosphorus is often tightly bound to soil particles, increases in sediment loading are commonly correlated with increases in total phosphorus loading.

To address the issues of nutrient loading Princeton Hydro conducted a pollutant load model that only quantifies loads generated from land uses within the watershed. It is important to

note that in many lakes and ponds, septic systems may also play a strong role in nutrient loading and are generally quantified for a proper nutrient budget. Septic systems were not included in this quantification, but do play a factor in the pollutant loading of Johnson Lake. A quick review of NJDEP's Sewer Service Areas GIS data reveals that none of the areas within the watershed boundary (specifically Urban) fall within the sewer service areas. Given the presence of the watershed in the Highlands Area, this is unlikely to change.

Watershed based nutrient loading is often times the largest contributor of nutrients and sediments to the receiving waterbody. The watershed area and land uses in conjunction with the soils and slopes which comprise the watershed are all prime determinants of the magnitude of nutrient loading to a lake system. For the purpose of calculating the watershed based nutrient load Princeton Hydro utilized the Unit Areal Loading (UAL) approach. The UAL approach is the recommended pollutant modeling technique as per 40 CFR Part 35, Appendix A, the USEPA's "Guidance for Diagnostic-Feasibility Studies". This modeling approach is widely used by both USEPA and NJDEP, and Princeton Hydro has applied it to compute the nutrient and sediment loads for well over 200 lakes and reservoirs located throughout the mid-Atlantic and New England states. The unit areal loading modeling approach is based on the premise that land use activities throughout a watershed have a direct impact on subsequent nutrient release and transport to a receiving waterbody. Essentially, those land uses which are disturbed (i.e. urban, commercial, and agricultural lands) serve to transport more pollutants to a receiving waterbody than those which are undisturbed (i.e. forest and wetlands). For the application of this model Princeton Hydro first utilized ArcGIS data provided by the NJDEP which contained the land uses (2012 data) of Johnson Lake watershed. This information was then utilized as the basis for the selection of pollutant export coefficients, in the units of (Kilogram of pollutant/Hectare/Year), which were most suitable for Johnson Lake's watershed given prevailing soils, slopes, geology, and climatic conditions. Sources of export coefficients chosen for the Johnson Lake watershed were derived primarily from the scientific literature which included but was not limited to those published by Reckhow, 1980 and Uttomark et al, 1974. Coefficients were chosen after carefully screening several variables which are critical to pollutant transport.

Table 1 presents the annual computed contribution of phosphorus (TP), nitrogen (TN) and sediments (TSS) to each sub-watershed, by Land Use/Land Cover Category.

Table 1 – Pollutant Loading by Land Use/Land Cover Category

Watershed Pollutant Loading

Watershed	Land Use	Area (Hectares)	TN (kg/yr)	TP (kg/yr)	TSS (kg/yr)
Ghost Pony Brook					
	AGRICULTURE	1.7	12.8	0.8	1700
	FOREST	51.6	129.0	10.3	12900
	URBAN	6.5	40.8	4.2	8425
	WATER	0.8	0.0	-0.2	-160
	WETLANDS	1.0	0.0	-0.3	-200
	Sum	**61.6**	**182.5**	**14.8**	**22,665.0**
Johnson Lake					
	FOREST	46.8	117.0	9.4	11700
	URBAN	24.5	149.2	15.0	18755.5
	WETLANDS	3.4	0.0	-0.9	-680
	Sum	**74.7**	**266.2**	**23.6**	**29,775.5**
	Total	**136.3**	**448.73**	**38.342**	**52440.5**

Overall, Johnson Lake receives approximately 448 kg of TN, 38 kg of TP and 52,440 kg of TSS over the course of a year. This external loading is a function of stormwater runoff. Pollutant transport occurs as a result of runoff discharged overland (sheet flow) to streams, sheet flow from the developed lots adjacent to the lake and stormwater discharged from stormwater collection systems (pipes and swales) servicing Tamarack Road, Manu Trail and Old Indian Spring Road.

These calculations represent the TN, TP and TSS loads Johnson Lake is receiving from the entire watershed, but do not accurately represent the true loads the lake receives. In fact, the kg/yr loading are probably lower than what is shown in Table 1. This is due to the pond at the end of Ghost Pony Brook, adjacent to Tamarack Road on the south side. This pond receives all of Ghost Pony Brook's surface water flow, as well as a significant amount of the sub-watershed's overland flow. This pond reduces the pollutant loads on Johnson Lake from the Ghost Pony Brook sub-watershed in two ways. First, the pond acts as a forebay. As stream and overland flow enter the pond, pollutants and sediment are able to settle as flow velocity reduces greatly in the standing water. This pond has an outlet structure that feeds Johnson Lake directly. But it's the location of the outfall pipe in Johnson Lake that is the second reason pollutant loads are reduced. Any pollutants the water is carrying that do not settle in the pond across the street and make it into Johnson Lake either do not stay within the waterbody long enough to make an impact, or only impact a small area of the lake. This outfall pipe is within 150 feet of the Johnson Lake dam. After a rain event, water flow, both into and out of the lake, are higher. Water / pollutants entering Johnson Lake from the pond outfall pipe are quickly swept due East towards the dam where they are removed from the lake. On normal water flow days, pollutants reaching Johnson Lake from the outfall pipe are settling somewhere between the outfall pipe and the dam, thus impacting only a very small portion of the overall lake. A more detailed study would need to occur to calculate the true impact the pond has on reducing the TN and TP pollutant loads, but without a doubt the pond plays a large role in removing TSS loads (sediment) Johnson Lake receives from the Ghost Pony Brook sub-watershed.

As illustrated in Table 2, although Urban Land Use accounts for only 22% of the watershed, runoff from developed lands is responsible for about 50% of the lake's annual sediment, phosphorus and nitrogen loads. It should be noted that although the Urban and Forested pollutant loads are similar (Table 1 and Table 2) the loading is much "flashier" from the developed as opposed to the forested lands. This is a function of the impervious nature of urban land, including the added runoff resulting from compacted soils and lawn surfaces. The negative loading values associated with the Water and Wetland categories reflects the nutrient and sediment ecological "sink" functions of ponds and wetlands. Basically, this means that annually there is a net retention of nutrients and sediments in the small impoundments and wetland areas occurring within the Johnson Lake watershed.

Table 2: Relative Annualized Pollutant Load Contribution by Land Use/Land Cover

		Percent Pollution Contributor		
Land Use	**% of Watershed**	**TN**	**TP**	**TSS**
AGRICULTURE	1.2%	2.8%	2.0%	3.2%
FOREST	72.3%	54.8%	51.5%	47.1%
URBAN	22.8%	42.3%	50.0%	51.7%
WATER	0.5%	0.0%	-0.5%	-0.3%
WETLANDS	3.2%	0.0%	-2.9%	-1.7%

The pollutant loading data in Tables 1 and 2 also show that the greatest external nutrient control improvements could be achieved through stormwater management efforts implemented within the developed areas of the watershed. This includes the use of both structural and non-structural stormwater management measures designed to reduce runoff volumes, filter sediment and particulates, and retain nutrients. Also, the pond at the end of Ghost Pony Brook should be maintained in order to achieve the highest efficiency of pollutant load removal from that sub-watershed before these pollutants can move into Johnson Lake. Table 3 below compares the sub-watershed of Ghost Pony Brook vs the overall watershed of Johnson Lake proper.

Table 3: Relative Annualized Pollutant Load Contribution by sub-watershed

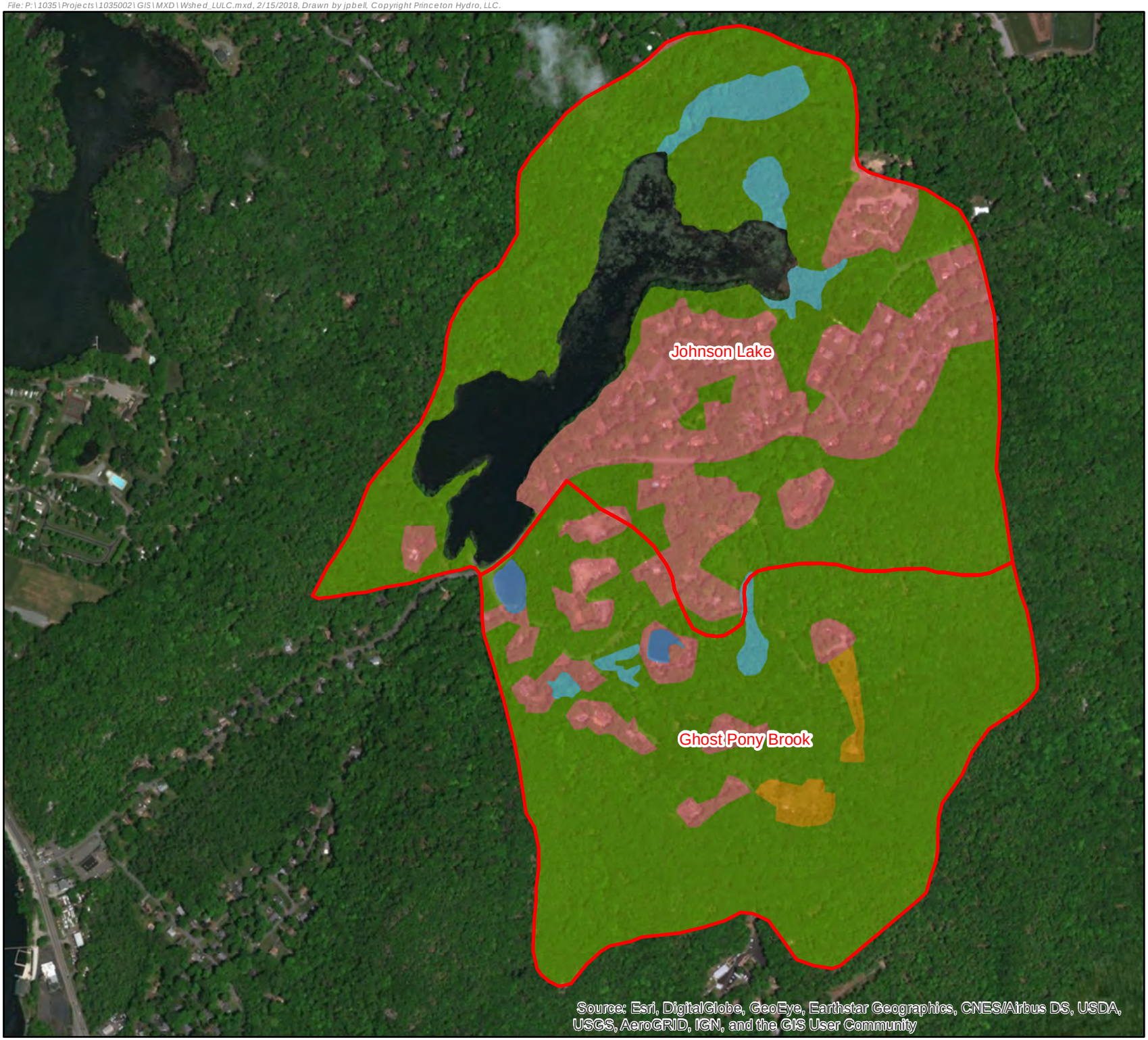
Watershed: Ghost Pony Brook

		Percent of Pollution Contributor		
Land Use	Percent of Watershed	TN	TP	TSS
AGRICULTURE	2.8%	7.0%	5.2%	7.5%
FOREST	83.8%	70.7%	69.7%	56.9%
URBAN	10.6%	22.3%	28.1%	37.2%
WATER	1.3%	0.0%	-1.4%	-0.7%
WETLANDS	1.6%	0.0%	-1.7%	-0.9%

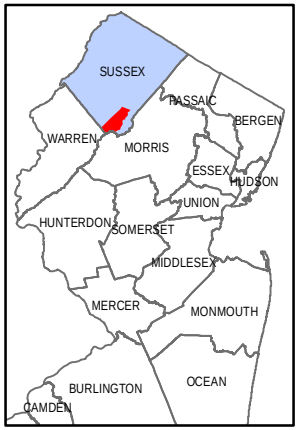
Watershed: Johnson Lake

		Percent of Pollution Contributor		
Land Use	Percent of Watershed	TN	TP	TSS
FOREST	62.7%	43.9%	39.7%	39.3%
URBAN	32.8%	56.1%	63.9%	63.0%
WETLANDS	4.6%	0.0%	-3.6%	-2.3%

File: P:\1035\Projects\1035002\GIS\MXD\Wshed_LULC.mxd, 2/15/2018, Drawn by jpbell, Copyright Princeton Hydro, LLC.



NEW JERSEY COUNTY MAP



PRINCETON HYDRO, LLC.
1200 LIBERTY PLACE
SICKLERVILLE, NJ, 08551
*with offices in NJ, PA and CT

N

1 inch = 800 feet

0 800 Feet

NOTES:

1. Watershed delineated by Princeton Hydro, LLC utilizing a 10-meter Digital Elevation Model obtained from the NJDEP, Bureau of GIS website.

2. 2012 Land Use/Land Cover data obtained from the NJDEP, Bureau of GIS website.

Map Projection:
NAD 1983 StatePlane New Jersey FIPS 2900 Feet

JOHNSON LAKE WATERSHED AND LAND USE/LAND COVER

THE NEW JERSEY CONSERVATION FOUNDATION

170 LONGVIEW ROAD
FAR HILLS, NEW JERSEY

Legend

- Watershed Boundaries

Land Use/Land Cover

- AGRICULTURE (4.1 Acres)
- FOREST (243 Acres)
- URBAN (76.5 Acres)
- WATER (1.7. Acres)
- WETLANDS (10.7 Acres)

4.0 Water Quality Monitoring

Sampling Methodology

In 2017, Johnson Lake was monitored by Princeton Hydro on 14 September. It is important to understand that although a single data point may provide a "snapshot" of the growing season and lake water quality, multiple sampling events conducted over the entire course of a single growing season (April through October) or preferably over multiple growing seasons yields a more robust database more indicative of a lake's trophic state.

Based on the objective of the sampling effort, coupled with the total area, morphometry and average/maximum depth of the lake, it was determined that the discrete (lab) sampling could be limited to one individual station (located near the face of the dam), with *in-situ* monitoring conducted at five individual stations distributed lake-wide. The location of the *in-situ* and discrete sampling stations are shown on Figure 1.

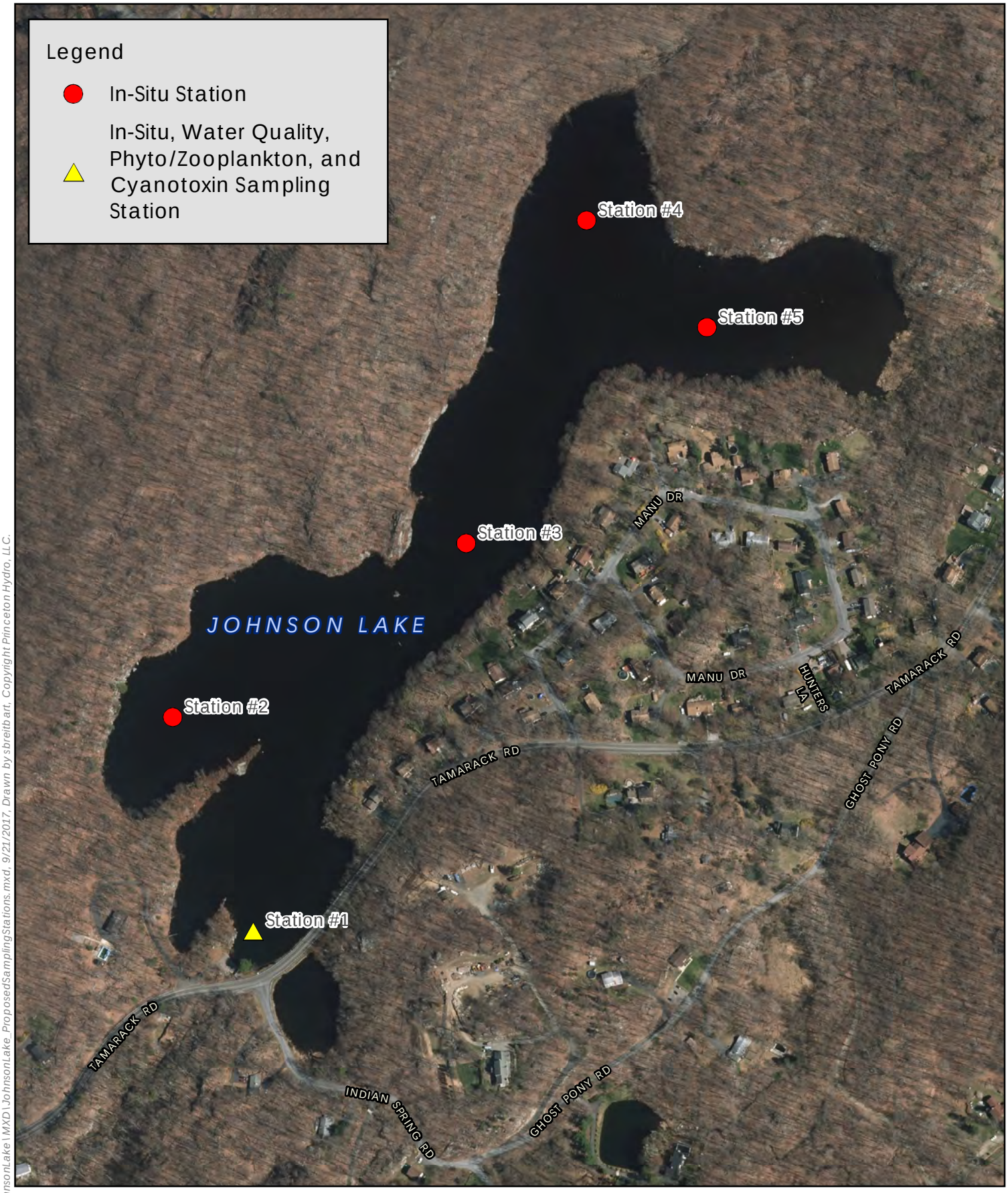
During the September monitoring date, a Eureka Amphibian/ Manta multi-probe meter and data logger was used to measure *in-situ* temperature, dissolved oxygen (DO), pH and specific conductivity in each of the five identified locations of the lake. Readings of each parameter were recorded at one-meter increments from the surface to the bottom of the water column[2]. Water clarity was measured using a Secchi disk at each sampling station. Mid-depth, discrete water quality samples were also collected at the discrete sampling station using a standard alpha bottle. Finally, samples for phytoplankton and zooplankton analyses were collected with standard plankton nets.

The discrete samples were analyzed for the following parameters using applicable USEPA and NJDEP certified laboratory methods:

- Total Phosphorus (TP)
- Soluble Reactive Phosphorus (SRP)
- Nitrate-N (NO_3-N)
- Total Suspended Solids (TSS)
- Chlorophyll *a*

Discrete samples were submitted for analysis to Environmental Compliance Monitoring Inc. of Hillsborough, NJ, a NJDEP certified laboratory. Zooplankton and Phytoplankton analysis was conducted in Princeton Hydro's in-house laboratory for identification to genera and analysis of species abundance. The findings, conclusions and recommendations provided herein are based on the results of the single 2017 monitoring event.

[2] Princeton Hydro is certified by the NJDEP (Laboratory #10006) for the in-field collection of these parameters using multi-probe water quality meters.



File: E:\GIS_Projects\JohnsonLake\MXD\JohnsonLake_ProposedSamplingStations.mxd, 9/21/2017, Drawn by sbreitbart, Copyright Princeton Hydro, LLC.

MONITORING STATIONS

JOHNSON LAKE LIMNOLOGICAL ASSESSMENT
NEW JERSEY CONSERVATION FOUNDATION
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

pH

PRINCETON HYDRO, LLC.
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P.O. BOX 720
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*with offices in NJ, PA and CT

NOTES:
1. 2015 orthoimagery obtained from New Jersey Information Network (NJGIN).

0 300 600 Feet

Map Projection: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Sampling Results

This section of the report presents and explains the date-specific water quality data. The *in-situ* data is provided in table format in Appendix A and the discrete (lab) data in Appendix B. Some of these data are also presented in the summary tables and below. Appendix E provides a description of each measured parameter, the water quality significance of the parameter and, if applicable, the parameter's NJDEP water quality standard as per N.J.A.C. 7:9b. It is important to understand that a single data point can be considered a "snapshot" of the growing season, and may not fully represent conditions observed over the course of some single or multiple growing seasons.

Water Clarity - Secchi depth is a standard measure of water clarity obtained by lowering a Secchi disk (a 9" diameter disk of contrasting black and white quadrants) through the water column. The average depth between which the disk is no longer visible and where it can once again be seen is considered the Secchi depth. This depth equates to approximately the point at which the incident sunlight is only about 10% of that measured at the surface, which equates to the depth at which photosynthesis becomes highly limited. As such, depths greater than the Secchi depth little algae, phytoplankton or SAV growth is expected to occur. Based on Princeton Hydro's in-house database of northern New Jersey lakes, most lake users perceive a waterbody as having unacceptable clarity when the Secchi depth is less than 1 meter (3.3 feet).

The Secchi depth clarity of Johnson Lake was between 1.6 and 1.8 meters (Table 3). This is much greater than the minimum threshold value of 1.0 meter (3.3 ft) indicative of acceptable Secchi clarity. Clarity in some areas was limited by the depth of the lake; that is the Secchi disk was observed all the way to the bottom. In other areas, the clarity was in part negatively affected by the shading caused by the dense surficial vegetation present in many of the shallow areas of the lake in September.

Table 3 – Johnson Lake Secchi Depths on 14 September 2017

Station Location	Secchi Depth (meters)	Total Depth (meters)
1	1.6	2.6
2	1.8+	1.8
3	1.8+	1.8
4	1.8+	1.8
5	1.6+	1.6

In-Situ Water Quality Data

Temperature, dissolved oxygen (DO), pH and specific conductivity were measured at half to one-meter intervals from surface to bottom at the referenced sampling stations. Princeton Hydro utilized a Eureka Manta PDA meter with Amphibian multi-probe to collect the *in-situ* data. The *in-situ* data are presented in Appendix A.

Temperature

Water temperature is an important attribute of a lake due to the fact that most chemical and biologic processes in aquatic ecosystems are driven by and are directly affected by increases or decreases in water temperature. In general, there is a greater amount of biological productivity and cumulative aquatic community respiration in warm versus cool or cold water. Due to the specific heat properties of water, lakes take time to warm up and time to cool down. Water therefore provides a relatively stable environment for aquatic life. Even though a lake's surface water temperature will change seasonally with air temperature, daily differences in water temperature tend to be gradual increasing from winter through the summer. The density of water also changes with temperature, basically becoming less dense with increases in water temperature. Lake's with uniform water column temperatures are easily mixed and circulated because the water column is of a uniform density.

The temperature of the lake although differing between stations by as much as 3^{o}C, was for the most part reflective of a non-stratified (thermally uniform) water column.

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is critical to the ability of a lake to support aquatic life. DO levels are controlled by the ongoing biological, chemical, and physical processes both internal and external to a lake. Physical factors affecting DO include water temperature, which effects oxygen solubility, and mixing by wind and wave action. During the day photosynthesis by phytoplankton and aquatic vegetation cause DO levels to rise. As such, highly productive lakes may achieve super-saturated (>100%) DO concentrations during peak periods of photosynthetic activity. Conversely, these same lakes at night, due to cumulative community respiration and biological demands, may experience drastic drops in DO concentrations. Additionally, sharp drops in DO may occur as a result of intense bacterial respiration following the treatment and die-off of excessive densities of phytoplankton, mat algae and aquatic vegetation. Lakes subject to daily (diurnal) major fluctuations in DO are prone to fish kills.

DO concentrations greater than 4.0 mg/L are generally considered necessary to support most aquatic life, in particular fish. The NJDEP surface water criteria for FW2-NT waterbodies is "not less than 4.0 mg/L at any time". Lower DO concentrations become progressively more stressful for most organisms with documented increases in mortality at DO concentrations ranging from 2.0 mg/L to 4.0 mg/L. DO concentrations less than 1.0 mg/L are considered anoxic (oxygen devoid). Under anoxia, sediment ReDOX (reduction and oxidation) conditions change resulting in the release of dissolved phosphorus, metals and minerals from the sediments into the overlaying water. The phosphorus "recycled" from the sediments during these periods of anoxia can stimulate additional algal growth independent of external phosphorus sources. The impact of this "recycling" of phosphorus rich waters can be especially important in shallow, well mixed lakes. Thus, although most associate the importance of measuring dissolved oxygen with the ability to support a healthy fishery, tracking DO levels is important for a number of other reasons, including understanding what triggers and controls algae blooms.

What may be the most significant finding of the September sampling event is the measurement of near anoxic (dissolved oxygen devoid) conditions at the bottom of the Lake (Appendix A). Even though the Lake is relatively shallow, near anoxic conditions were measured at every one of the *in-situ* stations. This is surprising given that the lake's water column had a fairly uniform water temperature (thermally unstratified). This condition should promote good water column mixing and prevent the on-set of dissolved oxygen depletion in the deeper waters of Johnson Lake.

The ramifications of this condition are basically two-fold. First, the deeper waters cannot support fish or another aerobic biota. Second, the lack of DO at the bottom of the lake promotes the internal recycling of phosphorus. As will be noted below, we did observe a significant difference in surface and bottom phosphorus concentrations. The lack of sufficient DO at the bottom of the Lake is the cause of this problem which has eutrophication implications.

pH

pH is a measurement of the concentration of free hydrogen ions present in water. It is expressed on a logarithmic scale from 1 to 14. Each one unit change in pH represents a ten-fold increase or decrease in hydrogen ion concentration. The pH of distilled water is 7, which is considered neutral. Water with a pH of 6 is ten times more acidic than distilled water, whereas water with a pH of 8 is ten times more alkaline than distilled water. Most water bodies in the northeast have average pH values between 6 and 9. The optimal pH for most aquatic organisms ranges between 6 and 8. The NJDEP surface water criteria for FW2-NT waterbodies is "6.5 – 8.5". The amount of pH fluctuation that occurs in a lake temporally is determined in part by the waterbody's alkalinity. More alkaline, hard water lakes (having greater amounts of $CaCO_3$), are bettered buffered than low alkalinity, soft water lakes, and thus less prone to large temporal shifts in pH.

Stormwater runoff, direct precipitation, wastewater and industrial discharges, along with groundwater intrusion can affect the pH of a lake. Chemical parameters that are significantly influenced by pH include phosphorus, ammonia, iron, and trace metals. The pH of a lake will also fluctuate as a result of photosynthesis, increasing as the amount of weed and algae growth increases. It is therefore not unusual to record high pH values in a lake experiencing an intense algae bloom or supporting dense aquatic weed growth. As a result of this link between higher pH and greater productivity, it is also not unusual to measure the highest pH reading in a lake later in the growing season when weed and algal communities reach their peak densities. Similarly, peak pH readings usually occur around mid-day when in-lake productivity peaks. Thus pH is an important water quality indicator as it both affects and is affected by a lake's chemical and biological processes.

During the September monitoring event the pH of Johnson Lake was in the slightly acidic range. The measured pH values did not indicate the presence of an algae bloom (normally indicated by pH values in the mid-alkaline range of 8-9 SPU).

Specific Conductivity

Conductivity is a measure of ions, typically salts and other inorganic substances, dissolved in lake water. While the majority of the dissolved solids measured in lake water are the result of natural processes, road salts, nutrients and/or sediment loads entering with storm water runoff can cause conductivity to spike. Similar to pH, a lake's conductivity can also be influenced by the amount of productivity and vice versa. As such, waterbodies with extremely low levels of productivity typically have conductivity values less than 0.1 mmhos/cm; while highly productive waterbodies usually have conductivity values greater than 0.5 mmhos/cm. The conductivity of most lakes in the northeast is typically in the 0.2 – 0.3 mmhos/cm range.

Specific Collected In-Situ Data

Although the lake was not thermally stratified on 14 September, anoxic conditions were present in the deeper reaches of the Lake. Additionally, the upper water column of was reduced in DO saturation (40% - 60%). This is undoubtedly the inability of the lake to have wind and wave action, which promotes mixing, due to the heavy surficial vegetation layer present lake-wide. The pH values in the lake were slightly below neutral and within what is considered the optimum range for most aquatic organisms (6.0 to 9.0) as well as the SWQS (6.5 – 8.5). No significant pH differences were noted within the Lake with increasing depth. Although late in the growing season, the pH data does not suggest any significant influence by phytoplankton, submerged aquatic vegetation (SAV) or benthic algae productivity, all of which occurs under the surface of the water. The lower chlorophyll *a* concentrations measured at the surface on this date verify this assumption. Specific Conductivity concentrations were elevated, yet consistent, ranging from 0.4 – 0.5 mmhos/cm. This is indicative of a moderate to major amount of dissolved substances in the Lake from the Lake's watershed that is fed by storm water runoff, as well as a large amount of biomass from each years decaying floating plant crop.

Summary of September In-Situ Data

The data suggest that Johnson Lake likely may become thermally stratified fairly easily. Although the water column did not vary that much in temperature from surface to bottom, it was stratified enough to prevent full water column mixing. This stratified or non-mixed state was reflected in the near oxygen depleted (anoxic) condition of the lake's deeper waters. We suspect that at times the Lake stratifies and remains in such a state for an extended period of time during the growing season. However, because it is shallow and not strongly stratified, is likely "turns over" during storms. These are the classic polymictic lake conditions; repeated stable and unstable water column conditions with corresponding DO depletion. The size, shape and density of water lily and SAV also lessen any opportunity for wind and wave action. This further decreases vertical water column mixing and lake-wide circulation. Even with the limitations of the single 2017 data point, given the total area of the lake relative to the total area of the watershed the Lake can most likely be categorized as a polymictic waterbody. Due to the relatively shallow depth, small size and volume of the impoundment, we feel that stratified conditions likely develop quite rapidly during quiet weather periods and when there is

limited inflow/outflow. However, the resulting stratification may be disrupted by storm events, a significant influx of storm water runoff, or even prolonged high winds during dry weather conditions.

Our emphasis on thermal stratification and DO concentrations in the bottom water of the lake is due to problems associated with the previously noted significant release and recycling of phosphorus that can occur from the sediments during periods of anoxia. In the absence of dissolved oxygen, the chemical bond between iron and phosphorus weakens, resulting in the release of phosphorus from the sediments into the overlying waters. The sediment phosphorus release rate under anoxic conditions can be 10 to 100 times greater than that when oxygen is present. The released dissolved phosphorus then accumulates in the overlaying waters and if transported by wind or wave energy back into the upper portion of the water column, stimulates the rapid development of an algae bloom should they be present.

Discrete Water Quality Data - Baseline

In addition to *in-situ* monitoring, limited discrete samples were collected from Johnson Lake during the Princeton Hydro sampling event and analyzed for a variety of chemical and biological parameters. Specifically, mid-lake samples were collected during the sampling event, transported to a State-certified laboratory and analyzed for the following: nitrate-N (NO_3-N), total phosphorus (TP), soluble reactive phosphorus (SRP) and total suspended solids (TSS).

In addition to the chemical samples, biological samples were also collected from the mid-lake sample station as part of the Johnson Lake sampling. Biological monitoring included the collection of samples for chlorophyll *a*, phytoplankton and zooplankton. Whole water samples were collected for chlorophyll *a*, while other samples were collected with a specific plankton net for both zooplankton and phytoplankton. The phytoplankton and zooplankton samples were preserved with a Lugol's solution then were identified to genus and enumerated in Princeton Hydro's in-house biological laboratory. The resulting data were then used to identify specific plankton abundance in Johnson Lake. General observations on the dominant aquatic plants and benthic algae, if any, were also made and recorded during each sampling event.

Phosphorus - Phosphorus is the primary nutrient needed to support the growth of phytoplankton and aquatic vegetation. However, compared to the other nutrients and minerals needed by plants and algae, phosphorus is often available in limiting amounts. This means that in most lakes and ponds that as the concentrations of phosphorus increase, the amount of weed and algae growth also increases. Simply put the more phosphorus, the more weeds and algae. The NJDEP surface water quality standard for total phosphorus (TP) is 0.05 mg/L for lakes and 0.10 mg/L for streams. However, TP concentrations as low as 0.03 mg/L can trigger nuisance algal blooms. The intensity and frequency of nuisance algal blooms typically increase as TP concentrations exceed 0.06 mg/L.

Two (2) forms of phosphorus were measured in the Lake; total phosphorus (TP), and soluble reactive phosphorus (SRP). Total phosphorus is a measurement of all the phosphorus in the

water; inorganic and organic, particulate and dissolved. Some of this phosphorus is already incorporated into the tissue of phytoplankton and zooplankton or bound to suspended sediment particles. Thus, not all of the measured TP is available for uptake and use by algae or plants. Nonetheless, most water quality models are based on in-lake TP concentrations. SRP is the form of phosphorus that can be easily assimilated by both planktonic and benthic algae. Although this form is usually not present in the water column in great amounts, it is the primary form of phosphorus that stimulates algae blooms. Thus, when elevated amounts of SRP are measured, an algal bloom is likely to be experienced.

The TP concentrations measured in Johnson Lake ranged from 0.02 mg/L at the surface to 0.11 mg/L in the bottom waters. The bottom water concentration is very elevated and likely the result of anoxic condition in the deeper waters. Thus, while the surface water TP concentrations did not exceed the 0.05 mg/L State standard and the 0.06 mg/L algae bloom ecological threshold value, the bottom waters did. This internal load can be enough independent of any external phosphorus loading, to drive in-lake productivity, especially algae blooms. Although we sampled the lake on only one date, we strongly suspect elevated TP concentrations to exist at the bottom of the lake for extended periods of time periodically throughout the growing season. These periods of anoxia present an opportunity within Johnson Lake for the rapid liberation of dissolved phosphorus (which is easily assimilated by algae) from the sediments.

The concentration of SRP measured in the lake was minimal, with both the top and bottom waters revealing non-detectable concentrations. Normally, SRP is usually present in low concentrations in the lake due to ease at which it can be assimilated by phytoplankton. As noted above, at this point in the growing season, these concentrations are not significant enough to stimulate an algal bloom or SAV infestation.

Nitrogen - While phosphorus is the most important nutrient, nitrogen is also very important with respect to defining primary productivity of lake ecosystems. Nitrogen is generally occurs at higher concentrations in lake environments than phosphorus. Because of the extreme solubility of most nitrogen species, groundwater is a much more important vector for nitrogen than it is for phosphorus. Nitrate (NO_3-N) is the most common form of nitrogen measured in lakes, because other species of nitrogen tend to oxidize to nitrate and it is produced through microbial nitrification or denitrification. Nitrogen is also fixed from atmospheric nitrogen gas by various soil microbes and by blue-green algae. Other sources include atmospheric dryfall and wetfall, runoff enriched with fertilizers, and septic effluent. Nitrate concentrations of less than 0.3 mg/L are typically associated with low to moderately productive lakes, whereas concentrations exceeding 0.6 mg/L are characteristic of more productive lake ecosystems. We have found that concentrations of nitrate as low as 0.3 mg/L are associated with streams displaying evidence of eutrophication (algae buildup on rocks, excessive weed growth, etc.). Therefore it does not take a lot of nitrate-N to stimulate or support algae and plant related problems.

While no ecological standard exists for nitrate-N, concentrations greater than 1 mg/L will support excessive amounts of algal and aquatic plant biomass. For comparison purposes, the USEPA and NJDEP drinking water quality standard is 10.0 mg/L. During the Johnson Lake sampling event, NO_3-N concentrations were 0.07 mg/L in the surface waters and 0.10 mg/L in the deeper waters. Thus, the lake's NO_3-N concentrations can be considered low when compared to the drinking water standard, as well as the standard associated with eutrophic waterbodies.

Total Suspended Solids - Total suspended solids (TSS) refers to all suspended particulate material in water, including inorganic soil particles as well as organic particles such as algae cells and decomposing organic detritus, such as leaf litter. This metric is distinct from settleable solids, generally coarser particles that are likely to quickly settle and would comprise much of the material accumulating at the tributary mouths. High solids concentrations can impact lakes by greatly increasing turbidity and color, contribute to some infilling and habitat loss, or in impairing fish respiration through interference with gill function. TSS is also correlated with phosphorus loading because phosphorus tends to bind to fine particles. Concentrations in excess of 25 mg/L are usually perceived as muddy by most lake users. The NJDEP surface water standard for all FW2-NT waterbodies is 40 mg/L.

TSS concentrations were minimal in the Lake during the single sampling effort. Concentrations ranged from ND <3 mg/L at the surface to 6 mg/L at the bottom. These TSS concentrations indicate a still waterbody at the time of sampling.

Chlorophyll a - Chlorophyll *a* (Chl *a*) is the primary photosynthetic pigment of algae and is used as a surrogate measure of phytoplankton algal biomass. The phytoplankton algae are the microscopic algae present in the water column. Typically, a severe or nuisance phytoplankton algal bloom is associated with chlorophyll *a* concentrations in excess of 25 to 30 mg/$m^{3.}$ The concentration of chlorophyll *a* measured in Johnson Lake during the sampling event was moderate, ranging from 7.2 mg/m^3 at the surface to 24 mg/m^3in the bottom waters. These chlorophyll *a* concentrations are in keeping with the fact that the majority of the lake's algal concentrations were both benthic and planktonic in form. As will be discussed later in Section 5.0, this algal productivity was more in the form of planktonic golden and green algae and not as much for the noxious blue-green algae species.

Summary

The TP concentrations measured in the Johnson Lake water column ranged from a low of 0.02 mg/L to a high of 0.11 mg/L. This bottom water TP concentration exceeded both the 0.05 mg/L State standard and the 0.06 mg/L algae bloom ecological threshold value.

This is why the TP/DO concentrations measured in Johnson Lake are so significant. These periods of anoxia present an opportunity within Johnson Lake for the rapid liberation of dissolved phosphorus (which is easily assimilated by algae) from the sediments. Based on this sampling event, this appears to be a particular problem for Johnson Lake.

The concentration of SRP measured in the lake was minimal. The samples collected at both stations had concentrations less than 0.002 mg/L. At this point in the growing season, SRP is usually present in low concentrations due to ease at which it can be assimilated by phytoplankton. As noted above, such low concentrations are not enough to stimulate an algal bloom or SAV infestation.

With respect to chlorophyll *a* concentrations, Johnson Lake did not exceed the 30 mg/m^3 threshold. In fact, the lake's surface chlorophyll *a* concentrations were below the 20 mg/m^3 threshold as well. The chlorophyll *a* concentrations may also be affected by the surficial plant infestation of the lake which would tend to suppress sunlight and phytoplankton productivity thus resulting in lower chlorophyll *a* concentrations. However, chlorophyll *a* concentrations of the bottom waters did reveal the presence of both benthic and planktonic algae forms. On a positive note, blue-green algae (cyanobacteria) were minimal in the plankton samples.

NO_3-N concentrations were below the 0.3 mg/L eutrophication guideline, ranging from 0.07 – 0.10 mg/L. For comparison purposes, the USEPA and NJDEP drinking water quality standard is 10.0 mg/L. Thus the lake's NO_3-N concentrations can be considered low when compared to both the drinking water standard, as well as the concentration range associated with eutrophic waterbodies.

The concentration of total suspended solids (TSS) measured in the water column was variable, but always well below the NJDEP 40 mg/L TSS standard. Further comparison of the TSS data, the limited Secchi transparency data and chlorophyll *a* data show no definitive consistent relationship shared by these three parameters.

5.0 Plankton Data

During the 2017 monitoring event, water samples were collected from the sampling station located nearest the dam for the identification and enumeration of phytoplankton and zooplankton. The complete data for these samples can be found in Appendix C.

Phytoplankton - Phytoplankton or algae are a functional group of microscopic plants and bacteria that form the base of many aquatic food webs. This consists of suspended or planktonic (free-floating), single cell and colonial algae, as well as benthic or filamentous algae growing near the bottom of the Lake or forming dense surface mats; both free-floating and attached. Algae are a necessary and important component of any lake system, but when they exhibit excessive growth leading to dense blooms, surface scum formation, or excessive mat growth they can cause a variety of impairments. This type of excessive growth or eutrophication is always a result of excessive nutrient concentrations that are usually linked to watershed pollutant loading, either diffuse non-point source pollutants such as those found in storm water and groundwater or from point-sources such as treatment plants, or from internal nutrient loading or nutrient recycling attributable to the decomposition of plants and algae or release from the sediments under anoxic conditions. The impairments related to excessive growth can run a wide gamut from:

- Aesthetic impairment including a loss of clarity,
- Excessive coloration, and odors,
- Recreational impairments including impacted boat navigation and poor fishing, and
- A variety of environmental and human health impacts including the production of harmful algae blooms (HABs) caused by blue-green algae, the liberation of cyanotoxins, oxygen depletion and accelerated internal nutrient generation, and loss of usable fish habitat among others.

As mentioned above blue-green algae tend to be a particularly noxious group because they produce cyanotoxins. Blue-greens tend to flourish in high phosphorus environments. Compared to other phytoplankton they are also very physiologically adept at utilizing sources of organic nitrogen and phosphorus and many can actually utilize atmospheric nitrogen as a nutrient source. Blue-greens are also not grazed upon by zooplankton and thus lack a natural biological control mechanism.

The phytoplankton samples collected on 14 September consisted of a mix of chrysophytes (common conditions), diatoms, chlorophytes (green algae; also common conditions) and a single blue-green alga (*Lyngbya*). The dominant alga was the chrysophyte *Dinobryon.*

Zooplankton - Zooplankton are a diverse group of small planktonic animals that form the trophic level above phytoplankton in the food web. They consume a wide variety of food items, including bacteria, detritus, algae, and other zooplankters. Zooplankton, especially large-bodied herbivores, are crucial in maintaining algae at acceptable densities in lakes, however

they are unable to graze blue-green algae for a variety of reasons. Zooplankton in turn are a crucial food source for zooplanktivorous fish and are an important part of the diet of almost all juvenile fish. Their numbers can be negatively affected by large anoxic zones, overgrazing by certain invasive fish such as Golden Shiners, certain pollutants, and copper algicides.

Despite the lower phytoplankton diversity and abundance, the zooplankton displayed low to moderate diversity and abundance. Only two of the three major groups of freshwater zooplankton were represented: copepods, and rotifers. No cladocerans (water fleas) were observed. This is of particular interest, because the presence of these large-bodied herbivorous zooplankters provides the highest grazing pressure on certain species of algae. However, the rotifer *Keratella* was present. This form was most likely responsible for maintaining the grazable algae (green) in acceptable densities.

Zooplankton samples collected on 14 Sept had a distinctly low abundance and diversity, however as stated earlier, herbivorous species were still present. Zooplankton groups identified were non-herbivorous rotifers and copepods. The copepods *Cyclops and Nauplius* were the most abundant of all the species identified.

Microcystins - Over the past decade we have learned more about the serious health implications associated with intense cyanobacteria (blue-green algae) blooms. Although cyanobacteria are not truly algae, these blooms have come to be labeled Harmful Algae Blooms (HABs). Cyanobacteria have a number of evolved advantages relative to "good phytoplankton." For example, many cyanobacteria are capable of fixing and assimilating atmospheric nitrogen, thus providing them with an unlimited source of a key growth-limiting nutrient. Most are also biologically adept at up-taking and utilizing organic phosphorus, another growth-limiting nutrient. Certain cyanobacteria can also regulate their position in the water column, thereby enabling them to capitalize on changing environmental conditions. Many also are adept at effectively photosynthesizing under low light conditions. Finally, they are selectively rejected as a food source by filter feeders and zooplankton. These "life history" strategies enable cyanobacteria to rapidly out-compete phytoplankton and exploit their environment leading to a bloom.

It has been repeatedly documented that, under the correct set of conditions, HABs may generate very high concentrations of cyanotoxins. These toxins are used by cyanobacteria to achieve dominance in a lake, pond or river. Swimming in waters with even low concentrations of cyanotoxin may cause skin rashes (even for dogs and livestock), ear/throat infections and gastrointestinal distress. At high concentrations, cyanotoxins can impact the health of humans, pets and livestock. Drinking water contaminated by very high cyanotoxin concentrations can actually be ***lethal***. Recently, increased attention is being given to possible links between cyanotoxins and neurodegenerative diseases, including Parkinson's, ALS and Alzheimer's.

The cyanobacteria of greatest concern include *Microcystis, Planktothrix, Anabaena, Aphanizomenon, Oscillatoria, Lyngbya* and *Gloeotrichia*. Different types of cyanotoxins are produced by these various cyanobacteria. The cyanotoxins receiving the most attention are

Microcystin-LR and Cylindrospermopsin, but Anatoxin–a, Saxitoxins and Anatoxin-a(S) are also very problematic.

Regulatory agencies are still struggling to define what constitutes a "problem" and how to deal with HABs. For a number of years the World Health Organization (WHO) has used a provisional drinking water standard of 1 µg/L microcystin in drinking water. The US Environmental Protection Agency (USEPA) recently issued cyanotoxin guidance for drinking water that provides different action levels for children versus adults and for microcystin and cylindrospermopsin. New Jersey has recently released guidance concerning cyanotoxins in both drinking water and recreational waterbodies. However, it is still currently difficult to define when a bloom constitutes a problem and, more importantly, what action to implement to protect the health and welfare of the public, pets and livestock, short of a complete closure of the water body.

Princeton Hydro collected a single sample for these cyanotoxins and performed a bench top analysis. This sample revealed non-detectable results for cyanotoxins.

Summary

The phytoplankton and zooplankton communities of Johnson Lake were only sampled once in 2017. However, several points can be made from the limited sampling effort. First, blue-green algae were identified in Johnson Lake in 2017. Second, the zooplankton community typically contained one to two herbivorous species during the sampling event. Additionally, the lake's phytoplankton community included a large number of chrysophytes (golden algae) and chlorophytes (green algae). These algae may be in part responsible for the lake's golden brown color. Lastly, the lake contained no cyanotoxins at the time of the single-day survey.

6.0 Aquatic Macrophytes

As with most shallow lakes, excessive densities of rooted aquatic plants have the possibility to be a water quality concern associated with Johnson Lake. Based on the variable clarity and shallow depth within Johnson Lake, nuisance plants may have the potential to attain densities that can negatively impact recreational activities such as canoeing and fishing. In addition, invasive aquatic plant species can out-compete the native aquatic vegetation that provides ecological benefits for resident wildlife. Given the potential impact aquatic plants have on the water quality and recreational use of Johnson Lake, detailed field observations (Transects) were made on the aquatic plant community during the 14 Sept monitoring event.

All monitoring was conducted by Princeton Hydro personnel trained in aquatic plant identification and survey methods. Species identifications were cross referenced and confirmed using various aquatic plant field guides including Borman (1997), Prescott (1969) and Hellquist (1980).

Transect lines by the transect number, as well as quadrat distance from the starting point (0', 50', 100', 150' from shoreline). For example, T-1:150 = Transect 1, 150' from the start point. The resulting plant observations made for each species within each quadrat along each transect were ranked according to abundance using the following simple formula: (A) **Abundant**, greater than or equal to 50% of total plant community, (C) **Common** 10 to 50% of total plant community, (P) **Present** less than or equal to 10% of total plant community.

The five (5) transects completed revealed that the majority of the Lake is covered in floating, emergent species. Specifically, a combination of water shield (*Brasenia schreberi*). Yellow water lily (*Nuphar spp.*) and white-water lily (*Nymphaea odorata*). These native species cover 80% - 90% of the lakes surface. In the few open spots of the Lake, it is important to note that the invasive species Eurasian watermilfoil (*Myriophyllum spicatum*) was observed.

Observations of the shoreline areas of the Lake revealed the typical presence of littoral zone base emergent plants. These species included Iris species (*Iris spp.*), Arrow arum (*Peltandra virginica*), Pickerelweed (*Pontederia cordata*) and cattails (*Typha spp.*). All of these species are native. The non-residential shorelines were approximately a 50% mix of bedrock and vegetation, while residential shorelines possessed maintained lawn nearly down to the lakes edge.

Based on field observations of shallow depths made during the Johnson Lake monitoring program, field conditions allow for optimum growth of SAV, both floating emergent and submerged. However, based upon the generally shallow, rich organic nature of Johnson Lake, the lake clearly possesses an emergent aquatic macrophyte dominated ecosystem; lily and waters-shield rather than a submerged aquatic vegetation dominated system.

Transect Data

Johnson Lake SAV Survey Transect 1					
Name		Quadrat			
Common	Scientific	0	50	100	150
Yellow water lily	*Spatterdock spp.*	A	A	A	A
White water lily	*Nymphaea spp.*	A	A	A	A
Watershield	*Brasenia schreberi*	C		C	C
Eurasian watermilfoil	*Myriophyllum spicatum*		P	P	

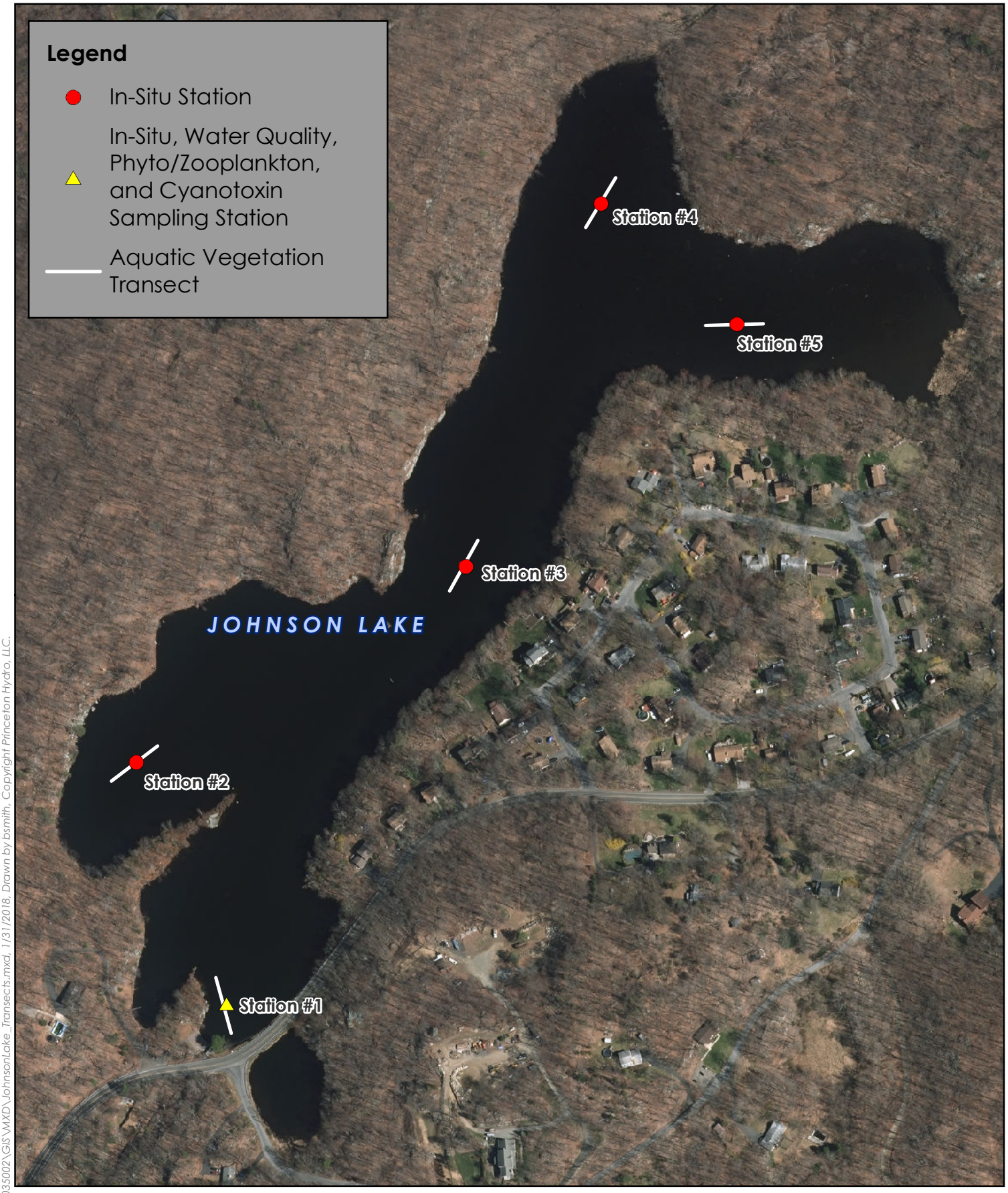
Johnson Lake SAV Survey Transect 2					
Name		Quadrat			
Common	Scientific	0	50	100	150
Yellow water lily	*Spatterdock spp.*	A	A	A	A
White water lily	*Nymphaea spp.*	A	A	A	A
Watershield	*Brasenia schreberi*	C	C		C

Johnson Lake SAV Survey Transect 3					
Name		Quadrat			
Common	Scientific	0	50	100	150
Yellow water lily	*Spatterdock spp.*	A	A	A	A
White water lily	*Nymphaea spp.*	A	A	A	A
Watershield	*Brasenia schreberi*			C	C

Johnson Lake SAV Survey Transect 4					
Name		Quadrat			
Common	Scientific	0	50	100	150
Yellow water lily	*Spatterdock spp.*	A	A	A	A
White water lily	*Nymphaea spp.*	A	A	A	A
Watershield	*Brasenia schreberi*	C			C

Johnson Lake SAV Survey Transect 5					
Name		Quadrat			
Common	Scientific	0	50	100	150
Yellow water lily	*Spatterdock spp.*	A	A	A	A
White water lily	*Nymphaea spp.*	A	A	A	A
Watershield	*Brasenia schreberi*	C			

(A) **Abundant**, greater than or equal to 50% of total plant community,
(C) **Common** 10 to 50% of total plant community,
(P) **Present** less than or equal to 10% of total plant community.



SAMPLING LOCATIONS

JOHNSON LAKE LIMNOLOGICAL ASSESSMENT
NEW JERSEY CONSERVATION FOUNDATION
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
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RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. 2015 orthoimagery obtained from New Jersey Information Network (NJGIN).
2. Sampling locations are approximate.

0 300 600 Feet

Map Projection: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

File: P:\1035\Projects\1035002\GIS\MXD\JohnsonLake_Transects.mxd, 1/31/2018, Drawn by bsmith, Copyright Princeton Hydro, LLC.

7.0 Conclusions and Recommendations

Based on our analysis of the data collected as part of the 2017 single-date water quality monitoring event, and or review of the available historical data, Princeton Hydro has developed a number of recommendations for the future management and restoration of Johnson Lake. These recommendations are as follows:

Watershed and Lake Management Plan – The existing Watershed and Lake Management Plan is outdated (2006) and is not fully consistent with the NJDEP's current regulations. It is therefore strongly recommended that an updated, comprehensive Watershed and Lake Management Plan be prepared for Johnson Lake. The need for such a plan is supported in the NJCF's recognition that the long-term improvement of the lake will require improved management of the lake's watershed. An updated Plan would be used to guide the NJCF's pursuit of grant monies or the implementation of some of the projects of greatest interest such as shoreline restoration, stormwater management and potentially even maintenance dredging. Given the potential cost and the magnitude of some of these projects of interest to the NJCF, proceeding to any implementation phase without an updated Plan in place could greatly limit the success of future lake and watershed management efforts. For example, changes in the Freshwater Wetland regulations (N.J.A.C. 7:7A) and Flood Hazard regulations (N.J.A.C. 7:13) since the previous plan affect the design and implementation of dredging, stream restoration and riparian buffer enhancement projects. The success of such projects is often predicated to ensuring that their design is consistent with the current regulations.

Some of the data that was collected as part to the 2017 single date monitoring effort can be utilized in the preparation of the Plan. For example, the bathymetric data serve as an excellent foundation for Plan development. However, the lake's hydrologic data need to be fully developed. Hydrologic data are critical to the proper selection, prioritization, design and fiscal budgeting of future in-lake and watershed-based BMPs of interest to the NJCF. The bathymetric data collected in 2017 can be combined with the updated hydrologic data to calculate Johnson Lake's hydraulic residence time and annual flushing rate, two important parameters directly related to the management of the lake. The hydraulic residence time, or its inverse the annual flushing rate, is basically the amount of time it takes for the lake to have a total volumetric exchange (to fully flush). The hydraulic residence time affects a wide array of biological and chemical lake processes such as sediment settling, lake mixing/stratification, and nutrient assimilation and affects the effectiveness of various lake restoration initiatives such as dredging, the efficacy of various herbicides or algaecides, aeration, and nutrient inactivation. Thus, having up to date hydrologic data makes it possible to better establish which management measures are best suited for the lake and how best to prioritize and implement those measures both within the lake and its watershed. The cost to develop a comprehensive Watershed and Lake Management Plan will vary based on specific details, however it would be assumed to be in the $25,000 - $35,000 range.

Dredging and Hydroraking - Dredging entails the removal of settled or accumulated material (i.e. sediments) from a water body. As documented via nutrient modeling, storm water and surface runoff transport soil and other particulate matter to Johnson Lake. Storm events transport a variety of pollutants, including particulate material to receiving waterbodies. Over time this material can accumulate in the waterbody and negative impact both its ecological health and recreational use. Dredging is a means of removing the material that has accumulated in a lake.

The data collected during the bathymetric survey showed that the majority (thickest and largest deposits) of unconsolidated sediment occur in the north western portion of the Lake. Although similarly thick deposits were recorded in the southwest cove, the impacts of sedimentation are far greater in the northwest area due to the shallow water depths. As per the data in Tables 2 and 3, even though the majority of the watershed is forested, there is still approximately 52,000 kg of sediment entering the lake annually. On a relative scale (as compared to other lakes with a more developed watershed) this is a fairly small annual load and is most likely less depending upon the specifics of the Ghost Pony Brook sub-watershed. Nonetheless, either as a result of larger-scale legacy loading or continual small-scale annual loading, appreciable amounts of sediment have accreted in given areas of the Lake.

While a whole lake dredging of Johnson Lake is not feasible, the selective or maintenance dredging of specific areas may be feasible. Specifically the bathymetric data supports the selective dredging of the northwest cove.

The NJDEP permitting costs should be lower than the permitting costs for a whole lake dredging project. Permit requirements are discussed in greater detail below. If the NJCF has some open fields or other nearby areas where the dredged material can be placed, again the overall cost of the selective dredging of these areas could be reduced. Also, depending on the consistency and physical structure of the unconsolidated material, it may be possible to re-claim and re-use the dredged material. However, this will become less feasible as the sediment's organic content (plant biomass) increases and the grain size shifts from sand to silt.

In spite of the higher degree of feasibility associated with the selective dredging of the northwest portion of the Lake, we are not making this a priority restoration item at this point in time. First, until the sources of the lake's sediment infilling are corrected, removing the currently accumulated sediments will have a short-lived positive impact. Second, management of the lake's water lily problem is a more significant issue and one that would have a greater overall benefit with respect to the lake's recreational use.

From a regulatory perspective, at best it may be possible to conduct maintenance type, site-selective dredging under a Freshwater Wetlands (NJAC 7:7A) General Permit #10 and one of the Flood Hazard Area (NJAC 7:13) General Permits. More than likely though, any dredging of Johnson Lake will require the issuance of a Freshwater Wetland GP#13 along with an appropriate Flood Hazard Area General Permit. Also, any maintenance dredging within 200 feet of the dam will require a letter of approval by the NJDEP Department of Dam Safety. Local

permitting will include a Sussex County Soil Conservation District approved Erosion and Sediment Plan. It will be necessary to collect a specific sediment sample from the areas in which dredging is anticipated and test these sediments in accordance with NJDEP requirements. This typically entails the measurement of the contaminants analyzed by means of the NJDEP-Site Remediation Standards list testing (which includes among other contaminants heavy metals, pesticides, and petroleum hydrocarbons). The physical composition of the sediments must also be analyzed. This constitutes the measurement of grain size, organic content and moisture content.

We anticipate that the permit application process (which encompasses engineering data and the aforementioned chemical testing) may cost as much as $30,000. As noted above, if the lake's sediments are free of contaminants and have the proper physical consistency (high sand content) it is possible that dredged materials could be disposed on-site or nearby. However, in planning for any dredging the NJCF should assume the material will need to be transported to a final disposal site, potentially a landfill. As such, the per cubic yard cost to dredge, remove and dispose of the lake's sediment will be in the range of $75 to $100. Given the volume of sediment in the overall Lake, this could be well in excess of $20 million dollars for a whole Lake dredging.

Even If the NJCF seeks to dredge specific areas of the lake, it will still be necessary to obtain all of the necessary permits, conduct the pre-dredging sediment testing, and develop a plan for the actual execution of the dredging operation. If the NJCF wishes to pursue even a scaled-down sediment removal effort, a Dredging Feasibility Study should be conducted. Such a study would generate detailed bathymetric and topographic data within the project area. These data would then be used to generate the signed and sealed engineering drawings required for the permit, prepare contractor specifications, conduct all of the necessary sediment testing, locate dredge material disposal sites, and refine project costs. Such a study would cost approximately $10,000.00 to $12,000.00.

The bathymetric survey of Johnson Lake showed distinct deposition patterns exist adjacent to the mouth of the stream inlets for Johnson Lake. If the upper layers of unconsolidated sediment in these specific locations are comprised mostly of leaf-litter and residual aquatic plant biomass, then these areas could be candidate locations for hydroraking. Hydroraking is not dredging. The NJDEP limits hydroraking operations to the removal of rooted aquatic SAVs and/or accumulated organic material such as leaf litter. Although some sediment is inherently removed, the amount of sediment removal is minimal as the equipment is not designed to dredge or scoop out large amounts of sediment. While the removal of the organic layers in these areas may result in a measurable increase in the water depth, the most significant benefit would be the removal of rooted SAV and the removal of the organic deposits colonized by benthic algae, including benthic cyanobacteria (e.g., *Lyngbya*). However, it is important to note that there are a number of logistical issues that need to be taken into consideration before implementing any hydroraking operation in any part of the lake. These issues include presence of stumps and large rocks within the targeted hydroraking area and the disposal of the hydroraked material.

In conclusion, it should be emphasized that the dredging of Johnson Lake is not an "all or none" scenario. A dredging feasibility study would provide the additional information needed to more accurately develop a "spot" or "maintenance" dredging approach that could be very beneficial to the long-term recreational use of the Lake. Although even though a partial dredging effort is expensive, the project would measurably improve the condition of the lake.

Alternatively, some of the same areas that would benefit from spot dredging could also benefit from hydroraking. Again this is especially true of the areas near the inlets, most of which are impacted by dense water lily growth.

Mechanical Harvesting – The majority of the Lake is impacted by rooted aquatic plants, especially water lilies. This is due in part to the shallow depth of the north end of the Lake and the accumulation of fine sediment deposits in this area. Given the size of Johnson Lake, the composition of its aquatic plant community, and its recreational use, a limited mechanical SAV harvesting operation could prove to be particularly cost effective and ecologically sound method of controlling nuisance SAV densities in Johnson Lake. One consistent advantage that mechanical harvesting has over other SAV control using herbicides is that phosphorus is removed from the lake along with the plant biomass.

The mechanical harvesting of SAV from Johnson Lake should be relatively easy. The lake has excellent access to a trailer mounted hydrorake outfitted with weed harvesting attachments or a small weed harvester. Either a small (6' wide) harvester or a properly equipped hydrorake will remove aquatic vegetation from a lake at the rate of 0.1 - 0.2 acres per day. As noted in the dredging section of the report, what makes the hydrorake particularly effective is that it removes submerged aquatic vegetation from the roots. This is especially effective for water lilies as the removal of the rhizome results in more effective control of these plants. The harvested material will still need to be disposed. Some farms, plant nurseries or composting operations may accept the harvested vegetation thus significantly reducing disposal costs. Hydroraking and small-scale weed harvesting operations typically cost in the $1,500.00 to $2,000.00 per day range plus material transport and disposal.

Although the per acre cost of hydroraking and mechanical harvesting are significantly higher (on average 2-3 times greater per acre) than the chemical control of plant growth, the environmental benefits of harvesting in terms of the reduction in nutrient loading and potential multi-year control due to the removal of the SAV root system, harvesting costs can balance out the added cost. Additionally, unlike chemical treatments there is no plant die-off triggered DO sags or post-treatment algae blooms.

Chemical Control of Aquatic Plants - Substantial amounts of both native and invasive aquatic vegetation are present in Johnson Lake. As noted above, although the chemical control of this growth can have negative environmental affects, aquatic plant control via the application of aquatic herbicides is the most commonly implemented control technique. Chemical control can be achieved through the application of systemic or contact herbicides.

Contact herbicides are very quick acting and impact plant growth by destroying the plant's cell structure. Contact herbicide treatments are also less expensive than systemic herbicide treatments due to lower product costs. Conversely systemic herbicides must be absorbed and assimilated by the targeted plant. Control is usually the result of the alteration of a biological process (for example the production of chlorophyll). As a result the die-off" is slower, but the control is usually longer-lasting, potentially 2-3 years per treatment.

The disadvantages of using herbicides include potential impacts to non-targeted plant species (native non-invasive pants), DO depletion as a result of bacterial decomposition of the dead plant material, and the recycling of nutrients back into the water column upon the decomposition of the treated plant biomass. The latter is the reason why algal blooms frequently occur immediately after contact herbicides treatments.

Depending on local climatic conditions and the nuisance species targeted for control, between two to four treatments may be required through the course of one growing season. Such a program would be expected to cost at least $15,000 - $20,000. The cost of a systemic herbicide treatment program for Johnson Lake, involving the application of fluridone (Sonar) will likely be in the range of $25,000, assuming as with the contact treatment that about 50% of the lake's total plant growth would be targeted.

Implement A Comprehensive Water Quality Monitoring Program – We highly recommend that should the NJCF decide not to immediately update the Watershed and Lake Management Plan, that additional in-lake water quality data be compiled. Such a study would cost approximately $7,500.00 to $10,000.00 annually. As previously noted, the most comprehensive water quality data for the lake (other than the data collected as part of this study) is over 5 years old. Princeton Hydro conducted a single-day monitoring event in 2017. In conducting additional lake monitoring, the annual sampling frequency should be increased to monthly events starting in May and continuing through September. Discrete sampling could be limited to a single station, located near the dam. However, we feel that it is prudent to also collect *in-situ* data at multiple stations. Specifically *in-situ* data should be collected at the same stations as occurred in 2017. The following details the level of effort that Princeton Hydro recommends for the 2018 monitoring program:

- *In-situ* measurement in profile (surface to bottom) of DO, temperature, specific conductivity and pH at one station within each of the lake's sample locations,
- Secchi clarity at one station within each of the lake's impoundments,
- Lab analysis of Alkalinity, Hardness, TP (surface and bottom), SRP (surface and bottom), chlorophyll *a*, TSS, NO_3-N (surface and bottom) collected at one station near the lake's dam,
- Collection and analysis of a Phytoplankton and Zooplankton sample, with cyanotoxin analysis from one station located near the lake's dam.

Fishery Survey – In terms of public recreation, a balanced fishery is fundamental to providing enjoyable, sustainable recreational fishing opportunities. From an ecological and water quality

perspective, a balanced lake fishery has enough piscivorous fish to keep the planktivorous population in check thus promoting a diverse zooplankton community, which is fundamental to keeping phytoplankton blooms naturally in check. A balanced, healthy and diverse lake fishery is characterized by the correct combination of planktivorous (zooplankton eating) fish, piscivorous (fish eating) fish, game fish and forage fish.

Given the constant vegetation covered state of Johnson Lake, it is very likely that the lake possesses long-term reduced dissolved oxygen concentrations. In order to determine the overall status of the Johnson Lake fishery it will be necessary to conduct a detailed fishery survey. A fishery survey would enable us to determine if the planktivore/piscivore fishery ratio is correct for Johnson Lake, especially with respect to maximizing the lake's recreational fishing opportunities. If the fishery survey were to reveal an imbalance in the ratio of the prey and predator populations, this could be corrected by stocking of large predator species. This could also be helpful in decreasing the grazing pressure exerted by panfish on zooplankton. Additionally, the fishery survey data used in combination with the bathymetric survey data and vegetation data could be used determine if there is enough fish habitat and structure to sustain a healthy fishery present in Johnson Lake. There is not enough fish data available to determine how best to maximize the lake's fishery from the perspective of either water quality management or recreational fishing.

Septic System Management - Generally speaking, it can be assumed that homes within 300' of a lakes shoreline have groundwater-based influence on the lake or tributary. The homes within the Johnson Lake watershed are serviced by septic systems (on-lot wastewater treatment systems). It should be noted that overall, the septic related load, as based on the total number of homes in close proximity to the lake is low (less than 10% of the computed watershed load). Nonetheless, septic management should be implemented as an additional means to decrease total nutrient loading. Septic management can also protect against septic failures that could result in bacterial inputs.

Successful septic management involves the integration of public education, product modification, septic system inspection and maintenance, and water conservation practices. In addition, it may rely on the use of advanced on-site wastewater renovation/treatment designs to correct failing systems or to dictate the construction of new systems in environmentally sensitive sections of the watersheds.

Product modification usually refers to the use of non-phosphorus or low phosphorus products that minimize septic-related phosphorus loading to the environment. However, it also applies to the use of septic tank chemical additives or the disposal of paint, solvents or left over household chemicals and cleaning products in septic systems. Public education fliers and brochures advising against such practices are readily available through the NJDEP and regional watershed groups (e.g., Lake Hopatcong Commission). Additional related public information fact sheets of this nature can be obtained through the EPA's Small Flows Clearing House, which specializes in the dissemination of information pertaining to septic systems and other types of

on-site waste water treatment systems. Such educational material would prove beneficial in this respect.

All of the residents in the watershed should be educated about the serious impacts to their septic systems of improperly disposed household chemicals and degreasing agents. These products can cause serious upsets to the biological treatment processes that occur in the septic tank itself and in the soils of the disposal field. Equally important, these products can result in serious groundwater pollution and the contamination of drinking water wells.

Also, the public should be educated concerning the lack of any benefit associated with enzymes, bacteria inoculants, or other products advertised as septic tank supplements. As demonstrated by the EPA (USEPA, 1997), these products do very little to enhance septic system operation. They also give a false sense of maintenance to the property owner and may actually dissuade them from regularly pumping or inspecting their system. Also, residents should be cautioned about the use of garbage disposal units/grinders. Excessive or improper use of these devices can increase organic loading and further stresses the system's operation by adding to both the sludge and grease layers. Furthermore, once ground up, the disposed solids can be converted into fine particulate material that resists settling. This can decrease the operational efficiency of a septic system and accelerate the clogging of the leach field.

Inspections and routine maintenance are usually the two controversial elements of most septic management programs. There is an innate resistance by homeowners to allow periodic inspections or to comply with a mandatory pump out schedules. Basically, the prevailing thought among most homeowners is "if it flushes, it's OK". However, as has been demonstrated in studies conducted as part of nationwide septic management studies, routine inspections help decrease the occurrence of large scale failures by identifying the more easily corrected, less costly problems early on (NYSDEC, 1994). Similarly, routine pump outs decrease the buildup of sludge and grease in the septic tank itself, both of which can be transported into the leach field and create clogging problems. In general, the inspections and pump outs should be viewed as an insurance policy for the long-term proper operation of the septic system and not an imposition of the property rights of a homeowner. It should be noted that for older tanks, there may be some liability associated with their pump out. For example, old metal tanks that have become corroded or hand built cesspools can collapse once the liquid and sludge has been removed.

Water conservation measures are intended to reduce hydrologic loading to the leach field. Included in this category are the use of low flush toilets, flow reduction fixtures and other similar devices designed to reduce water usage. It can also encompass lifestyle habits such as spreading out laundry wash loads over a number of days, shorter showers, and other similar cooperative techniques.

In summary, the immediate restoration needs of Johnson Lake entail:

1. Control of the lake's SAV, especially water lily. We feel that this can be effectively accomplished via hydroraking or harvesting. This is the most critical immediate management/restoration need for Johnson Lake.
2. Improve the lake's deep-water DO concentrations and control the lake's internal TP load. Theoretically this would be best accomplished via a whole lake destratification aeration system. However, before investing in an aeration system, the lake's SAV densities should be controlled as this alone may improve water column mixing and circulation enough to prevent thermal stratification and anoxia.
3. Selective dredging. This would have the greatest benefit in improving the ecological services and functions as well as the recreational utilization of the lake's northwest cove. However, as detailed above, dredging is expensive and more information needs to be compiled before implementing even a selective dredging program.
4. The NJCF would greatly benefit from a comprehensive lake and watershed study. The outcome of such a study would be a management plan that the NJCF could use to guide short-term and long-term lake and watershed management initiatives. Such a plan could also be used to support fund raising and grant applications.

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APPENDIX A

IN-SITU DATA

In-Situ Monitoring for Johnson Lake 9/13/17								
Station	**DEPTH (meters)**			**Temperature**	**Conductivity**	**Dissolved Oxygen**	**Dissolved Oxygen**	**pH**
	Total	**Secchi**	**Sample**	**(^{0}C)**	**(umhos/cm)**	**(mg/L)**	**(%)**	**(units)**
ST-1	**2.60**	**1.60**	**Surface**	18.56	412	5.86	64.8	6.76
			1.0	16.65	410.1	2.97	31.5	6.62
			2.0	16.41	398.7	<1	10.2	6.55
			2.5	16.44	511.7	<1	5.1	6.39
ST-2	**1.80**	**1.8+**	**Surface**	19.94	420.2	6.13	69.6	6.82
			1.0	16.71	424.8	3.61	38.4	6.63
			1.5	16.5	428.4	<1	10.2	6.57
ST-3	**1.80**	**1.8+**	**Surface**	19.62	420.9	4.13	46.6	6.63
			1.0	16.44	421.5	2.41	25.5	6.56
			1.5	16.15	420.5	<1	10.1	6.47
ST-4	**1.80**	**1.8+**	**Surface**	17.86	436.2	3.75	40.8	6.66
			1.0	16.17	430.8	1.25	13.1	6.53
			1.5	16.18	479.1	<1	10	6.42
ST-5	**1.60**	**1.6+**	**Surface**	17.03	424.7	4.37	46.8	6.66
			1.0	16.28	430.3	2.11	22.2	6.61
			1.5	16.19	457.9	<1	10.1	6.27

APPENDIX B

LABORATORY DATA

Parameter	Surface	Deep
Chl a (mg/M^3)	7.2	24
NO_3-N (mg/L)	0.07	0.10
SRP (mg/L)	ND <0.002	ND <0.002
TP (mg/L)	0.02	0.11
TSS (mg/L)	ND <3	6

APPENDIX C

PLANKTON DATA

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: Johnson Lake				**Sampling Date: 9/13/2017**				**Examination Date: 9/19/2017**				
Site 1: Mid-Lake												
Phytoplankton												
Bacillariphyta (Diatoms)	**1**			**Chlorophya (Green Algae)**	**1**			**Cyanophyta (Blue-Green Algae)**	**1**		
Asterionella				*Actinastrum*				*Anabaena*			
Aulacoseira				*Ankistrodesmus*				*Amphanizomen*			
Cocconeis				*Chlamydomonas*				*Aphanocapsa*			
Cyclotella				*Botryococcus*				*Chroococcus*			
Cymatopleura				*Chlorella*				*Cylindrospermum*			
Cymbella				*Coelastrum*				*Lyngbya*	R		
Denticula	R			*Eudorina*				*Microcystis*			
Fragilaria				*Gloeocystis*				*Nostoc*			
Frustulia				*Gonium*	R			*Pseudoanabaena*			
Gyrosigma				*Hydrodictyon*				*Oscillatoria*			
Melosira				*Monoraphidium*							
Nedium				*Mougeotia*							
Stauroneis	R			*Micrasterias*							
Stephanodiscus				*Microspora*							
Sururekka				*Ochromonas*							
Synedra	P			*Oedogonium*				**Euglenophyta (Euglenoids)**			
Tabellaria				*Oocystis*				*Colacium*			
				Scenedesmus				*Euglena (Phacus sp)*	P		
				Spirogya	C			*Euglena sp*			
				Staurastrum				*Trachelomonas*			
				Treubaria							
Chrysophyta (Golden Algae)				*Pediastrum*	P			**Pyrrhophyta (Dinoflagellates)**			
Dinobryon	C			*Volvex*	R			*Ceratium*	P		
Chromulina				*Zygnema*				*Peridinium*			
Mallomonas											
Synura	P			**Desmids (Green Algae)**							
				Hyalotheca							
				Staurastrum							
				Staurodesmus							
Zooplankton												
Cladocera (Water Fleas)	**1**			**Copecoda (Copepods)**	**1**			**Rotifera (Rotifers)**	**1**		
Bosmina sp.				*Cyclops sp.*	C			*Keratella cochlearis* (H)	P		
Daphnia sp.				*Dipatomus (H)*				*Keratella crassa (H)*			
Eubosmina sp.				*D Nauplius*	C			*Keratella quadrata* (H)			
Chydorus				*Skistodiaptomus oregonensis*				*Kellicottia longispina*	R		
Diaphniosoma				*Microcyclops sp*				*Asplanchnopus sp.*			
Ceriodaphnia				*Limnocalanus macrurus*				*Polyarthra*	P		
Leptodora kindti				*Leptodiaptomus coloradensis*				*Hexarthra mira*	C		
Scapholeberis mucronata											
Bosmina longirostris								**Arthropoda (Arthropods)**			
Diaphnosoma brachyurum								*Chaoborus punctipennis*			
Diaphanosoma birgei								*Ostracoda*			
Sites:	**1**			**Comments: Zooplankton are at moderate density. There appears to be minor abundance of Spirogyra and Dinobryon present.**							
Total Phytoplankton Genera	12										
Total Zooplankton Genera	6										
Sample Volume (mL)				**Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)**							
				Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)							

Princeton Hydro LLC
1108 Old York Rd, Ringoes, NJ 08551; Phone (908) 237-5660

APPENDIX D

HISTORICAL RECORDS SEARCH DOCUMENTATION

NJ DEP - Dam Safety Section

Atlas Number: 22-196 | View Assignment Entries | Status/Assignment Info | Admin Order Status | Loan Info | Emergency Contact Info Form

Federal ID: NJ00499 | View Status Entries | Add New Status Entry | Assignment Review

Dam Name: Johnson Lake Dam | Owner

City/Town: Byram Township

County: Sussex

Nearest City/Town:

Electronic Links
EAP
O-M
IR
Google Map

Compliance: 1-Total Compliant

Next Insp. Due: 5/7/2018

Repairs Completed (Y/N): Y

Latititude Degrees: 40 Latitude Minutes: 57.636

Longitude Degrees: 74 Longitude Minutes: 43.6

Dam Compliance Search Info

Warehouse Box No. 22-25, 22-40 | Order Box(es)

View scanned warehouse boxes

River/Stream: Lubbers Run-TR | Pine/Highlands (P/H/N): H | Lot:

Quad Sheet: Stanhope | Basin: Passaic | Block:

Class: L — H (High), S (Significant), L (Low), 0 (Breached or Removed)

Purpose: R — I (Irrigation), H (Hydroelectric), C (Flood Control and Stormwater Management), N (Navigation), S (Water Supply), R (Recreation), P (Fire Protection, Stock, or Small Farm Pond), F (Fish and Wildlife Pond), D (Debris Control), T (Tailings), O (Other)

Specifications

Dam Type: REPG — Indicate One or More Descriptive Codes: RE (Earth), ER (Rockfill), PG (Gravity), CB (Buttress), VA (Arch), MV (Multi-Arch), CN (Concrete), MS (Masonry), ST (Stone), TC (Timber Crib), OT (Other)

Large Dam (Y/N)	N	Ownership	Public	
Height	11.3 (feet)	Normal Capacity	198	(ac
Length	42 (feet)	Maximum Capacity		(acr
Normal Surface	33 (acres)	Spillway Capacity	58	
Drainage area	0.6 (sq. miles)	Spillway Type:	Concrete Overflow	
Normal Pool Elev.	(feet)	Design Storm Elev.		(feet)
Dike (Y/N)		Year Completed		
SDF		Legislative Dist:		

Dams with Overtopping Protection

Notes: | Endangered Plant: | Endangered Plant List

Overtopping Protection (Y/N) | Overtopping Protection Type:

Phase I Inspection (Y/N): Y | NRCS (Y/N) | Spillway Adequate (Y/N): | DAG Referral: No | Active DAG Referral:

EAP Submitted (Y/N/NR): NR | EAP Status Form | Click on EAP Status Form to see more detailed information in connection with the EAP for this structure

O and M Submitted (Y/N): Y | O and M Approved (Y/N): Y | ArcView inundation map location

View ALL Assignment Entries | View ALL Status Entries | Common Docs | Dam Info Searches | Consultant Information | Important Dates | EAPs located within EOC | Dam Incidents | Eunice's Incoming Mail doc | Dam Safety Equipment Database | Operating Status/Rapid Response

Last Date Inspected: 5/8/2014

Last Date P.E. Inspected 5/8/2014

Dam Condition: Satisfactory

Years in which IR performed

○ 2011	◉ 2014	○ 2017
○ 2012	○ 2015	○ 2018
○ 2013	○ 2016	○ 2019

Studies Req'd:

○ H and H ○ Failure/inundation

○ Stability ○ Other

CS Due:
EAP Due:
O_M Due:
Study/Permit Due:
Other Info Due:
Other Info Due Date:

Application Number: 1312
Application Received: 3/23/2009
Permit Issued: 7/13/2009
Open permit: No
Construction Start Date: 9/15/2009
Under Construction: No
Construction End Date: 11/20/2009

Owner Information

Owner 1: Township of Byram
DEP Owned (Y/N): N
Attention:
Division:

Owner Type: L — F (Federal), S (State), L (Local Government), U (Pulic Utility), P (Private)

Street: 10 Mansfield Drive
City: Byram
State: NJ
Zip Code: 07874
Phone:

Owner 2:
Disputed ownership (Y/N):
Attention 2:
Street 2:
City 2:
State 2:
Zip Code 2:
Phone 2:

Owner 3:
Fish Ladder:
Attention 3:
Street 3:
City 3:
State 3:
Zip Code 3:
Phone 3:

24 Hr Contact

Contact:
Phone:
Fax:
E-mail:

Top of Page

The New Jersey Department of Environmental Protection (NJDEP), acknowledges the receipt of your Open Public Records Act (OPRA) record request. The NJDEP will respond to your request within seven (7) business days.

If you have any questions, please contact the Office of Record Access at (609) 341-3121, or e-mail our office at: records.custodian@dep.nj.gov. The assigned OPRA Record Request Tracking #, identified in the Subject Line of this email, will facilitate future communications with our office.

Thank you,

NJDEP - Office of Record Access

OPRA Request Tracking Number: 215698

Date Received:	09/20/2017
Date Submitted:	09/20/2017
Access Method:	Send Electronic copies

Requesting Party Information

Name:	Chris Mikolajczyk
Affiliations:	Princeton Hydro LLC
Mailing Address:	1108 Old York Road Ringoes, NJ 08551
Phone:	(908) 237-5660
Email:	cmiko@princetonhydro.com

Request Information

Facility Name:	
Block\Lot:	360 39
Address:	Byram Twp - Sussex
Owner:	
Operator:	
Permit Type:	
License Type:	
Related IDs:	
Individual:	
Individual Type:	

Request Details:

We are interested in any records from the Bureau of Dam Safety

State of New Jersey

Department of Environmental Protection

GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

Please read this entire form carefully as it contains important information concerning the response to your record request, accessing records, disputing denials, and your rights concerning government records. For further information, access WWW.NJ.GOV/DEP/OPRA.

Requestor Information

First Name:	CHRIS	MI		Last Name	MIKOLAJCZYK		
Company:	PRINCETON HYDRO LLC						
Mailing Address:	1108 OLD YORK ROAD						
City:	Ringoes	State:	NJ	Zip:	08551	Email:	cmiko@princetonhydro.com
Business Telephone:	(908) 237-5660					Extension	
Facsimile Telephone:	(908) 237-5666						

State Use Only

Tracking #	215698
Received Date	09/20/2017
Access Method	**Send Electronic copies**

All matters relating to the response and access of any records identified for this request should be directed to:

NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420

Tele #: (609) 341-3121
Fax #: (609) 292-1177

Record Request Details:

We are interested in any records from the Bureau of Dam Safety

Disposition Notes	Record Request Response			
Based on this record request, responsive records have been identified and will be emailed when received from the program.Requestor may contact the Office of Record Access at 609-341-3121 to obtain further information.	**In Progress**	–	Open	
	Filled	–	Closed	X
	Denied	–	Closed	
	Partial	–	Closed	
Addendum Disposition Notes: NONE	Matthew J. Cofer			09/25/2017
	Custodian Signature			**Date**

Access to Government Records Under the New Jersey Open Public Records Act (N.J.S.A. 47:1A-1 et seq.)

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: 360 Lot: 39	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Sussex Municipality: Byram Twp	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
- **Filled** – Based on the information provided in your request, the Department was able to investigate and respond to your record request.
- **Denied** – Based on the nature of the request and/or the records sought, the Department has denied your request pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.
- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
- **Electronic Records Request** – Dependent on the size & nature of the e-records, the Department will email the records or provide a CD or DVD.
- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

Access to Government Records Under the New Jersey Open Public Records Act (N.J.S.A. 47:1A-1 et seq.)

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

Hard Copies:	Letter & Legal size	= $0.05 per page	**Electronic Records:** CDs = $0.55 per CD
	Oversized Maps (Color)	= $5.00 per map	DVDs = $0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map	

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.

3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.

4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.

5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.

6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.

7. **Resolution of Disputed Findings:**

   In the event that a requester does not agree with the Department's record response, the requester should:

   No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

   Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

   a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

   b. Institute a proceeding in the Superior Court of New Jersey

   c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.

8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: NONE

BYRAM TOWNSHIP

OPEN PUBLIC RECORDS ACT REQUEST FORM

10 MANSFIELD DRIVE, STANHOPE, NEW JERSEY 07874

PHONE 973-347-2500 FAX 973-347-0502
dflynn@byramtwp.org
Doris Flynn, Municipal Clerk

Important Notice

The last page of this form contains important information related to your rights concerning government records. Please read it carefully.

Requestor Information – Please Print

Chris MI L Last Name Mikolajczyk

E-mail Address cmiko@princetonhydro.com

Mailing Address 1108 Old York Road PO Box 720

City Ringoes State NJ Zip 08829

Telephone 908-237-5660 FAX 908-237-5666

Preferred Delivery: Pick Up _____ US Mail _____ On-Site Inspect _____ Fax _____ E-mail _X_____

If you are requesting records containing personal information, please circle one: Under penalty of N.J.S.A. 2C:28-3, I certify that I ***HAVE*** / ***HAVE NOT*** been convicted of any indictable offense under the laws of New Jersey, any other state, or the United States.

Signature _____ Date 9/20/17

Payment Information

Maximum Authorization Cost $

Select Payment Method

Cash Check Money Order

Fees: Letter size pages - $0.05 per page
Legal size pages - $0.07 per page
Other materials (CD, DVD, etc) – actual cost of material

Delivery: Delivery / postage fees additional depending upon delivery type.

Extras: Special service charge dependent upon request.

Record Request Information: Please be as specific as possible in describing the records being requested. Also, please note that your preferred method of delivery will only be accommodated if the custodian has the technological means and the integrity of the records will not be jeopardized by such method of delivery.

We are conducting a limnological assessment of Johnson Lake, located on Block 360, Lot 39. We are interested in any records the Township may have for the lake specific to the dam, herbicide treatments, pesticide treatments, etc.

Please let me know if you have any questions. Thanks.

AGENCY USE ONLY	AGENCY USE ONLY	AGENCY USE ONLY

Est. Document Cost		**Disposition Notes**		**Tracking Information**	**Final Cost**
Est. Delivery Cost		Custodian: If any part of request cannot be delivered in seven business days, detail reasons here.		Tracking #	Total
Est. Extras Cost				Rec'd Date	Deposit
Total Est. Cost				Ready Date	Balance Due
Deposit Amount				Total Pages	Balance Paid
Estimated Balance				**Records Provided**	
Deposit Date		In Progress - Open			
		Denied - Closed			
		Filled - Closed			
		Partial - Closed		**Custodian Signature**	**Date**

DEPOSITS

The custodian may require a deposit against costs for reproducing documents sought through an anonymous request whenever the custodian anticipates that the documents requested will cost in excess of $5 to reproduce.

Where a special service charge is warranted under OPRA, that amount will be communicated to you as required under the statute. You have the opportunity to review and object to the charge prior to it being incurred. If, however, you approve of the fact and amount of the special service charge, you may be required to pay a deposit or pay in full prior to reproduction of the documents.

YOUR REQUEST FOR RECORDS IS DENIED FOR THE FOLLOWING REASON(S):

(To be completed by the Custodian of Records – check the box of the numbered exemption(s) as they apply to the records requested. If multiple records are requested, be specific as to which exemption(s) apply to each record. **Response is due to requestor as soon as possible, but no later than seven business days**.)

N.J.S.A. 47:1A-1.1

- ☐ Inter-agency or intra-agency advisory, consultative or deliberative material
- ☐ Legislative records
- ☐ Law enforcement records:
  - ☐ Medical examiner photos
  - ☐ Criminal investigatory records (however, N.J.S.A. 47:1A-3.b. lists specific criminal investigatory information which must be disclosed)
  - ☐ Victims' records
- ☐ Trade secrets and proprietary commercial or financial information
- ☐ Any record within the attorney-client privilege
- ☐ Administrative or technical information regarding computer hardware, software and networks which, if disclosed would jeopardize computer security
- ☐ Emergency or security information or procedures for any buildings or facility which, if disclosed, would jeopardize security of the building or facility or persons therein
- ☐ Security measures and surveillance techniques which, if disclosed, would create a risk to the safety or persons, property, electronic data or software
- ☐ Information which, if disclosed, would give an advantage to competitors or bidders
- ☐ Information generated by or on behalf of public employers or public employees in connection with:
  - ☐ Any sexual harassment complaint filed with a public employer
  - ☐ Any grievance filed by or against an employee
  - ☐ Collective negotiations documents and statements of strategy or negotiating
- ☐ Information that is a communication between a public agency and its insurance carrier, administrative service organization or risk management office
- ☐ Information that is to be kept confidential pursuant to court order
- ☐ Certificate of honorable discharge issued by the United States government (Form DD-214) filed with a public agency
- ☐ Social security numbers
- ☐ Credit card numbers
- ☐ Unlisted telephone numbers
- ☐ Drivers' license numbers
- ☐ Certain records of higher education institutions:
  - ☐ Research records
  - ☐ Questions or scores for exam for employment or academics
  - ☐ Charitable contribution information
  - ☐ Rare book collections gifted for limited access
  - ☐ Admission applications
  - ☐ Student records, grievances or disciplinary proceedings revealing a students' identification
- ☐ Biotechnology trade secrets **N.J.S.A. 47:1A-1.2**
- ☐ Convicts requesting their victims' records **N.J.S.A. 47:1A-2.2**

☐ Ongoing investigations of non-law enforcement agencies (must prove disclosure is inimical to the public interest) **N.J.S.A. 47:1A-3.a.**
☐ Public defender records **N.J.S.A. 47:1A-5.k.**
☐ Upholds exemptions contained in other State or federal statutes and regulations, Executive Orders, Rules of Court, and privileges created by State Constitution, statute, court rule or judicial case law **N.J.S.A. 47:1A-9**
☐ Personnel and pension records (however, the following information must be disclosed:
- An individual's name, title, position, salary, payroll record, length of service, date of separation and the reason for such separation, and the amount and type of any pension received
- When required to be disclosed by another law, when disclosure is essential to the performance of official duties of a person duly authorized by this State or the US, or when authorized by an individual in interest
- Data contained in information which disclose conformity with specific experiential, educational or medical qualifications required for government employment or for receipt of a public pension, but not including any detailed medical or psychological information **N.J.S.A. 47:1A-10**

N.J.S.A. 47:1A-1

☐ "a public agency has a responsibility and an obligation to safeguard from public access a citizen's personal information with which it has been entrusted when disclosure thereof would violate the citizen's reasonable expectation of privacy."

Burnett v. County of Bergen, 198 N.J. 408 (2009). Without ambiguity, the court held that the privacy provision "is neither a preface nor a preamble." Rather, "the very language expressed in the privacy clause reveals its substantive nature; it does not offer reasons why OPRA was adopted, as preambles typically do; instead, it focuses on the law's implementation." "Specifically, it imposes an obligation on public agencies to protect against disclosure of personal information which would run contrary to reasonable privacy interests."

Executive Order No. 21 (McGreevey 2002)

☐ Records where inspection, examination or copying would substantially interfere with the State's ability to protect and defend the State and its citizens against acts of sabotage or terrorism, or which, if disclosed, would materially increase the risk or consequences of potential acts of sabotage or terrorism.
☐ Records exempted from disclosure by State agencies' proposed rules.

Executive Order No. 26 (McGreevey 2002)

☐ Certain records maintained by the Office of the Governor
☐ Resumes, applications for employment or other information concerning job applicants while a recruitment search is ongoing
☐ Records of complaints and investigations undertaken pursuant to the Model Procedures for Internal Complaints Alleging Discrimination, Harassment or Hostile Environments
☐ Information relating to medical, psychiatric or psychological history, diagnosis, treatment or evaluation
☐ Information in a personal income or other tax return
☐ Information describing a natural person's finances, income, assets, liabilities, net worth, bank balances, financial history or activities, or creditworthiness, except as otherwise required by law to be disclosed
☐ Test questions, scoring keys and other examination data pertaining to the administration of an examination for public employment or licensing
☐ Records in the possession of another department (including NJ Office of Information Technology or State Archives) when those records are made confidential by regulation or EO 9.

Other Exemption(s) contained in a State statute, resolution of either or both House of the Legislature, regulation, Executive Order, Rules of Court, any federal law, federal regulation or federal order pursuant to N.J.S.A. 47:1A-9.a.

(Please provide detailed information regarding the exemption from disclosure for which you are relying to deny access to government records. If multiple records are requested, be specific as to which exemption(s) apply to each record.)

REQUEST FOR RECORDS UNDER THE COMMON LAW

If, in addition to requesting records under OPRA, you are also requesting the government records under the common law, please check the box below.

A public record under the common law is one required by law to be kept, or necessary to be kept in the discharge of a duty imposed by law, or directed by law to serve as a memorial and evidence of something written, said, or done, or a written memorial made by a public officer

authorized to perform that function, or a writing filed in a public office. The elements essential to constitute a public record are that it be a written memorial, that it be made by a public officer, and that the officer be authorized by law to make it.

☐Yes, I am also requesting the documents under common law.

If the information requested is a "public record" under common law and the requestor has a legally recognized interest in the subject matter contained in the material, then the material must be disclosed if the individual's right of access outweighs the State's interest in preventing disclosure.

Please set forth your interest in the subject matter contained in the requested material:

_____

_____

_____

Note that any challenge to a denial of a request for records under the common law cannot be made to the Government Records Council, as the Government Records Council only has jurisdiction to adjudicate challenges to denials of OPRA requests. A challenge to the denial of access under the common law can be made by filing an action in Superior Court.

1. All government records are subject to public access under the Open Public Records Act ("OPRA"), unless specifically exempt.
2. A request for access to a government record under OPRA must be in writing, hand-delivered, mailed, transmitted electronically, or otherwise conveyed to the appropriate custodian. N.J.S.A. 47:1A-5.g. The seven (7) business day response time does not commence until the records custodian receives the request form. If you submit the request form to any other officer or employee of the ***Name of Agency***, that officer or employee must either forward the request to the appropriate custodian, or direct you to the appropriate custodian. N.J.S.A. 47:1A-5.h.
3. Requestors may submit requests anonymously. If you elect not to provide a name, address, or telephone number, or other means of contact, the custodian is not required to respond until you reappear before the custodian seeking a response to the original request.
4. The fees for duplication of a government record in printed form are listed on the front of this form. We will notify you of any special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by cash, check or money order payable to the ***Name of Agency.***
5. ***You may be charged a 50% or other deposit when a request for copies exceeds $25.*** The ***Name of Agency*** custodian will contact you and advise you of any deposit requirements. You agree to pay the balance due upon delivery of the records. Anonymous requests in excess of $5.00 require a deposit of 100% of estimated fees.
6. Under OPRA, a custodian must deny access to a person who has been convicted of an indictable offense in New Jersey, any other state, or the United States, **and** who is seeking government records containing personal information pertaining to the person's victim or the victim's family. This includes anonymous requests for said information.
7. By law, the ***Name of Agency*** must notify you that it grants or denies a request for access to government records within seven (7) business days after the agency custodian of records receives the request. If the record requested is not currently available or is in storage, the custodian will advise you within seven (7) business days after receipt of the request when the record can be made available and the estimated cost for reproduction.
8. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.
9. If the ***Name of Agency*** is unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form or other written correspondence and send you a signed and dated copy.
10. Except as otherwise provided by law or by agreement with the requester, if the agency custodian of records fails to respond to you within seven (7) business days of receiving a request, the failure to respond is a deemed denial of your request.
11. If your request for access to a government record has been denied or unfilled within the seven (7) business days required by law, you have a right to challenge the decision by the ***Name of Agency*** to deny access. At your option, you may either institute a proceeding in the Superior Court of New Jersey or file a complaint with the Government Records Council ("GRC") by completing the Denial of Access Complaint Form. You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also answer other questions about the law. All questions regarding complaints filed in Superior Court should be directed to the Court Clerk in your County.
12. Information provided on this form may be subject to disclosure under the Open Public Records Act.

APPENDIX E

OVERVIEW OF KEY WATER QUALITY PARAMETERS

Temperature - As per the State's surface water quality standards (N.J.A.C. 7:9B), the temperature of a FW2-NT waterbody shall not exceed a daily maximum of 31°C or a rolling seven-day average of the daily maximum of 28°C, unless due to natural ambient conditions. In shallow waterbodies such as these, water temperature is largely dictated by seasonal air temperature. However, water temperature from the surface to bottom of the water column may also be affected by several factors including clarity, water column circulation/mixing, and total depth. Most chemical and biological processes in aquatic ecosystems are driven by water temperature. Typically increases in the rates of these processes increases with an increase in water temperature.

Dissolved Oxygen - Dissolved oxygen (DO) is a very important parameter. The concentration of DO obviously affects the ability of a reservoir to support aquatic life. However, DO concentrations can also affect chemical processes; for example the liberation of phosphorus, minerals and metals into the water column from the reservoir's sediments. As per N.J.A.C. 7:9B, the DO of a FW2-NT waterbody shall have a twenty-four hour average not less than 5.0 mg/L, and not less than 4.0 mg/L at any time. DO concentrations are affected by the various biological, chemical, and physical processes and interactions. Physical factors affecting DO include water temperature, which effects solubility, and mechanical mixing at the surface through artificial aeration and/or natural wind and wave action. While photosynthesis by phytoplankton and submerged aquatic vegetation (SAV) increases DO concentrations, the biological respiration and the bacterial decomposition of organic material (including dead phytoplankton and SAV) exert a demand on available DO concentrations. DO concentrations greater than 4.0 mg/L are generally considered necessary to support most aquatic organisms, especially fish. As DO concentrations dip below 4 mg/L conditions become increasingly stressful for many aquatic organisms with documented increases in fish mortality occurring at DO concentrations between 2.0 mg/L to 4.0 mg/L. DO concentrations under 1.0 mg/L are considered reflective of an anoxic (or near anoxic) state. Anoxic conditions also cause changes in the redox state of the reservoirs' sediments, accelerating the rate of release of interstitial sedimentary phosphorus. This internal recycling of phosphorus from the sediments can stimulate algal growth if the phosphorus rich water is transported into the lite, epilimnetic portion of the water column.

pH - As per N.J.A.C. 7:9B, the pH of a FW2-NT waterbody shall be in the range of 6.5 – 8.5. The pH of water is an important water quality indicator since it is a major factor impacting most chemical and biological reactions. The pH is a measure of the concentration of free hydrogen ions and is expressed on a logarithmic scale from 1 to 14; that is each one unit change in pH represents a ten-fold increase or decrease in the hydrogen ion concentration. Changes in pH influence the chemistry of both water and sediments. Chemical parameters significantly affected by fluctuations in pH include phosphorus, ammonia, iron, and trace metals. A reservoir's pH can change dramatically both temporally and spatially due to stormwater runoff, precipitation, anthropogenic discharges, and groundwater inflow as well as photosynthetic activity. Higher rates of photosynthesis lead to increased pH levels, with more alkaline (> 9.0) pH values often indicative of an algae blooms and/or dense SAV growth.

Alkalinity- Alkalinity is a measurement of the buffering capacity of a waterbody or its ability to resist changes in pH. Specifically it is a measure of carbonates, bicarbonates, and hydroxides. Alkalinity values in surface waters should range between 20 to 200 mg/L, with optimal concentrations between 100 and 200 mg/L to protect against rapid pH swings. Alkalinity can also be used to gauge the approximate productivity of a fresh water system with higher values usually indicative of increased productivity.

Hardness- Hardness in water is caused by the ions of calcium and magnesium. Although ions of iron, manganese, strontium and aluminum also produce hardness, they are typically not present in significant quantities in natural waters. Water hardness is largely the result of geological formations of the waters source (groundwater, spring, runoff, etc.). The USEPA designates a drinking water secondary standard of 250 mg/L.

Secchi Disk Clarity - Secchi Depth is a standard measure of water clarity or visibility. The measurement equated to the depth at which a 9" diameter, alternating black /white disk, is no longer visible. This depth coincides approximately with the depth at which incident sunlight has decreased 90% relative to that measured at the surface. This is called the compensation depth, the point in the water column at which there is just enough light to support photosynthesis. Often, Secchi depth is used to quantify or characterize the trophic state of a waterbody. Waterbodies with less phytoplankton growth tend to be clearer than waterbodies that support a lot of algae growth.

Nitrate-N - 10 mg/L drinking water standard (primary).

Total Suspended Solids - Total suspended solids (TSS) is a measurement of the amount of particulate material in water. This particulate material may consist of fine soil particles, algae and zooplankton cells, and other organic or inorganic suspended material. The water quality standard for TSS as per N.J.A.C. 7:9B is 25 mg/L. In general, TSS concentrations greater than 25 mg/L will give a waterbody a murky or muddy appearance.

Total Phosphorus – The majority of freshwater lake in New Jersey are phosphorus limited. This means that as more phosphorus is added to the system, the more primary production (typically planktonic algae growth) can be expected to occur. Therefore, TP is considered a critical parameter in the assessment of the water quality and trophic state of most lakes. Studies have shown that TP concentrations as low as 0.03 mg/L can stimulate elevated rates of algal growth. As per N.J.A.C. 7:9B, the TP concentration shall not exceed 0.05 mg/L for any FW2-NT lake, pond or reservoir, or in a tributary at the point where it enters such bodies of water.

Lakes and reservoirs that stratify may also be subject to large-scale internal fluxes of phosphorus that can in themselves trigger large algae blooms upon turnover or mixing. Although the phosphorus present in the sediment will remain bound to iron under oxic conditions, under DO depleted, anoxic conditions the iron-phosphorus bond breaks down and sedimentary phosphorus is quickly released into the overlying waters. The recycling or upwelling of this phosphorus rich bottom water into the upper, photic zone of the water

column can trigger major algae blooms independent of the external introduction of phosphorus into the system.

Total phosphorus (TP) and dissolved organic phosphorus (DOP) make up the most primary forms of phosphorus in a waterbody. Measuring these species of phosphorus enables one to quantify how much of each form of phosphorus is present in the water column at any specific time. In summary, TP measures all phosphorus forms present in the water column, labile, particulate, and organic. TP is used by the NJDEP and USEPA, as well as most lake ecologists and limnologists, as the primary means of evaluating potential lake productivity. In general, the greater the amount of TP present in the water column, the greater the amount of algal biomass that can be supported by the lake. However, TP includes forms of phosphorus that are not available for uptake and utilization by algae, such as the phosphorus bound to suspended sediment or the phosphorus already incorporated in algae, plant and animal tissue. Therefore, although TP is used as the leading indicator of potential productivity, it is not always the best parameter to measure. DOP is a form of phosphorus that is available and can be easily assimilated by both planktonic and benthic algae. When elevated amounts of this form of phosphorus are measured, an algal bloom is likely to be experienced.

Soluble Reactive Phosphorus - While TP is used as the primary indicator of potential productivity, it is not always the easiest form of phosphorus to measure. Soluble Reactive Phosphorus (SRP) is a component of the total phosphorus. This form of phosphorus is assimilated by both planktonic and benthic algae but many blue-green algae are better adapted at utilizing SRP. As a result, SRP is not usually present in the water column in great amounts, and when elevated amounts of SRP are measured, an algal bloom is likely to be experienced. In low productivity lake systems (oligotrophic lakes), SRP is usually measured at concentrations less than 0.005 mg/L.

Chlorophyll *a* - Chlorophyll *a* is a pigment present in the cells of all algae. It is the organic compound that enables algae (as well as other plants) to photosynthesize. Thus, measuring the amount of chlorophyll *a* in the water is an excellent means of assessing algal biomass in the absence of a full phytoplankton analysis (Bellinger and Sigee, 2010). In general, chlorophyll *a* concentrations greater than 25 - 30 mg/m^3 are considered unfavorable and indicative of an algae bloom that negatively affects recreational use or aesthetics. At concentrations greater than the 30 mg/m^3 threshold, algal blooms and surface scums are usually obvious. The dense blooms associated with these high chlorophyll *a* concentrations can trigger a number of biochemical reactions that impact the waterbody's overall ecology that are often linked to the taste and odor problems.

ok
3/9/95

NATURAL RESOURCES INVENTORY of **BYRAM** TOWNSHIP

June 1994

Prepared by the Byram Township Environmental Commission.

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was funded by a $2,500 grant from the
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For other acknowledgements please see the 'Bibliography and Acknowledgements" at the end of each chapter.

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Folded, in plastic protector) LARGE MUNICIPAL KEY MAP, showing streets, street names, and property lines.

INTRODUCTION

PURPOSE

The purpose of this Natural Resources Inventory is twofold. Under the provisions of NJSA 40: 56A-1 et seq., this document describes Byram Township's natural resources. Under the provisions of NJSA 40: 55D-27, it makes recommendations to the Township's residents and officials about the use of those resources.

All development proposals have environmental implications. The Environmental Commission intends that this document be used to help protect Byram's environmental quality while allowing orderly development.

CONTENTS

The first five chapters of this document describe the Township. Chapter 1 gives a general description; Chapter 2 describes historical features; Chapters 3, 4, and 5, respectively, inventory Byram's geological, hydrological, and biological resources.

The last two chapters consider potential impacts on those natural resources and suggest means of mitigating adverse impacts. Chapter 6 presents a composite picture of all natural features, indicating which areas are most environmentally sensitive. Chapter 7 makes recommendations to achieve the ongoing goal of environmental protection.

COMMENTS FROM THE TOWNSHIP PLANNER

The Byram Township Environmental Commission has for many years been deeply concerned about the protection of the Township's natural resources. As Byram is a "Township of Lakes," the Commission has realized that two of the major elements which have drawn residents and businesses to the area have been its scenic value and the quality of the local natural features. These features include: forested hills, widely varied plant and wildlife populations, clean water and air, and large tracts of undeveloped land. These, in combination with wide, unobstructed viewscapes, make Byram Township a pleasant, safe and enjoyable place to live and work.

From the current review of the Natural Resources Inventory, the Environmental Commission has found that some natural elements, identified as critical in recent years, need to be isolated, mapped, and their importance and sensitivity to the effects of development emphasized. In the original Natural Resources Inventory prepared by the Environmental Commission (June 1976), physiography, lithology, historical geology, glacial geology, groundwater hydrogeology, mining, soils, septic suitability, lands subject to flooding, soils capability, and direction of surface water runoff were generally discussed and mapped.

Of particular concern is the health of the various lakes of the Township. Discussed in the original inventory, these important resources have, over the past 15 years, continued to be adversely affected by development and redevelopment of residential property.

The emphases of this up-date to the Natural Resources Inventory are a consideration of the importance of the relationship of geology/subsurface water supply to desirable development densities, wetlands and their role in natural systems, and the land use implications of uncontrolled surface drainage.

Eric Snyder, Township Planner since 1987

COMMENTS FROM THE COMMISSION CHAIRWOMAN

Byram's future will depend on how well the Township manages the dilemma of its location. Located on the border of Morris County and at the junction of Routes 80 and 206, Byram will be the target of ever greater growth, especially in the new sewer district. However, the Township's land and water supply are not suited to dense development.

Almost all of Byram's land is characterized by at least one, and often by several, critical natural limitations. More than two-thirds of the Township is marked by slopes greater than 15% (half of those areas are 25% or more) and by severely restricted septic soils and bedrock near the surface. Wetlands and high water tables are scattered throughout the Township, as are large areas of high groundwater recharge which are critical to maintaining water levels in Byram's lakes, streams, and wells.

One of the most important constraints is Byram's limited supply of drinking water. Unlike much of the rest of Sussex County, the Township has few extremely prolific aquifers.

These limitations mean that the Township must carefully direct and limit its growth or confront the difficult and costly problems that come from growing too rapidly and from overburdening natural resources.

The search for good ratables can very quickly be undone by the costs of excessive development. Commercial-industrial ratables are estimated by some planners to pay at best $1.00 for every 85 cents of municipal services they require. Some of those ratables are less beneficial, depending on what they are and where they are located; and most commercial-industrial growth attracts residential growth, which may cancel any tax‘benefit. Many studies suggest that more development, of any kind, means more taxes.

On the other hand, many studies show that open space is often the best ratable. Although it pays little or no taxes, open space requires minimal services. It also provides invaluable natural engineering, to filter the air, buffer wind and weather, control erosion and flooding, resupply lakes,

streams and wells with water, provide habitat and recreation, and boost the value of nearby developed areas. When that natural engineering is overburdened and must be replaced by costly man-made projects, taxes often escalate.

The Environmental Commission hopes that this update of the Natural Resources Inventory will help the Township continue to map and protect its critical natural features.

The Commission is recommending a system of greenways to set aside features that should never be disturbed--steep slopes, ridgelines, buffers around lakes and streams, large forested tracts, wetlands, critical aquifers and groundwater recharge areas, important habitats, recreational trails. The Commission is also recommending that densities in developable areas be based on natural features, with special emphasis on water supply and safe septic operation. In the sewer district, the speed and density of development should be carefully controlled to insure that Byram's water supply remains adequate and that the Township is not overtaken by other problems resulting from excessive development.

If Byram continues to map and protect these resources, it can meet the best goals of the three regional planning studies that include Byram (the Highlands and Skylands studies and the State Development and Redevelopment Plan) and of the New Jersey Municipal Land Use Law:

*protecting the quality -and quantity of water supplies;
*protecting natural beauty and environmental quality;
*planning for reasonable densities;
*promoting the health, safety and welfare of the community.

Margaret Dull McGarrity, Chairwoman
Byram Township Environmental Commission

Chapter 1

A GENERAL DESCRIPTION OF BYRAM

(Refer to the following maps in the Appendix of this document-- Current Zoning, Topography, and the large folded Key Map, which gives a detailed description of lakes, streams, roads, and property lines.)

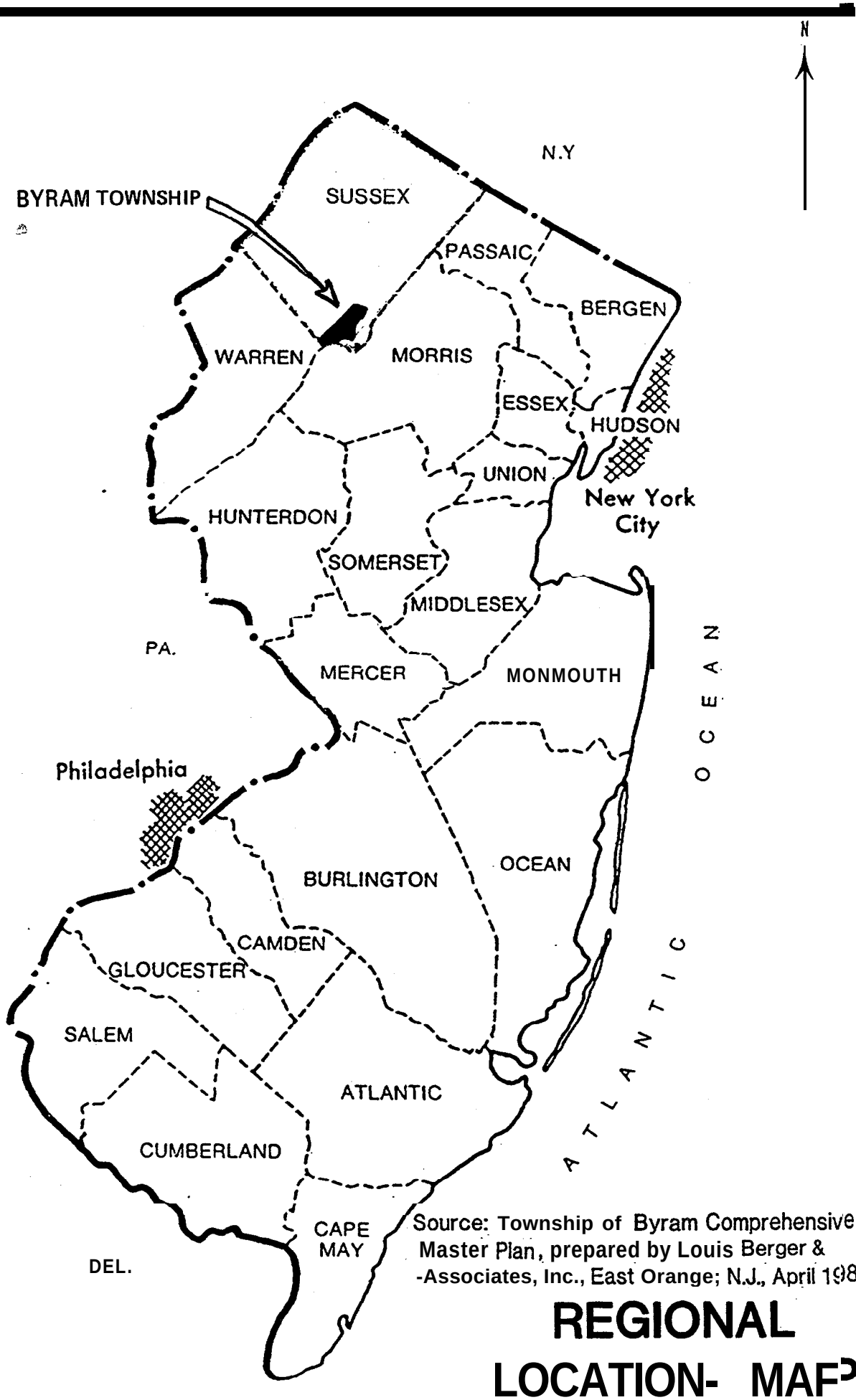
LOCATION AND SETTING

Byram Township is located in the southeast corner of Sussex County within the New Jersey Highlands region. It lies at latitude 40 degrees 75 minutes north and longitude 74 degrees 42 minutes west, and its altitude ranges from 640 to 1,220 feet.

Byram is about 50 miles west of New York City and is traversed by two major roadways, Interstate 80, which cuts across the Township's south-western border, and state Route 206, which bisects the Township in a north-south direction. Along with **Stanhope** and Hopatcong, **Byram** is called "The Gateway to Sussex County."

It is also "The Township of Lakes," having more than two dozen lakes and ponds, most of the large ones heavily settled. The Township is drained by three major rivers: Lake Mohawk is the headwater of the Wallkill; the Pequest drains a small north-central area, including Forest and Panther lakes; the Musconetcong drains about 90% of the Township and, with its tributary Lubbers Run, forms the Township's southern border.

Byram covers 22.48 square miles or about 13,000 acres. This figure is from the Sussex County Planning Department; various other sources give figures ranging from 20.6 to 22.85 square miles. Approximately **1/5** of the township (2,600 acres) at the southwestern end is owned by the state Green Acres program as part of Allamuchy Mountain State Park. Another 6,472 privately owned acres, mostly forested, remain undeveloped.



Source: Township of Byram Comprehensive Master Plan, prepared by Louis Berger & -Associates, Inc., East Orange; N.J., April 1989

REGIONAL LOCATION- MAP

CLIMATE

Byram's climate is typical of Sussex County, as described in Table I.

TABLE I: BYRAM'S CLIMATE

Record high and low temperatures: -26 degrees F and IO4 degrees F
Average January Temperature: 23.1 degrees F
Average low temperature in January: 12.7 degrees F
Average July temperature: 70.8 degrees F
Average high temperature in July: 83.3 degrees F
Average annual snowfall: 36.8 inches
Average precipitation (rain plus snow converted to rain on a 10:1 ratio): 46 inches
Most precipitation: July and August Least: February
Average growing 'season: 154 days
Last and first killing frosts: late May and early October
Pipe depth to prevent frost damage: 30"

POPULATION

Most of Byram's population is clustered around Cranberry, Forest, Johnson, Mohawk, and Panther lakes, as well as in the East and West Brookwood neighborhoods and in the Tamarack Road area just off Route 206. In 1986 the Township had 2,941 housing units (estimated by the Sussex County Planning Department); in 1990, it had 2,973 (U.S. Bureau of the Census). About 60% of the Township's population is located within two miles of Route 206.

TABLE II: POPULATION CLUSTERS

Area	*Approx. percentage of housing units*	*Approx. units and acres*
East Brookwood	6%	*177 units/l34 acres*
West Brookwood	15%	*450 units/244 acres*
Cranberry Lake	17%	*520 units/l82 acres*
Forest and Panther Lakes	14%	*430 units/279 acres*
Lake Lackawanna	*11%*	*336 units/l59 acres*
Tamarack Road and Johnson Lake	7%	*217 units in scattered sub-areas*
Mohawk and Tomahawk lakes, Lee Hill	23%	*680 units in three major clusters*

For the past four decades, **Byram** has been one of the fastest growing municipalities in Sussex County, often more than doubling its population each decade as the following table shows. **Byram's** 1989 Master Plan projects a population of between 10,232 and 10,571 in 1995.

TABLE III: POPULATION GROWTH

	BYRAM *TOWNSHIP*		*SUSSEX COUNTY*	
Year	***Population***	*% Change*	***Population***	*% Change*
1940	*373*	--	*29,632*	--
1950	*761*	*104.0*	*34,423*	*16.2*
I960	*1,616*	*112.4*	*49,255*	*43.1*
I970	*4,592*	*184.2*	*77,528*	*57.4*
I980	*7, so2*	*63.4*	*172,916*	*49.8*
1990	***8,048****	*7.3*	*196,921*	*13.9*

**about 393 persons per square mile*

ECONOMIC CHARACTERISTICS

Byram is described as a 'suburban-rural community'--a rapidly developing municipality near an urban center. Most of **Byram's** workers commute, especially to Morris County and eastward to New York City. (About 60% of Sussex County's workers commute, 25% going to Morris County.) Several Township residents work at the International Trade Center, just south of the Route 80-206 interchange in Mt. Olive.

In 1980, 87.4% of **Byram's** men worked and 53.1% of its women. In 1985, **Byram's** per capita income was $13,587 (compared to $12,819 for all of Sussex County), putting **Byram** in 6th place among the county's 24 **mu**nicipalities.In 1990, 24.1% of **Byram's** residents had graduated college.

COMMERCIAL AND INDUSTRIAL DEVELOPMENT

Byram has minimal commercial-industrial development. About 69 acres, almost entirely along Route 206, contain small commercial establishments typical of such a corridor. **Byram** Plaza, a larger shopping center with plans for a **ShopRite** supermarket, a fast-food concession, and other smaller stores, had been proposed since the early 1980s at the corner of Route 206 and Lackawanna Drive, but wastewater and other

planning problems had stalled the project. In the mid-1990s, the project was restarted after obtaining a share of the 60,000-100,000 daily gallonage Byram was granted by the Musconetcong Sewerage Authority in Mt. Olive.

Byram's few industries occupy about 56 acres and include a salvage yard and a quarry on Route 206, a second salvage yard on Lackawanna Drive east of the lake community, and an explosives factory in the middle of the Township on Old Indian Spring Road. Several other large tracts along Route 206 are zoned for industrial development.

WASTEWATER MANAGEMENT

Until the mid-1990s, all of Byram was served by individual septic systems, except for the Intermediate School which had a package treatment plant discharging into Lubbers Run.

In early 1993, the Township was granted 60,000 gallons per day in sewer allotment from the Musconetcong Sewer Authority in Mt. Olive, with another 40,000 gallons promised for late1996 or early1997, once the plant was expanded and re-rated.

By 1995, a sewer line was expected to be in use from a pumping station near the corner of Route 206 and Acorn Street, north along Route 206, east along Lackawanna Drive, and south along Mansfield Drive. The initial 60,000 gallons was expected to serve businesses on Route 206, the proposed shopping plaza at the corner of Lackawanna and 206, the Elementary and Consolidated schools, and the municipal building. It was to replace the Consolidated School's package plant, which was at least 15 years old, and the proposed package groundwater-injection plant at the shopping plaza.

WATER SUPPLY

Most of Byram's residences are supplied by 11 water companies, the smallest serving 16 and the largest about 400 Byram homes. Many other homes, all businesses, the schools and the municipal complex have individual wells. Detailed information about the water companies is given in Chapter 5. Please refer to the index.

GOVERNMENT AND SERVICES

In 1985, Byram changed its form of government to the Council-Manager Plan, as allowed under the state's Optional Municipal Charter Law (the Faulkner Act). The mayor and four council-members are chosen at large, in non-partisan elections occurring in May. They serve four-year staggered terms. Under the Faulkner Act, this form of government gives voters the powers of recall, initiative and referendum.

Byram is in the state's 24th Legislative District and is represented in Trenton by one state senator and two assemblymen, elected for four- and two-year terms respectively. It is in the 1 lth Congressional District.

The Township does not have its own post office. Mail is delivered through the Andover, Netcong, Stanhope; and Sparta offices.

Household garbage is collected by a private firm, which also picks up various recyclables. Residents may also deliver their recyclables to the township's own recycling center, at the municipal complex.

Emergency services are provided by the volunteer Lakeland Emergency Squad and by two Cranberry Lake Volunteer Fire Department stations, located near Cranberry and Lake Lackawanna.

The Police Department is located at the municipal complex on Mansfield Drive and consists of one chief, two sergeants, one detective, nine patrolmen, nine Class I special police, and four Class II special police.

Telephone service is provided by New Jersey Bell and United Telephone; electricity, by Jersey Central Power and Light.

SCHOOLS

A Type II district, Byram has two schools for K-8 grades and sends its high school students to Lenape Valley Regional High School in Stanhope. As of September 1990, the number of Byram students totalled 1,039. The Board of Education is elected, and the budget is subject to voter approval.

SUSSEX COUNTY 208 WATER QUALITY MANAGEMENT PLAN

The county's 208 program was established by the freeholders in 1976, under the federal Clean Water Act of 1972. The 208 committee advises the freeholders and makes recommendations to protect water quality in the county.

Byram participates in the 208 program by sending a representative to the county Water Quality Management Plan Policy Advisory Committee and by incorporating some suggested 208 land use policies and regulations in its master plan.

NEW JERSEY DEVELOPMENT AND REDEVELOPMENT PLAN

The State Planning Act of 1985 called for a state plan to address the following goals:

- -provide beneficial economic growth, development and renewal
- -provide adequate public services at reasonable costs
- -protect natural resources (including farmland)
- -revitalize urban areas
- -provide housing at reasonable costs
- -preserve and enhance historic, cultural, recreational lands and structures and open space
- -ensure sound and integrated planning statewide

The Plan directs the various state government offices to apportion infrastructure money and to grant permits according to the Plan's objectives. It calls upon local planners to think regionally and to help prevent expensive sprawl development and protect the state's dwindling resources. Byram recognizes some of the Plan's goals in its municipal master plan.

Various drafts of the Development and Redevelopment Plan were proposed, in discussion with county and municipal governments. A final Plan was adopted in June1992. Like most of the rest of Sussex County, Byram was placed in Planning Area 4 (rural planning) and Planning Area 5 (environmentally sensitive). These areas call for little or no growth and very low densities.

Sussex County officials and many municipal officials, including some in

Byram, do not agree with these designations and have been reluctant to make changes in local planning decisions to follow the plan's objectives. Their opposition centers on fears that the county will not receive adequate infrastructure funding and will not be able to attract desirable ratables.

4

The Township is also included in two other regional planning areas, the federal Highlands study and the New Jersey Skylands study, which propose similar environmental protections and resource-based planning.

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Climate information is from the National Oceanic and Atmospheric Administration, available through the Department of Meteorology, Cook College, Rutgers University, 908-932-9551.

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Optional Municipal Charter Law (Faulkner Act) As Amended, January 1987.

NOTE: for information about New Jersey state environmental regulations and state regulatory offices, as well as about the powers and duties of municipal agencies, please see The Environmental Manual for Municipal Officials, prepared by the Association of New Jersey Environmental Commissions, Mendham, and the New Jersey Department of Environmental Protection, fall 1992.

Chapter 2

A HISTORY OF BYRAM

(Refer to the Historical Map in the Appendix of this document. In the text, sites are identified by their numbers on this map.)

Accounts of Byram's history vary. I used the most available information, including the chapter in the 1976 Natural Resources Inventory, to rewrite this short history. I then sent it for review to Kevin Wright, Curator of the Steuben House in River Edge, N.J., a well-known Sussex County historian whose ancestors lived in Byram. Where Mr. Wright's research varies significantly from the usual accounts (this is especially true of the history of Waterloo village), I have usually depended on his work and have indicated this by placing an asterisk at the end of the passage.

For greater historical detail, see the references in the bibliography and Mr. Wright's notes in the Environmental Commission files at the Municipal Building.

Margaret McGarrity, Chairwoman, Environmental Commission

NATIVE AMERICAN INHABITANTS

The ancestors of the **Lenape** Indians were the first inhabitants of this area, arriving in post-glacial times, perhaps as long as 11,500 years ago

Lenape is generally used to refer to Indian groups who lived in and around what is now New Jersey and is most often translated as "male," "our men" or "the ordinary people." The **Lenape** are generally divided into Unami-speakers, who lived in the more southern parts of the New Jersey area, and Munsee-speakers (both are Algonquian dialects) who lived in the northern parts of New Jersey above the Raritan River and the Delaware Water Gap. 'Munsee' or 'Minsi' may be a corruption of the earlier 'Minisink' or 'Minising' and is usually translated as "people of the stony country."

These Indians have also been called the Delaware, the name given the river by the early 17th century English after Lord De la Warre, governor of the Virginia colony. They are also referred to as the Lenni **Lenape,** an

unnecessary duplication of terms (reiterating the first syllable), translating as "the common, ordinary people."

By the early 1700s few Indians were left in this area and, following some hostilities during the French and Indian War (1754-63), most of the remaining Indians in New Jersey moved west under the terms of the Treaty of Easton (1758).

Many accounts name two Indian sites in Byram, one about a mile south of Johnson Lake on Old Indian Spring Road (#42 on the Historical Map) and a larger one just southwest of Frenche's Pond, near the current Boy Scout camp (#41), but whether these were actually villages is in question.* The Frenche's Pond site was apparently used from about 100-1,500 A.D., and many arrow points have been found there. There are also said to be Indian burial grounds near Lake Lackawanna and Waterloo, although the latter is probably 18th century European'and was probably Byram's burial ground before the Lockwood Cemetery came into use.*

Wolf Den, a large cliff, boulder, and cave formation northwest of Cranberry Lake (#43) is generally thought not to have been an occupied Indian site, although it may have been used as a shelter.

ESTABLISHMENT OF BYRAM TOWNSHIP

Sussex County was first explored by the Dutch in the17th century; but by 1753, when the county was officially formed, there were only about 600 inhabitants.

Byram Township was established on February 5, 1798, having been separated from the vast area that was then Newton. The name honored the Byram family, surveyors who had settled in the area before the. Revolution. In 1798, the head of the family was Jephthah Byram, who is buried in Sparta cemetery. The Byram family homestead (#44 on the Historical Map) was located on Lackawanna Drive near Lubbers Run, now the location of the entrance to Columbia Valley Campgrounds. A brick chimney, restored by campground owner and former township mayor Carl 0. Johnson, still marks the spot.

Between 1798 and 1957, Byram's borders changed six times, including

the secession of Hopatcong in 1898 and Stanhope in 1904.

The earliest non-Indian settlements in Byram centered on iron mines and forges, particularly in the areas of town known as Roseville (#23), Columbia (#2 1), Lockwood (#22), Waterloo (originally called Andover Forge)(#33), and Brooklyn (now Hopatcong). Most of these sites are said to have been operating before the Revolution, and many continued well into the 19th century.

IRON WORKS AND MINES

Most mines were open pit excavations, although some tunneling did occur. In Byram, two types of ore were removed--magnetite, a strongly magnetic, black iron oxide; and hematite, a non-magnetic, reddish-brown to black ferric oxide. *See pages 17-24 for detailed maps of the current Status of the Allis. Cascade. Charlotte. Frenche's. Gaffnev. McKean. Roseville. and Silver mines.*

Besides Waterloo, which is discussed later, the other iron mining or manufacturing centers include:

Columbia Forge or Anchor Factory (#21 on the Historical Map), situated on Lubbers Run, near the original Byram homestead, about one mile northeast of Lake Lackawanna. The dam is still visible just north of the road. Built about 1800, in 1856, this factory made 40 tons of anchors.

Lockwood Forge or Bloomery(#22) which also made anchors, located on Lubbers Run, where it crosses Route 206, just north of the Waterloo Road intersection. Just north of the furnace site on the east side of Route 206 is the early 19th century Lockwood Cemetery (#36), which was originally part of the Lockwood Methodist Episcopal Church, built in 1835. Some of the congregation relocated to Waterloo in 1859 (#12). North of the cemetery, on the west side of Route 206 at its intersection with Lackawanna Road was located the McKain Hotel or Lockwood Tavern (#47)(now Barone's Restaurant). The tavern was built about 1807, on the state's first chartered turnpike, the Morris Turnpike*(sometimes called the Morris and Sussex Turnpike). The turnpike was chartered on March 9,1801, and ran from Elizabeth through Morristown and Newton and along what is now Route 206 to the Delaware River at Milford, Pa. (#51).

Roseville Bloomery (near #21), on Lubber's Run one mile south of the Columbia Bloomery. Built in 1828, in 1856 it produced 64 tons of

blooms (usually square bars of iron made by hammering).

New Andover Bloomery (#34), situated on the Musconetcong River 1.5 miles east of Waterloo near the river's confluence with Lubbers Run. It was built about 1804 by Lemuel DeCamp; sold to John Smith in 1816; and rebuilt in1857. The name of this hamlet later was changed to Old Andover, after the name of the original Andover Forge was changed to Waterloo in 1839. The bridge across the Musconetcong at this location was the first bridge built by the Sussex County Freeholders, indicating that this was the main road in earlier times. Several foundations, including that of the bloomery and an inn, can still be found here. In the 1830s, when New Andover, Columbia and Lockwood were the main centers of Byram, this hamlet contained a store, a saw mill and six to eight dwellings.

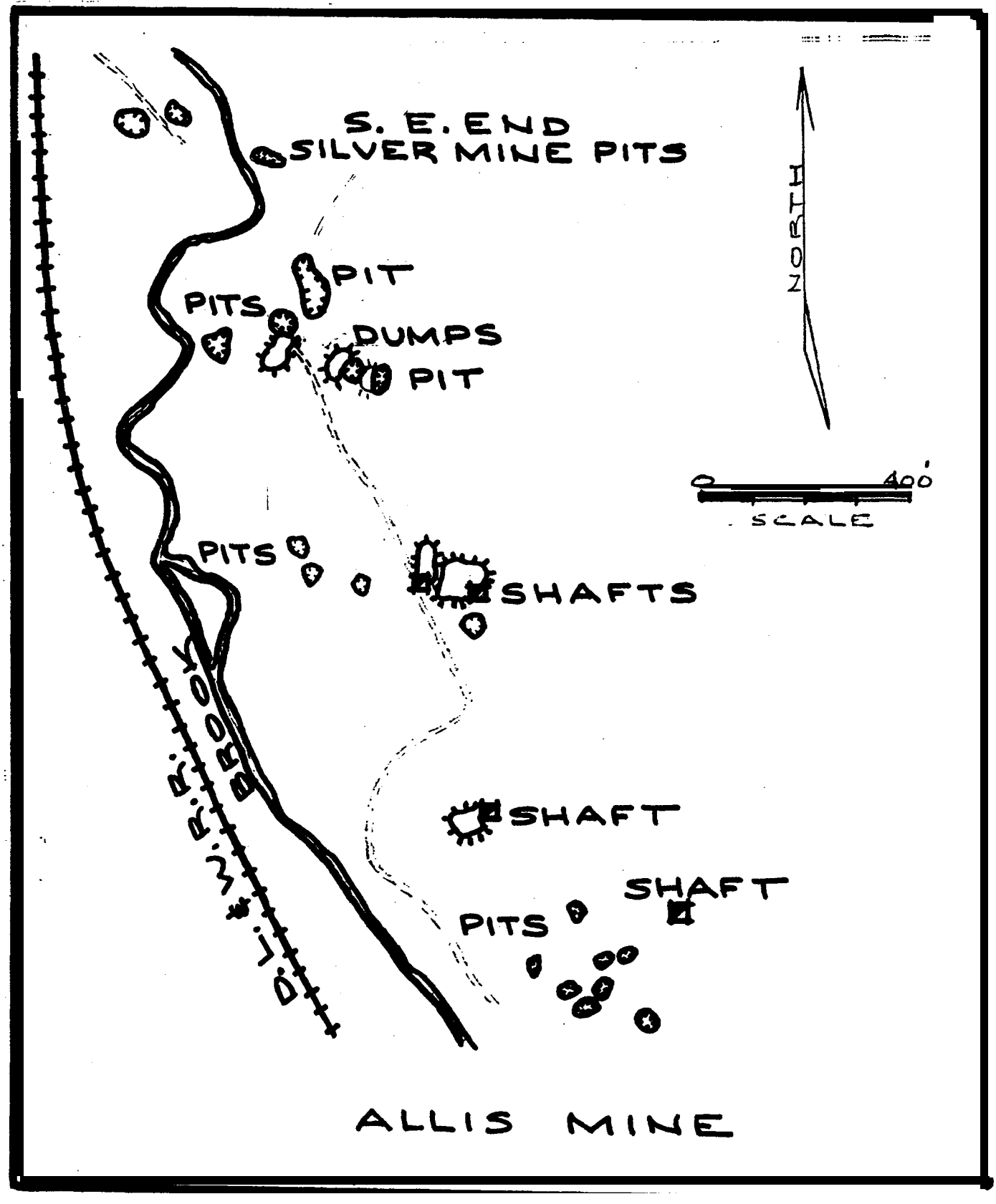
Roseville Mine (#23), in the eastern corner of the intersection of Roseville and Amity roads. Still visible are a large open cut about 700 feet long and various pits. It was first worked about 1850-1870 and briefly in1880. Total production was about 70,000 tons of magnetite. There are conflicting reports about whether a forge was also located here, near the old foundations of what were miners' houses, just across Amity Road from the works. The Trenton Iron Company and, after 1868, the Andover Iron Company operated this site.

Gaffney Mine (#24), about 400 feet east of Lee Hill Road near the Jersey Central Power & Light right-of-way. Still visible are four fair-sized pits, some probably collapsed shafts, and two small dumps. The original openings are old but later openings date from 1874-1876. It was worked briefly in 1880. Some workings, known as the Lawrence Farm explorations, are also said to be southwest of the Gaffney Mine.

McKain Mine (or McKean or McCain--or Bird?)(#25), located south of Tamarack Road opposite the south end of Johnson Lake. Now there are some small pits, shafts and dumps. This mine was first opened in 1873 with a 40-foot shaft and operated intermittently until 1880, with later shafts of 90 feet. Total yield was about 4,000 tons of magnetite.

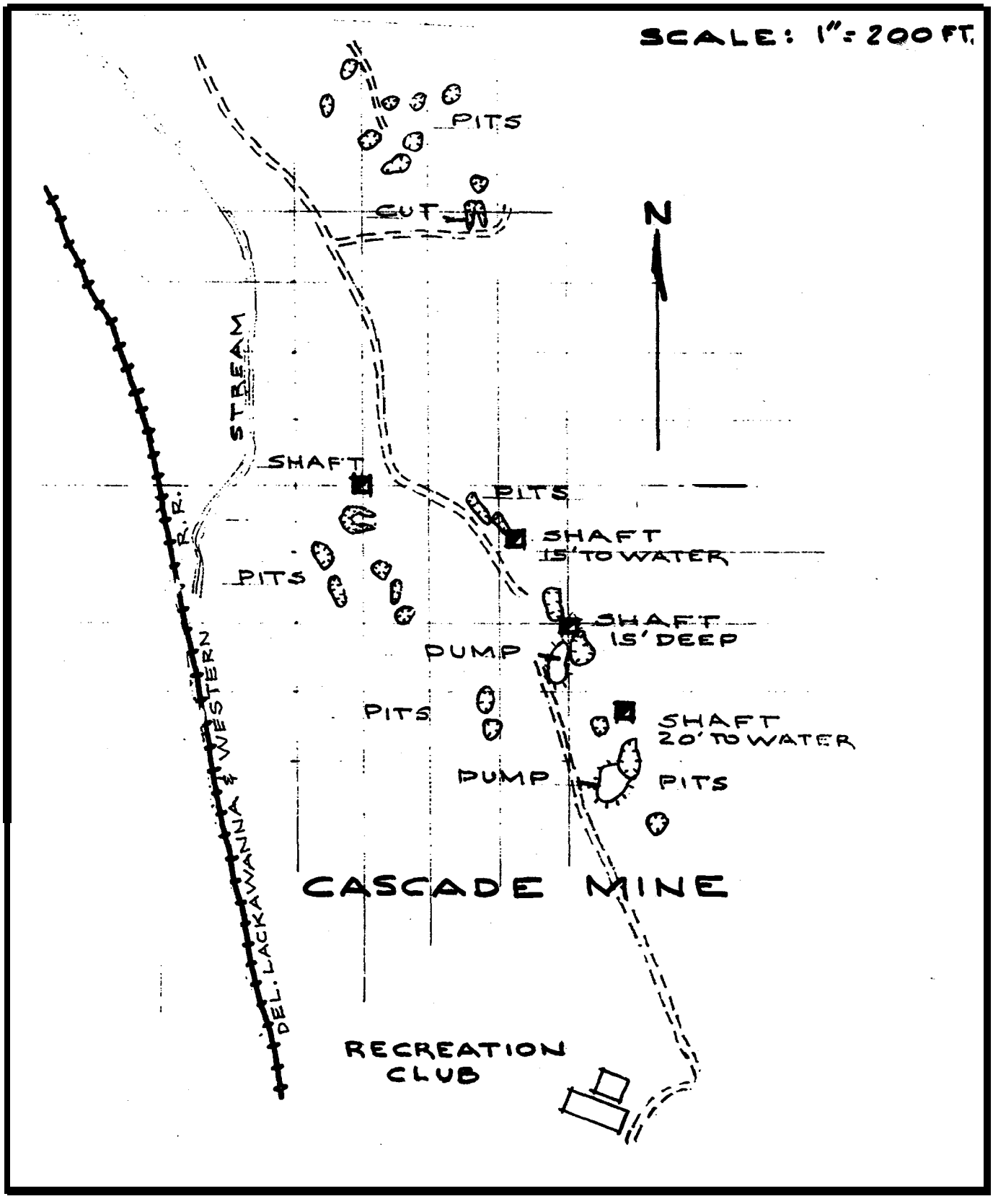
Cascade or Smith Mine (#26), about 1/4 mile north of Jefferson Lake on the east side of the abandoned Delaware Lackawanna & Western Railroad. The shafts and pits of what was probably a substantial operation filled with water in 1978 and are unprotected. The mine was worked about 1850 and reopened in 1869-1877 and briefly in 1883.

Silver Mine (#27), on both sides of the abandoned Delaware Lackawanna & Western Railroad several thousand feet south of Cranberry Lake where Dragon Brook crosses the railroad bed. Still visible are several small pits. The workings were probably exploratory only and sought iron



ALLIS MINE

BYRAM TOWNSHIP
SUSSEX COUNTY
MINE SAFETY SECTION
N.J. DEPT. OF LABOR & INDUSTRY



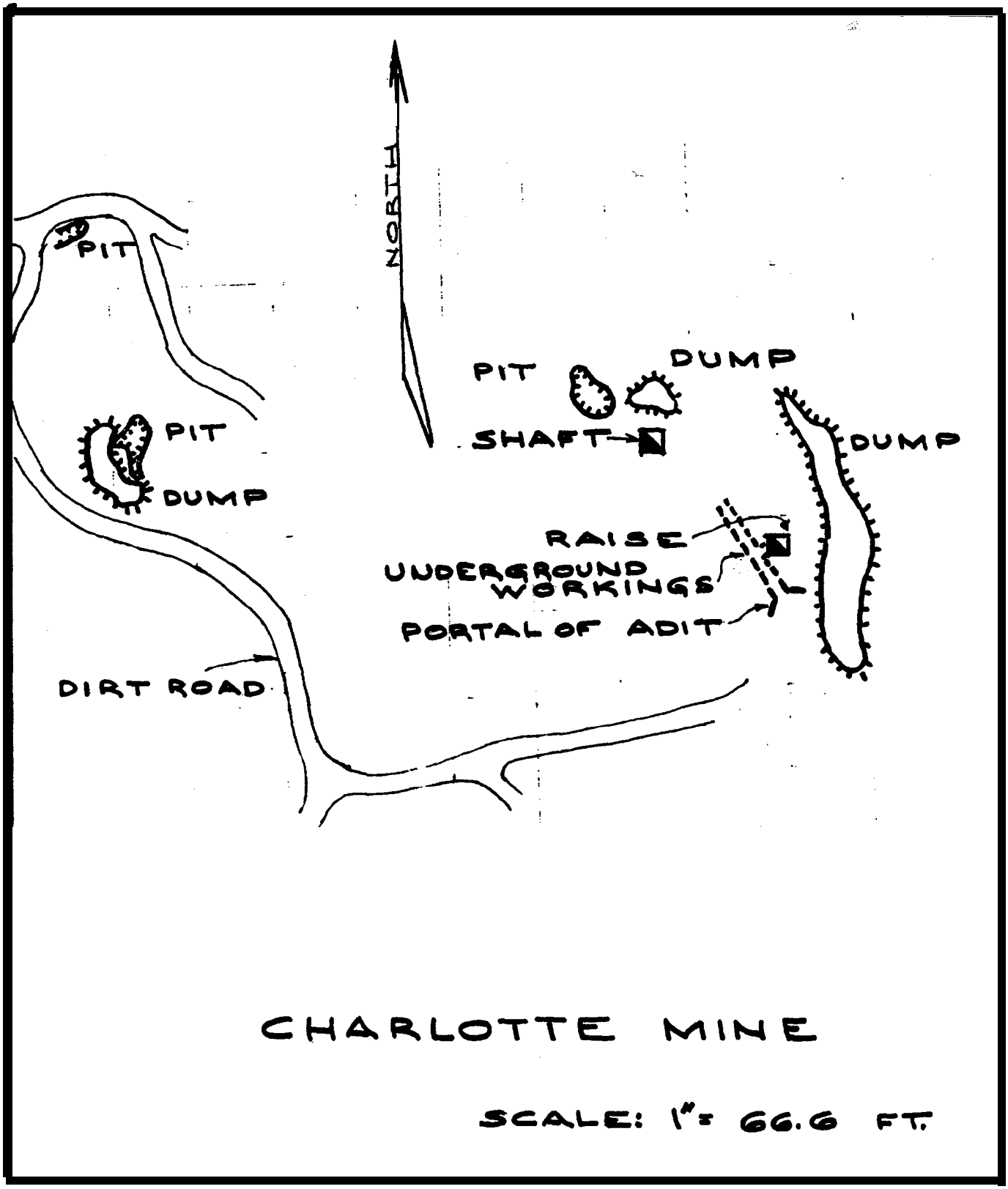
CASCADE MINE

BYRAM TOWNSHIP

SUSSEX COUNTY

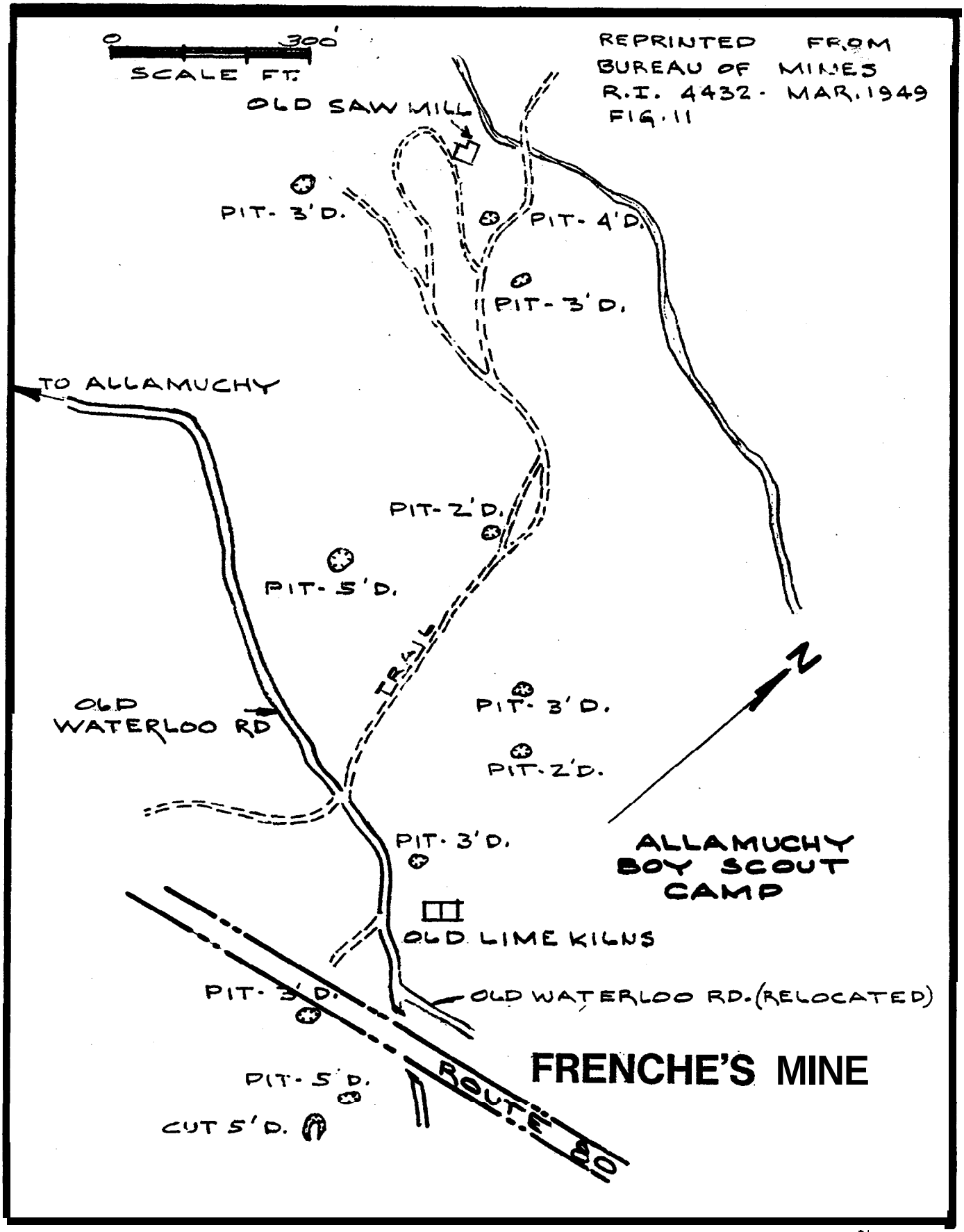
MINE SAFETY SECTION

N.J. DEPT. OF LABOR **&** INDUSTRY



CHARLOTTE MINE

BYRAM TOWNSHIP
SUSSEXCOUNTY
MINE SAFETY SECTION
N.J. DEPT. OF LABOR & INDUSTRY



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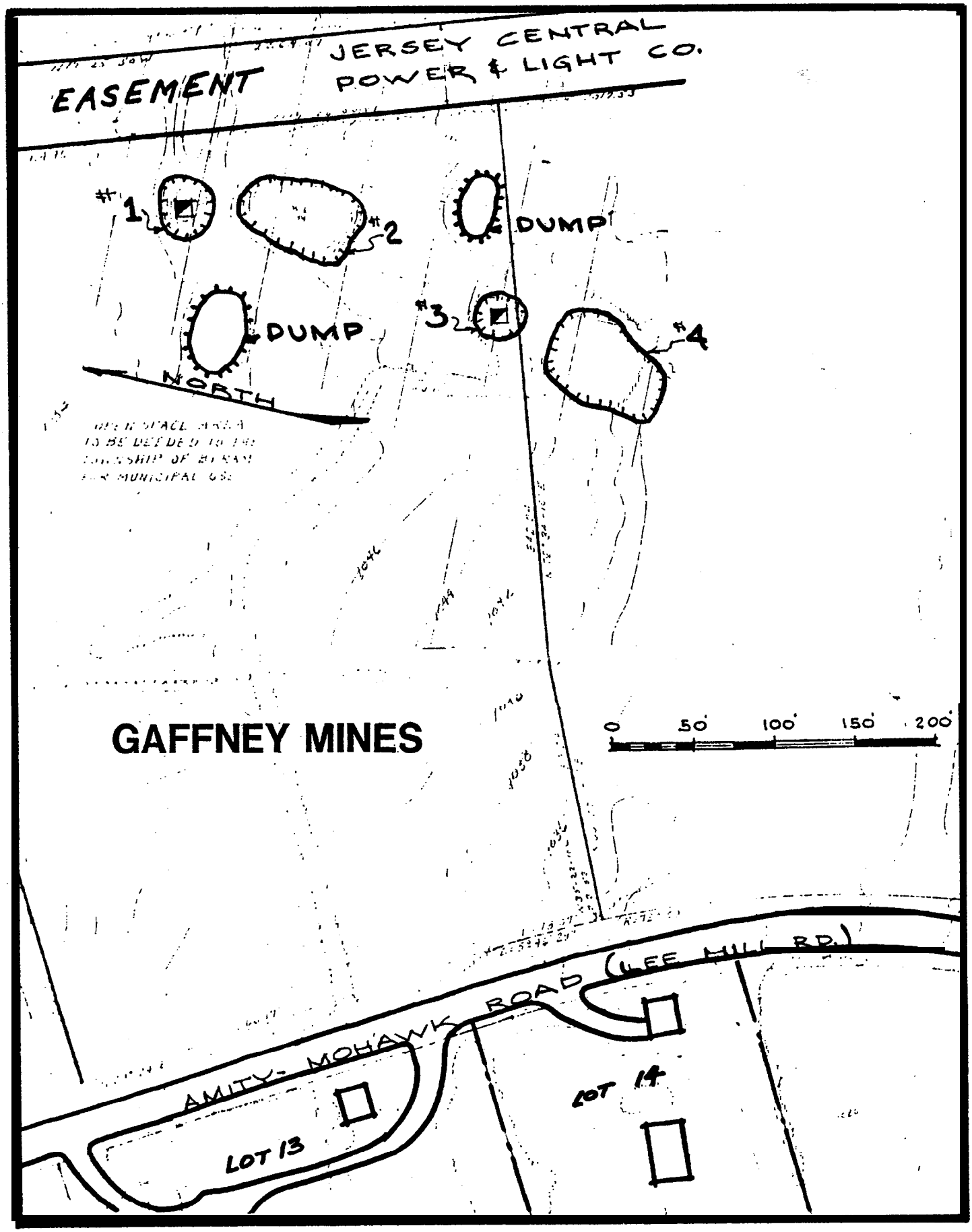
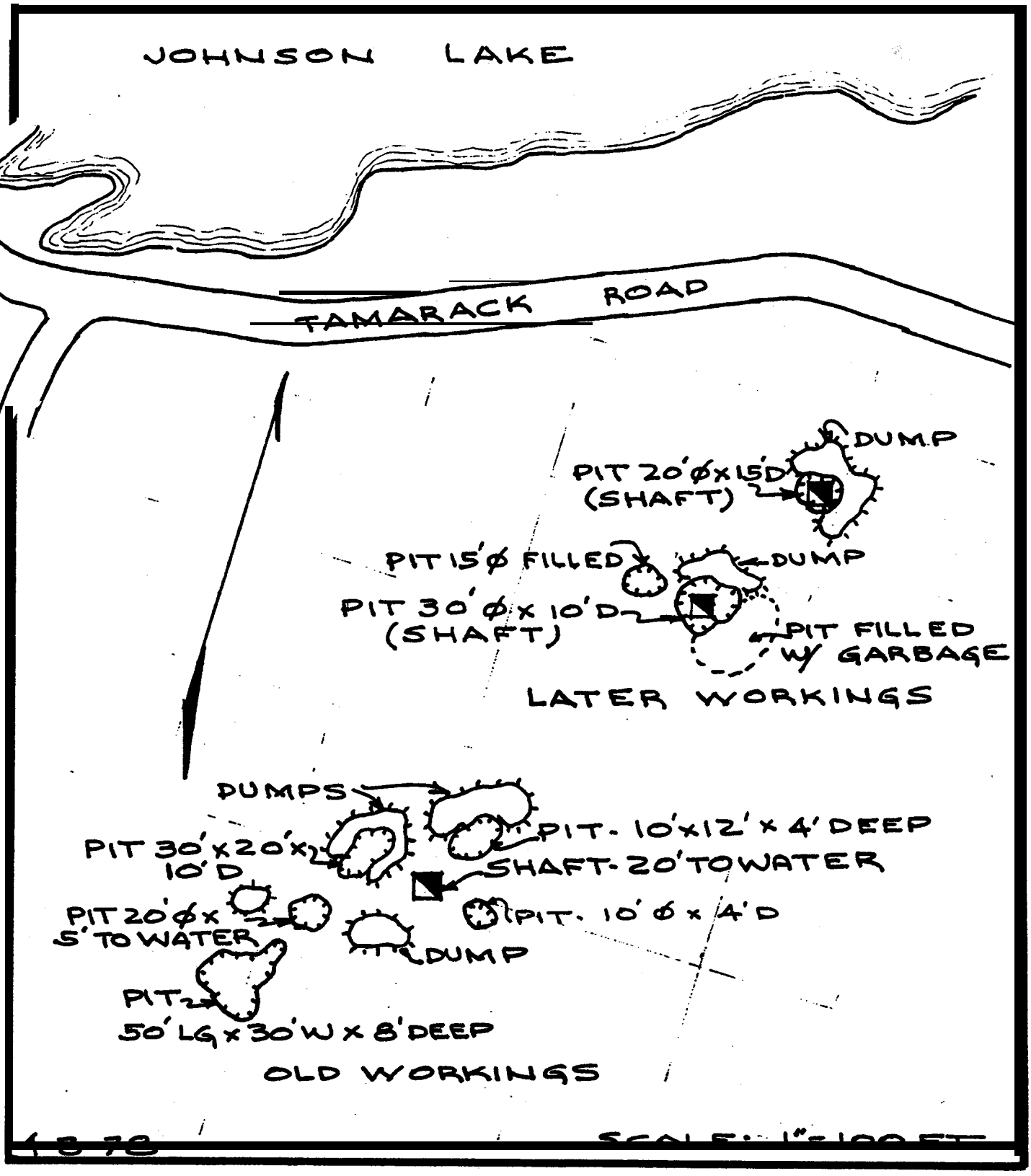
SUSSEX COUNTY
MINE SAFETY SECTION
N.J. DEPT. OF LABOR & INDUSTRY

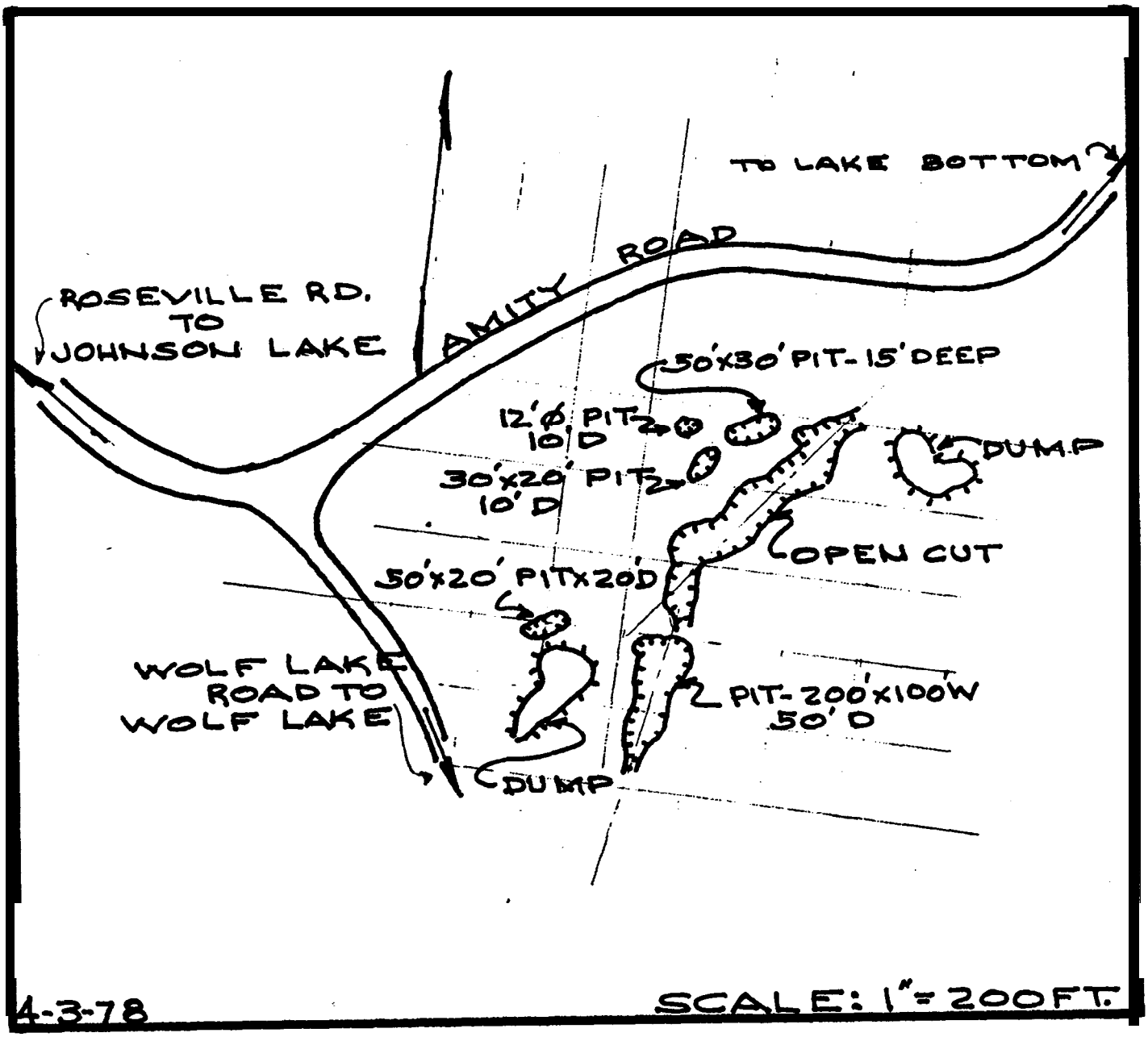


BYRAM TOWNSHIP
SUSSEX COUNTY
MINE SAFETY SECTION
N.J. DEPT. OF LABOR & INDUSTRY



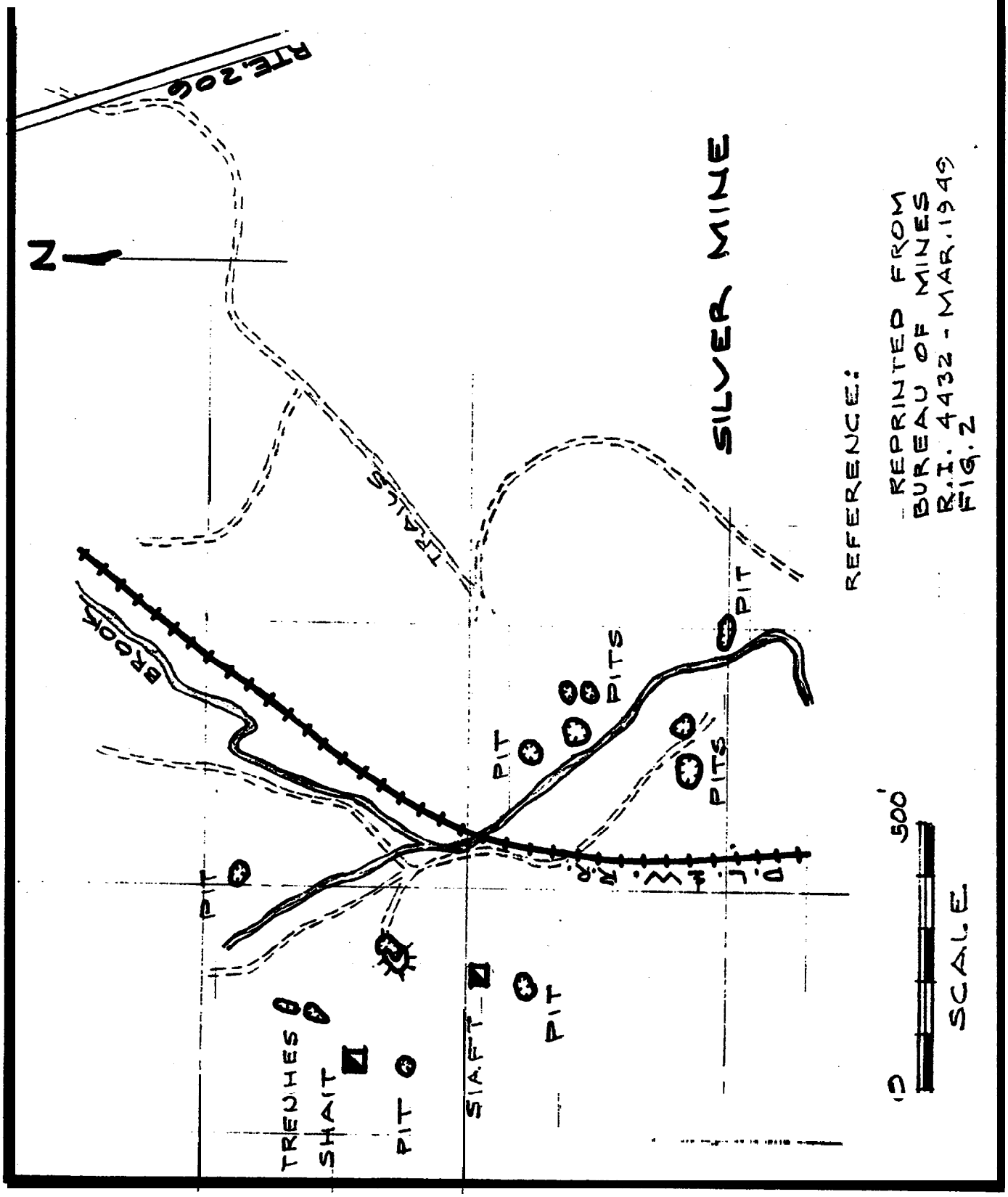
MC" KEAN MINES

BYRAM TOWNSHIP
SUSSEX COUNTY
MINE SAFETY SECTION
NJ. DEPT. OF LABOR & INDUSTRY



ROSEVILLE MINE

BYRAM TOWNSHIP
SUSSEX COUNTY
MINE SAFETY SECTION
N.J. DEPT. OF LABOR & INDUSTRY



SILVER MINE

BYRAM TOWNSHIP
SUSSEX COUNTY
MINE SAFETY SECTION
N.J. DEPT. OF LABOR & INDUSTRY

(magnetite) not silver.

Frenche's Mine (#28), on the west side of Frenche's Pond, where some small pits remain. About 1,000 tons were mined before 1873, when it was abandoned.

Bedell Mine (#29), said to be 1/4 mile south of the Gaffney Mine, although the state has found no evidence of mining here despite reports of workings in the 1890s. All traces of work may have been obliterated by the Jersey Central Power and Light right-of-way.

Allis Mine or Exnlorations (#30), north of Cascade Mine on the east side of the old railroad bed. Unknown quantities of ore were mined before 1873, and the operations were abandoned shortly thereafter.

Bverlv Openings (#31), reportedly on the west slope of a high ridge southwest of the Roseville Mine, although the state has not found evidence of mining activity. It may have been worked about 1873.

Many of these mines supplied ore via the Morris Canal to the Lehigh Valley anthracite furnaces in Pennsylvania.

A uranium mine is also located south of Cranberry Lake on the west side of the railroad bed near where Dragon Brook crosses under the high concrete bridge. Known as the Charlotte Mine (#32) or sometimes the Bemco Prospect, there are several cuts and shafts, which are now fenced by the state, since the area lies within the Allamuchy Mountain State Park. About 95 tons were removed during the middle of this century.
A summary of the state study of this site follows on page 26.

Other mines which were once in Byram but are not within the Township's current boundaries include:

Lawless or Lawson Mine, at the west end of Byram Cove on Lake Hopatcong.

Haggerty Mine, now in Stanhope near the border of the roads to Roseville and Lake Hopatcong.

Stanhope or Hude or Wright Mine, on the south side of a ridge about one mile northwest of Stanhope on Route 206.

WATERLOO (#33)

This iron works was established in 1759* by the Philadelphia firm of Allen and Turner, which owned the Andover Furnace at Andover Borough

THE STATUS OF THE CHARLOTTE URANIUM MINE

In 1980, a member of Byram's Planning Board told the N.J. Department of Environmental Protection about possible safety and radiological hazards at the Charlotte Mine just south of Cranberry Lake (see the Historical Map). In 1981, officials from the Division of Parks and Forestry and the Bureau of Radiation Protection visited the site and produced a report (the report is in the Byram Environmental Commission files under "Charlotte Uranium Mine").

Summary of the June 1981 N.J.D.E.P. Bureau of Radiation Protection Report:

1. Site description (January 1981). The main mine entrance is a 6-foot-wide by lo-foot-high adit (a nearly horizontal passage) driven 25 feet into the hillside in a north-northwesterly direction; 2/3 of the way in, a S-foot diameter vertical shaft goes to the surface about 25 feet above. Ninety feet north-northwest of the vertical shaft is a second vertical shaft, 5 feet in diameter and 25 feet deep, not leading to the main adit. Fifty feet west of the main adit is a 6-foot wide by IO-foot high adit driven 30 feet into the hillside. Scattered around the area are several small horizontal open cuts, 10 feet deep or less. Four trails come to the site, although there is no access from a main road. Two small foundations, remnants of an ore flume (slide) from the main tunnel, rusted machinery and other debris were found at the site.

The property belongs to the Division of Parks and Forestry (part of Allamuchy Mountain State Park) but mining rights were keep by the previous owner who prospected here as recently as 1978. More than 95 tons of uranium ore were mined between 1958 to 1968, trucked to the nearby Delaware, Lackawanna and Western RR and shipped to a refinery in Snake River, Wyoming.

2. Radiological survey (April 1981). Water and soil samples were taken, showing low uranium and radium concentrations in the easily accessible areas, such as trails (10-50 microrems per hour on southern trails and 100-500 microrems per hour on northern trails) and around the main adit (average 50 microrems per hour but with hotspots of 4,500 microrems). However, readings were much higher in the adits, shafts and mine tailings areas (a 50-square-yard area of mine tailings at the base of the main shaft had a general reading of 2,000 microrems per hour, with hotspots of 3,000 microrems); a person spending 250 hours here would receive more than the 500 millirem per year limit for non-occupational exposure. Uranium and radium concentrations in the soils exceed state and federal decontamination' standards for New Jersey (uranium readings 1,500 picocuries per gram--standard 40 pCi/gm; radium readings 1,100 pCi/gm--standard 5 pCi/gm).

3. Conclusion and recommendations. "Since there is access to these areas by way of the many trails that interlace the wooded region and because this mine is a curiosity to transients, the region presents an unnecessary safety and radiological hazard." The two vertical shafts pose the greatest safety hazard, since they are well concealed deep pits. With respect to radiation, children are most at risk for excessive exposure because they may visit the area more, without suspecting the risk, and because they are more sensitive to radiation damage.

To reduce the radiological risk, the mine tailings should be returned to the secondary vertical shaft, refilling it. For general safety, the vertical shafts should be fenced horizontally with heavy anti-rock-slide fencing, bolted to the surface.

4. Action taken as of 1993. The Byram Township Environmental Commission checked with several offices within the N.J. Department of Environmental Protection and Energy (including the Bureau of Radiation Protection and the park superintendent in charge of Allamuchy Mountain State Park) and were told that inspectors had visited the site in the mid-late 1980s but that the only work done to protect the site was fencing one or both of the vertical shafts.

and the Andover Forge on the Musconetcong River at the site of Waterloo. William Allen, a Philadelphia merchant, and Joseph Turner, an English sea-captain, were joined in the venture by two junior partners, John Hackett and Lynford Lardner, and their firm was called the Andover Iron Company.

The name of the Musconetcong site was changed to Waterloo about 1839 to avoid confusion with the New Andover Bloomery site upstream near the confluence of the Musconetcong and Lubbers Run. Waterloo was named not for the English victory over Napolean at Waterloo, Belgium, but because Waterloo was the ancestral home of the Smith family, who then owned the Musconetcong site.

The Andover Forge Tract comprised 3,876 acres along the river and on Allamuchy Mountain (not, as is sometimes reported, part of the property originally granted to William Penn*) . Mr. Hackett also purchased another approximately 3,000 acres, part of it in Byram and Green northwest of Cranberry Lake, Panther Lake, and Forest Lake (the northeastern third of this tract is now Andover Borough) and the rest along Limecrest Road where the Andover Mine is located. He also bought what is now Lake Iliff.

The Andover Furnace produced pig iron. These crude castings were then taken to the Andover Forge and to other sites for conversion to the bar iron used by blacksmiths, wheelwrights and other craftsmen. Pig iron from the Andover Furnace was also sent to the steel works at Trenton and Philadelphia during the Revolution to make steel blades for the Continental Army.*

The ore used at Andover Furnace originally came from the mines on what is now Limecrest Road in Andover Township. By 1763, the Allen and Turner site produced 30,000 pounds a week; and it was, by some accounts, one of the largest and best reputed works in the Colonies and perhaps unique in producing iron good enough for manufacturing gun barrels (Mr. Wright disputes these accounts).

But while the Furnace operated during the war, there is no evidence that the Andover Forge at Waterloo was working then.* The dam across the Musconetcong burst before or during the war, leaving the site without water power until as late as 1782.*

Contrary to usual accounts, the Andover Iron Company's works were not confiscated during the war.* The Forge at Waterloo was leased to another operator in 1792, who ran the site poorly, destroying much of the value of the land and machinery.*

In 18 12, John Smith purchased the Andover Forge Farm, as it was then called.* The Smith family farmed the tract and built a flax mill, which later burned, and were the owners of the Waterloo site when it became a port on the Morris Canal.

THE MORRIS CANAL (#48)

Waterloo's most prosperous period began with the opening of the Morris Canal in 183 1. The canal was built to supply coal to the iron forges and furnaces of northwestern New Jersey and to carry iron and other products to market. Dug by hand from Phillipsburg on the Delaware River to Newark on the Passaic River, in 1836 the canal was extended to Jersey City on the Hudson. Seventy-five ton barges were pulled by mules at speeds of about two miles per hour:

About 3/4 mile of the Canal's 102 miles crossed Byram Township, from Waterloo west to the Warren County line. Waterloo has the distinction of having within one mile all of the major features of the canal: one of the canal's 34 locks , (there were 23 lift locks and 11 guard or tide locks, such as the one at Waterloo); one of its 23 inclined planes, a unique innovation by which canal boats were raised or lowered on rails (now a National Historic Engineering Site); a level section; a dammed area in the river; and a mule bridge.

For 50 years, although it remained a small hamlet, Waterloo was an active stopover point on the Canal and later on the railroad. In 1806, the general store at Waterloo reported $75,000 in business, estimated to equal $1-2 million today.

In 1901, changes in rail routes directed traffic away from Waterloo, and the village began a gradual decline. The Morris Canal, which had been losing traffic for decades because of rail competition, was closed in 1924 and dismantled in 1929.

THE WATERLOO FOUNDATION FOR THE ARTS

Shortly after World War II, Percival Leach and the late Louis Gualandi founded the Waterloo Foundation for the Arts, Inc., to protect and restore Waterloo Village. The Smiths' plan for a residential development called Lake Waterloo Estates had collapsed following the 1929 stock market crash, and the site had been sold to Olaf Casperson; Casperson had rented space at the village to Leach and Gualandi for an interior decorating business.

Waterloo Village opened to the public in 1964. Located within Allamuchy Mountain State Park, Waterloo is now one of the only true restored villages in the United States with many buildings on original foundations.

The more than two dozen buildings and structures, or parts of them, date from the Colonial to the Victorian era and include several homes, an 1859 church which still holds services, an apothecary, the Towpath Tavern (one of four restaurants), a general store, blacksmith shop, working grist mill and sawmill, a Victorian garden, a reproduction of an early 17th century Lenape Indian village, and a canal museum. Some of these are historical remnants of the village's history, and some have been added to recreate a typical village of those eras. Various crafts are demonstrated, and the village has recently added craft classes.

Also located at the village are the Waterloo Festival of the Arts and the Waterloo Festival School of Music, which from May through October present concerts and other events ranging from poetry and dance to rock, jazz and classical music 'by world-renowned artists. The Foundation now plans- to restore the inclined plane and erect new buildings for the arts festival, all of that work to occur across the river in Mt. Olive Township.

OTHER EARLY LOCAL INDUSTRIES

Charcoal Making

Before the railroads brought anthracite coal from Pennsylvania in the mid to late nineteenth century, locally-produced charcoal was the common fuel. Even after coal was available, most of Byram's forges used charcoal.* This was an important rural industry, with the product also being carted to

urban areas for sale. The occasional circular depressions still found in the wooded areas of Byram, usually less than 15 feet across, are what is left of the charcoal-making industry. Great quantities of green wood were stacked in teepee-like shapes and covered with earth to create a slow-burning fire, which had to be carefully tended for several days and nights. Byram's hills were often nearly bare of timber to meet the demand for charcoal.

Lime Kilns

A remnant of another local industry can also be found in Byram. Just north of Lackawanna Drive near the abandoned sections of Old Indian Spring Road are the remains of a lime kiln (#46), where lime was made by burning limestone in large stone furnaces at temperatures often reaching 2000 degrees Fahrenheit.

Most of these kilns, which appear in the towns surrounding Byram and throughout Sussex and Warren counties, were built and used in the 19th century, often by local farmers who used the lime to reduce the acidity of local soils. Some were still in operation in the early 20th century.

The kilns were built into hills and were loaded from above, with alternate layers of fuel (wood or coal) and limestone chunks. The burnt lime filtered through a grate below the fire.

There were large commercial operations as well. The lime was used for mortars and cements, to clean outhouses and pigpens, for whitewashing, and in the purification of iron.

Ice Cutting (#52)

By about 1890, harvesting ice from lakes and ponds had become another important local industry. The ice was stored in hay-insulated ice houses and shipped to towns and cities in the warmer months, particularly to the Newark meat-packers. Ice cutting lasted until the1920s, when refrigerators and refrigerated rail cars came into use.

Icehouses were located along the rail routes in Byram. A set of five huge houses was built in 1892 at Waterloo Lake (the channel along the northwest bank of the river just above the lake, which now passes between the Indian village display and the mainland, was dug to redirect the current and its debris away from the ice-cutting areas). There were also

icehouses at Jefferson and Cranberry lakes. As many as a dozen harvestings could occur in a winter.

RAILROADS

While there are no railroads in Byram today, the Township was once traversed by two lines, the Lackawanna 'Cut-off' or mainline from New York to Buffalo and the Sussex Branch of the Lackawanna Railroad from Port Morris in Morris County to Branchville in Sussex County.

The Cut-off (#39)

The Cut-off right-of-way is still very visible, running north-south along the eastern side of Lake Lackawanna and Wolf Lake and along the western side of Roseville Pond, just about in the middle of the township.

The Cut-off was built by the Delaware, Lackawanna & Western Railroad (DL&W) between 1908 and 1911, providing 28.45 miles of almost gradeless, straight bed from Lake Hopatcong to the Delaware Water Gap. The 73 bridges and viaducts eliminated the need for grade crossings.

The project set records for its use of concrete and for its extensive cuts and fills. The Paulins Kill Viaduct near the Delaware was then the largest concrete bridge in the world (115 feet high, 1,100 feet long), and the Pequest Fill, which crosses Route 206 just north of Byram below Andover Borough, was the largest railroad fill ever built (110 feet high, 6,625,000 cubic yards of fill). The Cut-off remains one of the railroad engineering wonders of the world.

In 1983-84, Conrail tore up the tracks, and shortly thereafter the entire Cut-off was sold to a Sussex County developer for $1 million. The state is now considering buying back the right-of-way and re-establishing passenger service.

In Byram there are three road tunnels under the Cut-off and one roadway overpass as well as the 1/5-mile Roseville Tunnel (#40), bored through solid rock between C.O. Johnson Field and Roseville Pond.

The Sussex Branch (#38)

The older and more local rail line was the Sussex Branch, which began

in 1848 as the Sussex Mine Railroad, the first railroad in Sussex County.

Opening in 185 1, the Sussex Mine Railroad operated for only three years, hauling ore by mule power from the Andover Mine on Limecrest Road to the Morris Canal at Waterloo. Abram Hewitt and Peter Cooper built the line to supply ore to their furnace in Phillipsburg. Cooper and Hewitt also owned the Roseville Mine, purchasing it in 1854, and the Bedell mine, both in Byram.

In 1853, the Sussex Mine Railroad was replaced by the Sussex Railroad and its steam locomotives. This line was extended to Newton by December 1854, to Branchville by 1866, and to Franklin in 1872, ultimately reaching the Pochuck Mine in McAfee Valley in 1872. It followed some of the Sussex Railroad's route, but swung to the east and west in various places between Cranberry Lake and the Musconetcong and paralleled Route 206 on the west rather than the east. It also entered Waterloo on the south side of the Musconetcong in Mt. Olive rather than on the north side in Byram, joining the Morris and Essex Railroad there.

In 1881 the Delaware Lackawanna & Western Railroad purchased the Sussex Railroad, which was now called the Sussex Branch of the Lackawanna (by some locals, the DL&W was nicknamed the Delay, Linger & Wait) and later the Erie-Lackawanna. The last train ran on this line on October 2, 1966, stopping in Byram at Cranberry Lake. The tracks were torn up in July 1977.

During its 100 years of operation, this line was an important factor in the economic and social life of Byram and Sussex County. From stations at Waterloo and Cranberry Lake, Byram residents went to shop, to work and to school in Newton and also to jobs in the metropolitan areas to the east. Sussex County's products were shipped out by train--iron and zinc ores, timber, quarry products, ice, milk and other farm produce--food, coal, mail and building materials and other products were brought in.

LAKES AND STREAMS

Byram, the "Township of Lakes," has more than two dozen lakes and ponds within or on its borders. The most heavily developed lakes are

Cranberry, Lackawanna, Forest, and also Mohawk, which lies only partly within Byram.

A small, completely separate part of the township known as "Byram Island' (see Insert on Historical Map) lies on the northern end of Lake Musconetcong and was.kept as Byram's foothold on the Morris Canal.

Cranberrv Lake

Originally called Cranberry Bog and then Cranberry Reservoir, this lake was dammed in the 1830s to serve as a feeder for the Morris Canal to help maintain water levels there. In the late 1920s, the level of the lake was raised three feet to its current 190 acres to provide better recreational use, and the Cranberry Lake Development Company began building roads and selling lots for vacation homes. The Cranberry Lake Community Club was formed in 1924 and now numbers about 2/3 of the lake's approximately 500 homeowners among its members. About 3/4 of those homes are now used year-round.

From 1902 until 19 11, Cranberry Lake was a popular amusement park (#49), developed by the Lackawanna Railroad. On Sundays and holidays, as many as 1,000 people (some reports say 4,000-6,000) enjoyed a dance pavillion, a miniature railroad, bowling, ball playing, a midway and picnicking on 30-acres in what is now the Frenche's Grove neighborhood. There were also 50 rowboats for rent and trips around the almost uninhabited lake by naphtha launch. A large hotel (#53) was built in 1903 where the community clubhouse now stands and a wide bridge connected the railway station with the amusement area. The hotel burned in 1910, and in 19 11, after many complaints from local residents about rowdiness at the park, the bridge was hitched to a locomotive.and pulled into the lake and the park was closed.

Lake Lackawanna

This 117-acre lake was created in 19 10, by damming Lubbers Run at the foot of Hopatcong Mountain. Byram's first summer colony, it was originally a private community on 657 acres of land surrounding the lake. There are now approximately 300 homes, with only about 10 still being summer vacation homes.

The Lake Lackawanna Investment Co., Inc., a small corporation of about 100 stockholders (only about 30 are lake residents), bought most of the

property surrounding the lake in 1925. The Investment Company still owns about 280 acres at the eastern end between the lake and the 'Cut-off' railroad bed, which it plans to keep undeveloped. The Investment Company owns the lake, the beach, boat launch, and charges a fee for lake access. The Company also built the clubhouse in 1925 and Byram's only golf course, nine holes on the lake's southern shore.

Forest Lakes

The 44-acre Forest Lake was created in the 1950s by the Casperson family as the center of a 300-acre year-round residential development. About 50 homes were built by '1960, and today the community numbers about 400 residences. Aware of the problems brought on by lake front development at Cranberry Lake and Lake Hopatcong, the Caspersons reserved a green belt around the lake, an unusual plan at that time. There are a beach, a club house, a common water system, and other facilities for residents, who may elect to join the Forest Lakes Club.

The mid-19th century Sussex Mine Railroad used to run through part of the Forest Lakes area on its way from the Andover Mine to the iron works at Waterloo.

Just beyond Peach Tree Street within the development is the Colby (or Tamarack) Cemetery **(#35),** which contains just three graves--those of Franklin G. Colby, 1858-1941, Josephine W. Colby, 1862-1930, and John Tynan, their servant, 1875-1928. The Colbys owned a large portion of what later became the Forest Lake community and had a mansion on Tamarack Road in the early 20th century. The mansion is still visible, on the site of the former MKY Corporation, also known as Mykroy or Mycalex, a maker of specialized ceramics.

Lake Mohawk

The Crane Company created Lake Mohawk in 1926 after having bought the 2,300 acres where the lake and homes would be situated. It was one of the first planned communities in the United States. The first house was built in 1927, and the road around the lake was finished in 1936. Most of the lake and its homes, the Country Club and Boardwalk (placed on the State and National Register of Historic Places in 1988) are in Sparta, with residential neighborhoods at the west end and on part of the south shore being in **Byram.** Membership in the club is mandatory.

Other Water Bodies

Byram's other less developed and smaller lakes and ponds include Waterloo, Panther, Roseville (also called Wright's or Hammett's), Jefferson, Johnson, Tomahawk (the site of an amusement park with swimming, picnicking and waterslides), Frenche's, Stag, Chemical, Wolf, Dallis and several unnamed ponds. The Musconetcong River and Lubbers Run, Byram's two largest streams and ultimate receptacles of almost all of the township's overland and surface water drainage, form the southern border of the township.

HISTORIC SCHOOLS

The schools shown on the accompanying historical map were in use during the following time periods, according to interviews with several older township residents:

The LOP School (#7) near the Cut-off just north of Lackawanna Road--about the 1850s until the construction of the Cut-off from 1908-1911 overran the site.

Roseville Schoolhouse (#8) at the western end of Lake Lackawanna just north of Lackawanna Road--about 1854 to 1924; it was then put to various uses, including as an Episcopal Church, and in 1985, through the efforts of a citizens group, was moved to a special site near the municipal building to serve as a museum.

Amity One-Room Schoolhouse (#9) near the intersection of Sparta-Stanhope Road and Amity Road--about 1875 until the 1930s; it is now a house just opposite Lynn Drive.

The Mud School (#10) at the northeastern corner of Tamarack Road and Route 206--19th century; on the location now is an office building.

Cranberry-Lake Schoolhouse (#11) on the north side of Tamarack Road between Route 206 and Johnson Lake--early 20th century; the building is gone.

THE HUDSON GUILD FARM (#50)

In1917, John T. McRoy, Gella Hecht, and Alexander Bing donated approximately 500 acres in Byram and Hopatcong to The Hudson Guild, a social service organization founded in 1897 in New York City. About 86.5

acres of The Hudson Guild Farm lie in Byram just north of the intersection of Sparta-Stanhope and Lackawanna roads.

The Guild, whose offices are on West 26th Street in N.Y.C., was part of the settlement house movement begun in Chicago by Jane Addams and was also closely tied to the Society for Ethical Culture, a group also founded in 189.7 which emphasized the ethical development of society and pioneered kindergarten and adult education.

John Lovejoy Elliott was the founder of The Hudson Guild and a central figure in the Society for Ethical Culture. Gertrude Stein and Lewis Mumford were both associated with the Society for Ethical Culture, as were many other important social thinkers. Mumford and other Society members often visited The Hudson Guild Farm for conferences and retreats.

The farm also offered low-rent summer housing for urban families who were required to donate a certain number of hours each week to working in the Farm's gardens, fields or dairy.

Today, the Farm hosts conferences and retreats and a senior camp, and has trails that are open to the public for a fee.

BIBLIOGRAPHY AND ACKNOWLEDGEMENTS

The Environmental Commission would like to thank Byram residents C.O. Johnson, Robert Dennis, Herman Boepple, and Justus Von Lengerke for their assistance, with special thanks to Mr. Dennis for his work on the section on railroads. Also thanks to Bill Moss, President of the Canal Society of New Jersey: Lee McIntyre, director of The Hudson Guild Farm: Mark Thelin, president of the Lake Lackawanna Investment Co.

Very special appreciation goes to Kevin Wright, Curator of the Steuben House,, 1209 Main Street, River Edge, N.J. 07661, who reviewed and made substantial additions and corrections to this chapter. Mr. Wright's notes, which contain far more detail than could be included here, are in the Environmental Commission files at the Byram municipal building.

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Chapter 3

NATURAL HABITATS AND ENDANGERED SPECIES

(Refer to the Natural Habitats Map in the Appendix of this document.)

BYRAM'S SIX HABITATS

Byram's habitats include:

1. mesic upland woods--the dominant habitat.

2. lakes and streams--a very important feature, including more than two dozen lakes and ponds and roughly 35 miles of streams. The Township's southeastern border is formed by Lubbers Run (the longest stream at seven miles in length) and the Musconetcong River (the largest stream, only about three miles of it in **Byram**). ***Lakes and streams are discussed in Chapter 6, WATER RESOURCES.***

3. wetlands (marshes, bogs, swamps, floodplains)--a subtantial number scattered throughout the Township and often associated with its lakes, ponds, streams, and areas of poorly drained soils. Township Planner Eric Snyder, in his 1991 NRI work, advises that "the potential impact on these areas from future development gives rise to the need to seriously consider additional protection of these areas."

4. planted trees--a few areas scattered throughout the Township, mostly conifer tree stands. ***These areas are shown*** on ***the Habitat Map, but will not be discussed further because they occupy a very small part of the Township. However. 'the edge.' where vlanted or natural woods meet oven areas (habitat #5). is a significant habitat for songbirds and many other fauna. Development often disturbs or erases small 'edge' areas. and many studies show that the incremental loss of this habitat is one factor in the diminishing number of songbirds.***

5. fields and open lands--very few, including minimal agricultural and pasture lands, abandoned fields, mowed areas at schools and parks. Most were once mesic forested land. If left alone they undergo a gradual vegetative succession back to forests. This succession is described at the end of the section on mesic upland woods.

6. developed areas--mostly residential construction and roads, plus

some commercial areas and minimal industrial development. These ***areas will not be discussed further in this chapter because they are man-made habitats, although the different types of development are shown on the Natural Habitats Map.***

DESCRIPTION AND TYPICAL VEGETATION: MESIC UPLAND WOODS

Byram's forests are important for several reasons:

1. Trees are the primary source of oxygen for living things.
2. Much of this forested land is unsuited for development.
3. Forests help prevent erosion and loss of soil nutrients.
4. Forests increase the infiltration of water to recharge aquifers.
5. Forests help reduce flooding from heavy storms.
6. Tree stands affect climate by reducing wind and cooling the air.
7. Trees and shrubs reduce noise pollution, an important factor along highways and between residential and commercial areas.
8. Trees and shrubs help reduce air pollution and form barriers to control the dispersion of pollution, for instance from highways.
9. Forests provide wildlife habitat.

Most of **Byram** and of the entire Highlands area of New Jersey is **characterized** as a ***Mixed Oak Forest,*** one of nine forest regions within the Eastern Deciduous Forest located in the eastern half of the United States. ***Table IV*** describes the Mixed Oak Forest in detail because it is the most common forest in **Byram.**

A less common and very different looking forest, the ***Hemlock-Mixed Hardwoods Forest,*** is also found in a few places in **Byram, occuring** on cooler and moister sites (ravines or north-facing slopes leading into ravines or valleys). Hemlocks account for more than half the larger trees. The **understory** of trees and the undergrowth of shrubs and plants are not very dense. Other trees may include sweet or yellow birch, basswood, ash, red oak, and sugar and red maple.

A third type of **mesic** uplands forest, ***the Sugar Maple-Mixed Hardwoods Forest,*** thrives in limestone valleys, and so is even less common in **Byram,** which has only a few limestone areas (see the Bedrock Geology Map in the Appendix).

These **mesic** upland woods generally show no standing water but do retain a good supply of moisture in their soils. **Mesic** refers to this **middle**-range of soil moisture conditions, neither very wet nor dry. This habitat can include slopes, hilltops, valleys, ravines, and flat topography. But, if climate and moisture conditions are similar, the vegetation on these different terrains is also similar.

TABLE IV: TYPICAL MESIC UPLAND WOODS VEGETATION

(MIXED OAK FOREST)

Common Name	***Scientific Name***
	DOMINANT TREES
Red oak	***Quercus rubra***
White oak	***Quercus alba***
Black oak	***Quercus velutina***
	OTHER TYPICAL TREES
Chestnut oak	***Quercus prinus (dominates on slopes in higher elevations; more tolerant of drier, poorer soils than other oaks)***
Scarlet oak	***Quercus coccinea***
Hickories	***Carya sp.***
Red maple	***Acer rubrum***
Sugar maple	***Acer saccharum***
White ash	***Fraxinus americana***
American beech	***Fagus grandifolia***
Tulip tree	***Liriodendron tulipifera***
Black cherry	***Prunus serotina***
Sweet birch	***Betula lenta***
Black gum	***Nyssa sylvatica***
Slippery elm	***Ulmus rubra***

(The species above form the overstory; the larger trees have mature heights from 60-100 feet. Younger trees frequently are not oak but rather red maple, sugar maple, sweet birch, and ash.)

	UNDERSTORY TREES
	(mature heights of 20-40 feet)
Flowering dogwood	***Cornus florida (dominant)***
Sassafras	***Sassafras albidum***
Hop hornbeam	***Ostrya virginiana***
Ironwood	***Carpinus caroliniana***
American chestnut	***Castanea dentata (sprouts)***

	SHRUBS
Maple-leafed viburnum	*Viburnum acerifolium*
Black haw	*Viburnum prunifolium*
Arrowwood	*Viburnum den tatum*
Spicebush	*Lihdera benzoin*
Witch hazel	*Hamamelis virginiana*
Red dogwood	*Cornus stolonifera*
Gray dogwood	*Cornus racemosa*
Also, in very acidic soils, the following shrubs:	
Blueberry	*Vaccinium sp.*
Huckleberry	*Gaylussacia sp.*
Pinnter flower	*Rhododendron nudiflorum*
	VINES
Poison ivy	*Rhus toxicodendron*
Virginia creeper	*Parthenocissus quinquefolia*
Japanese honeysuckle	*Lonicera japonica (non-native, successful colonizer)*
Wild grape	*Vitis sp.*
	HERBS
	(vary with time of year and location)
May apple	*Podophyllum peltatum*
Violets	*Viola sp.*
Spring beauty	*Claytonia virginica*
Wood anemone	*Anemonella quinquefolia*
Jewelweed	*Impatiens pallida*
Jack-in-the-pulpit	*Arisaema triphyllum*
Solomon's seal	*Polygonatum pubescens*
Wild sarsaparilla	*Aralia nudicaulis*
False lily-of-the-valley	*Maianthemum canadense*
Asters	*Aster sp.*
Goldenrod	*Solidago sp.*
Grasses	--
Sedges	*Carex sp.*
Ferns	--
Skunk cabbage	*Symplocarpus foetidus*
Pokeweed	*Phytolacca americana*

The typical succession of vegetation as an open field develops into mesic upland woods is as follows:

First year--annuals such as ragweed, wild radish, wintercress, foxtail

grass dominate the disturbed site.

Second to about tenth year--perennials such as goldenrods, asters, and other herbs such as little bluestem, Queen Ann's Lace, common mullein, black-eyed Susan become established.

Tenth year--the first plants that are taller than herbs, including red cedar or gray birch, large-toothed aspen and some red maple, black cherry, sassafras, shrubs, poison ivy, and Virginia creeper begin to appear.

Twenty to thirty years--trees dominate and shade out herbs.

Fifty to sixty years--young mixed oak woodland or tulip tree stand is established.

DESCRIPTION AND TYPICAL VEGETATION: WETLANDS

Byram's wet areas are important for several reasons:

1. Wetlands serve as flood storage areas by withholding water and gradually releasing it into streams or lakes. In this way, wetlands maintain a critical base flow to surface waters, particularly during droughts.

2. Floodplains also provide important protection against flooding by absorbing excess water when streams rise above their banks, as Byram's streams often do in the spring and fall. This protection is based on a delicate balance between the stream channel and flow and the floodplain. Any kind of building activity or alteration of natural vegetation on floodplains disturbs this process and results in more intense flooding downstream. Streams without wetlands (common in Byram) are especially susceptible to flooding and water quality degradation if their floodplains are disturbed.

3. Wetlands also are important aquifer recharge areas, replenishing underground drinking water supplies.

4. Wetlands and their vegetation help to filter pollutants (especially nitrogen, phosporous and heavy metals) from water that is being recharged to drinking-water aquifers and to streams, lakes and ponds.

5. By providing a transition zone between dry land and water courses, wetlands retard soil erosion.

6. Wetlands are among the most productive ecosystems in the world. They support as much as 12 tons of plant life per acre per year and provide food, nesting and spawning areas, rearing and resting sites for a great diversity of fish and wildlife.

There are three types of wetlands in Byram:

1. Lacustrine--associated with lakes;

2. Riverine--associated with rivers and streams;
3. Palustrine--marshes, swamps, bogs.

For regulatory consideration, wetlands are defined by the presence of appropriate vegetation, by the presence of hydric soils, and by the presence of water at or near the surface. Vegetation and hydric soils are usually adequate to define an area as wetlands.

In their appearance and typical vegetation, wetlands are divided into three subgroups: freshwater marshes; bogs; swamps-floodplains.

TABLE V: TYPICAL FRESHWATER MARSH VEGETATION

Freshwater marshes occur along the edges of streams, lakes, ponds or wherever low areas are flooded regularly or have high water tables. They appear as tree-less grassy meadows with many grass-like herbaceous plants, cattails, ferns and other herbs.

Common name	*Scientific name*
Cattail	*Typha sp.*
Reed grass	*Phragmites sp.*
Pickerelweed	*Pontederia sp.*
Bulrush	*Scirpus sp.*
Swamp loosestrife	*Lythrum virgatum*
Arrow-head	*Sagittaria latifolia*
Arrow-arum	*Peltandra virginica*
Blue flag	*Iris versicolor*
Spike rush	*Eleocharis sp.*
Bur reed	*Sparganium sp.*
Water dock	*Rumex verticillatus*
Sedges	*Carex sp.*
Also, on higher land:	
Marsh fern	*Thelypteris thelypteroides*
Swamp milkweed	*Asclepias incarnata*
Jewelweed	*Impatiens pallida*

TABLE VI: TYPICAL BOG VEGETATION

Bogs do have trees, but they are typically conifers. Bogs are not flooded as regularly as marshes but have poor drainage; they often occur in glacial depressions, kettle holes, or where there are drainage barriers formed by glacial deposits. Bogs are acidic; because many microorganisms cannot live in acidic conditons, the organic matter that accumulates in bogs does not

decompose well. This partially decomposed organic material is called peat; it forms a floating mat of vegetation that may accumulate in deposits up to 20-40 feet deep.

Common name	Scientific name
DOMINANT TREES	
Black spruce	Picea mariana
Larch (tamarack)	Larix laricina
Red maple	Acer rubrum
Black gum (sour gum)	Nyssa sylva tica
LESS DOMINANT TREES	
Hemlock	Tsuga canadensis
White cedar	Chamaecyparis thyoides
White pine	Pinus strobus
Yellow birch	Betula lutea
DOMINANT SHRUBS (typically Heath family shrubs)	
Leatherleaf	Chamaedaphne. calyculata
Sheep laurel	Kalmia angustifolia
Swamp azalea	Rhododendron viscosum
Sweet pepperbush	Clethra alnifolia
Cranberry	Vaccinium macrocarpon
Highbush blueberry	Vaccinium corymbosum
Huckleberry	Gaylussacia sp.
Bog rosemary	Andromeda glaucophylla
Labrador tea	Ledum groenlandicum
LESS COMMON SHRUBS	
Black alder (Winterberry)	Ilex verticilla ta
Staggerbush	Lyonia mariana
Fe tterbush	Leucothoe racemosa
Inkberry	Ilex glabra
Rosebay rhododendron	Rhododendron maximum
HERBS	
Sphagnum moss	Sphagnum sp.
Sedges	Carex sp.
Swamp loosestrife	Lythrum virgatum
Marsh marigold	Caltha palustris
Pitcher plant	Sarracenia purpurea
Sundews	Drosera sp.
Marsh fern	Thelypteris thelypteroides
Chain fern	Woodwardia sp.

TABLE VII: TYPICAL SWAMP AND FLOODPLAIN VEGETATION

Although swamps and floodplains differ in origin, their moisture conditions are similar enough to support similar groups of plants. Both have standing water only part of the year, usually in spring and late fall.

Swamps are former marshes or bogs which became drier because of sediment accumulation. Swamps are less acidic than bogs.

Floodplains are well-defined, broad, flat, valley surfaces that are covered with water when a stream or river overflows its banks. Because they are only periodically flooded, they exhibit a wide variety of habitat types, sometimes supporting wetlands plants and sometimes upland plants.

Common name	*Scientific name*
TREES	
Red maple (most common)	*Acer rubrum*
Yellow birch	*Betula lutea*
LESS COMMON TREES	
White ash	*Fraxinus americana*
Basswood	*Tilia americana*
Tulip tree (yellow poplar)	*Liriodendron tulipifera*
Black gum (sour gum)	*Nyssa sylvatica*
Hornbeam (ironwood)	*Carpinus caroliniana*
River birch	*Betula nigra*
SHRUBS	
Box elder (ash-leaved maple)	*Acer negundo*
Alder	*Alnus serrulata*
Willow	*Salix sp.*
Buttonbush	*Cephalanthus occidentalis*
Spicebush	*Lindera benzoin*
Witch hazel	*Hamamelis virginiana*
Swamp azalea	*Rhododendron viscosum*
Winterberry	*Ilex verticillata*
Viburnum	*Viburnum sp.*
Highbush blueberry	*Vaccinium corymbosum*
HERBS	
Skunk cabbage	*Symplocarpus foetidus*
Cinnamon fern	*Osmunda cinnamomea*
Sedges	*Carex sp.*
Mosses	--

ENDANGERED SPECIES

Plants and animals are a very important natural resource in any community. The failure of species to thrive or survive is often a direct reflection of stresses caused by development. Plant or animal species may begin to fail or die out as a result of the degradation, elimination or reduction in size of habitats. Such apparent stresses should alert planners and officials to the need to evaluate unperceived or unanticipated effects of human activity.

The following list of endangered and threatened species is based upon probable occurences and on information from the New Jersey Natural Heritage Program regarding sightings of endangered plants and animals within and adjacent to **Byram.** The Natural Heritage Program requires inclusion of the following notice:

CAUTIONS AND RESTRICTIONS ON NATURAL HERITAGE DATA

The quantity and quality of data collected by the Natural Heritage Program is dependent on the research and observations of many individuals and organizations. Not all of this information is the result of comprehensive or site-specific field surveys. Some natural areas in New Jersey have never been thoroughly surveyed. As a result, new locations for plant and animal species are continuously added to the data base. Since data acquisition is a dynamic, ongoing process, the Natural Heritage Program cannot provide a definitive statement on the presence, absence, or condition of biological elements in any part of New Jersey. Information supplied by the Natural Heritage Program summarizes existing data known to the program at the time of the request regarding the biological elements or locations in question. They should never be regarded as final satements on the elements or areas being considered, nor should they be substituted for on-site surveys required for environmental assessments. The attached data is provided as one source of information to assist others in the preservation of natural diversity.

Developers or others who may disturb the habitat areas shown on the Natural Heritage maps (see pages 48 and 49) should check Natural Heritage files for specific information and also take observations at the site to verify the presence of endangered or threatened species in order to minimize the impact on their habitats. Pages 50 and 52 give some specific information on Natural Heritage sightings of rare species and natural communities.

This Endangered and Threatened Fauna list is based on probable occurences within **Byram** and nearby areas:

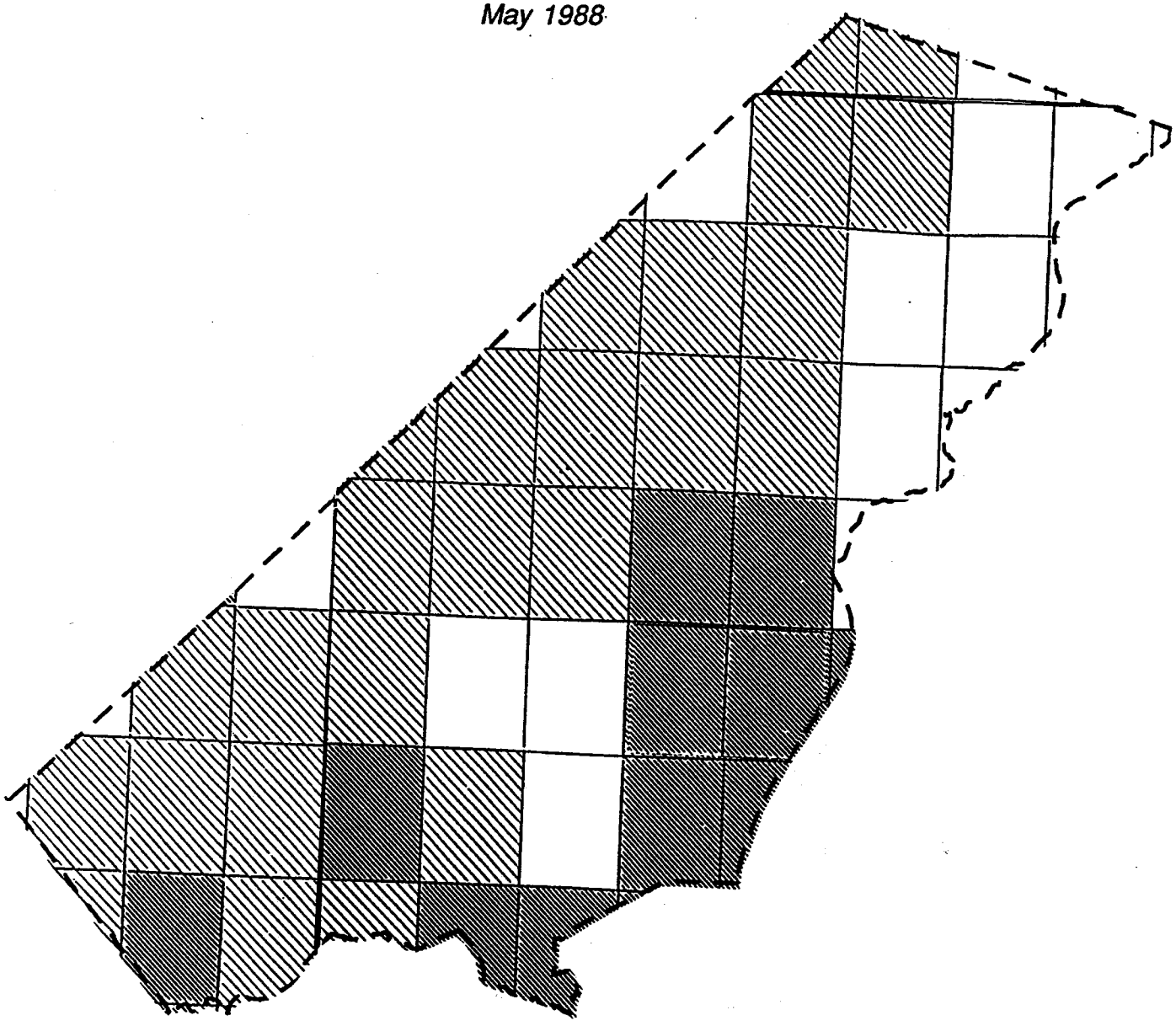
TABLE VIII: ENDANGERED AND THREATENED FAUNA

These birds and animals would potentially use Byram's habitats for feeding, breeding, wintering, or as a migratory refuge. Site sampling or observation would be required to determine the actual presence of these species.

Group	Species	Status
AMPHIBIANS	Tremblay's salamander	Endangered
	Blue spotted salamander	Endangered
	Eastern tiger salamander	Endangered
	Long tailed salamander	Threatened
	Eastern mud salamander	Threatened
BIRDS	Cooper's hawk	Endangered
	Northern harrier	Endangered
	Bald eagle	Endangered
	Peregrine falcon	Endangered
	Piping plover	Endangered
	Upland sandpiper	Endangered
	Least tern	Endangered
	Roseate tern	Endangered
	Black skimmer	Endangered
	Short-eared owl	Endangered
	Cliff swallow	Endangered
	Sedge wren	Endangered
	Henslow's sparrow	Endangered
	Vesper sparrow	Endangered
	Red-shouldered hawk	Endangered
	Merlin	Endangered
	Great blue heron	Endangered
	Yellow-crowned night heron	Endangered
	Red-headed woodpecker	Endangered
	Bobolink	Endangered
	Barred owl	Endangered
	Savannah sparrow	Endangered
	Ipswich sparrow	Endangered
	Grasshopper sparrow	Endangered
	Osprey	Threatened
	American bittern	Threatened
	Cliff swallow	Endangered
	Northern goshawk	Threatened
	Pied-billed grebe	Endangered
FISH	Brook trout	Threatened
REPTILES	Corn snake	Endangered
	Bog turtle	Endangered
	Wood turtle	Threatened
	Northern pine snake	Threatened
	Timber rattlesnake	Endangered

NATURAL HERITAGE DATA
Generalized locations for rare and endangered elements of natural diversity

May 1988



KEY

documented location known precise/y

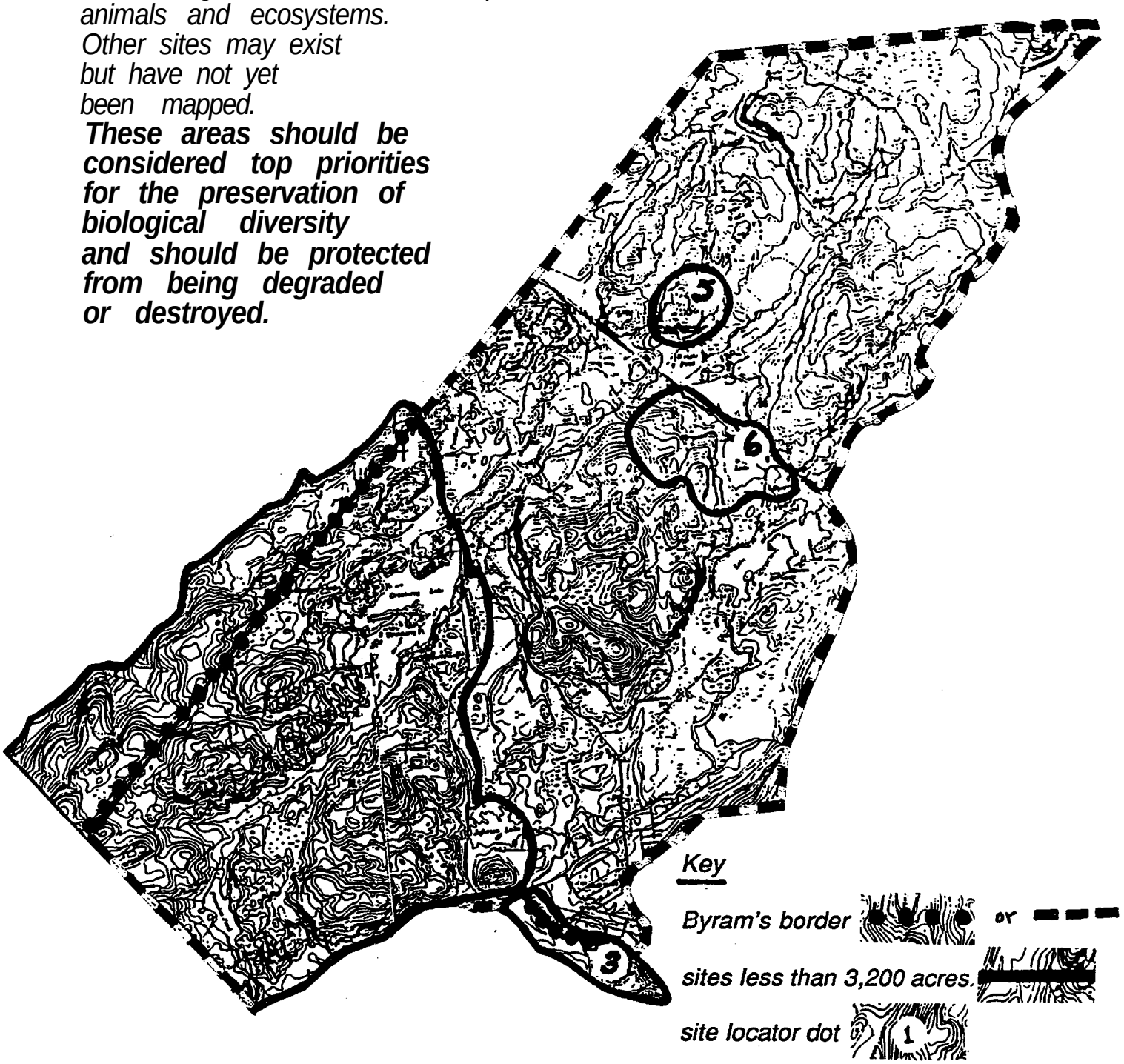
documented location known within 1.5 miles

*For more detailed information, see the September 1991 Natural Resources Inventor\! **Update** by Township Planner Eric Snyder in the Environmental Commission files at the Municipal Building.*

NATURAL HERITAGE PRIORITY SITE MAP

Some of the ***most*** *important sites in* ***N.J.*** *for endangered and threatened plants, animals and ecosystems. Other sites may exist but have not yet been mapped.*

These areas should be considered top priorities for the preservation of biological diversity and should be protected from being degraded or destroyed.



For more detailed information, see the September 1991 Natural Resources Inventory Update by Township Planner Eric Snyder in the Environmental Commission files at the Municipal Building.

PRIORITY SITES WITHIN OR ADJACENT TO BYRAM TWP., SUSSEX COUNTY
RARE SPECIES ANU NATURAL COMMUNITIES PRESENTLY RECORDED IN
THE NEW JERSEY NATURAL HERITAGE DATABASE

NAME	COMMON NAME	FEDERAL STATUS	STATE STATUS	REGIONAL STATUS	GRANK	SRANK	DATE OBSERVED	IDENT.
*** Allamuchy Mountain (Site 7 on Tranquility, Site 4 on Stanhope Quadrangle)								
ACCIPITER COOPERII	COOPER'S HAWK ✓		E		G4	S2	1988-04-27	Y
AGROPYRON TRACHYCAULUM VAR GLAUCUM	SLENDER WHEATGRASS		E		G5T5	S1	1885-07-28	Y
ATHYRIUM PYCNOCARPON	GLADE FERN		E		G5	S1	1982-06-21	Y
CAREX LEPTONERVIA	FINELY-NERVED SEDGE		E		G4	S1	1905-05-30	Y
CLEMMYS INSCULPTA	WOOD TURTLE		T		G5	S3	1981-06-29	Y
CLEMMYS MUHLENBERGII	BOG TURTLE ✓	a	E		G3	S2	1981-05-26	Y
CLEMMYS MUHLENBERGII	BOG TURILE	C2	E		G3	S2	1977-06-15	
ERIOPHORUM GRACILE	SLENDER COTTONGRASS		E		G5	SH	1904-05-29	Y
PANICUM BOREALE	NORTHERN PANIC GRASS			E	G5	S1	1906-06-24	Y
PLATANTHERA HOOKERI	HOOKER'S ORCHID		E		G5	S1	1905-06-16	Y
PLATANTHERA ORBICULATA	LARGE ROUND-LEAVED ORCHID		E		G5?	S1	1907-07-21	Y
POTENTILLA PALUSTRIS	MARSH CINQUEFOIL		E		G5	S1	1943-06-06	Y
TIARELLA CORDIFOLIA	FOAMFLOWER		E		G5	S1	1979-05-21	Y
*** Bridge to Nowhere (Site 3 on Stanhope Quadrangle)								
CARDAMINE PRATENSIS VAR PALUSTRIS	CUCKOO FLOWER				G5T4T5	S2	1990-05-01	Y
DIRCA PALUSTRIS	LEATHERWOOD				G4	S2	1990-04-03	Y
DIRCA PALUSTRIS	LEATHERWOOD				G4	S2	1990-04-25	Y
EQUISETUM PRATENSE	MEADOW HORSETAIL		E		G5	S1	1990-04-03	Y
LEMNA TRISULCA	STAR DUCKWEED				G5	S2	1990-04-25	Y
MILIUM EFFUSUM	TALL MILLET GRASS		E		G5	SH	1980-??-??	Y
** Wolf Lake (Site 6 on Stanhope Quadrangle)								
MEGALODONTA BECKII	WATER-MARIGOLD		E		G4G5	S1	1985-??-??	Y
*** Wrights Pond Blufft (Site 5 on Sttnhopt Quadrangle)								
MUHLENBERGIA CAPILLARIS	LONG-AWNED SMOKE GRASS		E		G5	S1	1987-09-04	Y
RANUNCULUS FASCICULARIS	EARLY BUTTERCUP		E		G5	S1	1987-04-??	Y

PRIORITY NATURAL HERITAGE SITES WITHIN BYRAM

26 AUG 1991

BYRAM TOWNSHIP, SUSSM COUNTY
RARE SPECIES AND NATURAL COMMUNITIES PRESENTLY RECORDED IN
THE NEW JERSEY NATURAL HERITAGE DATABASE

NAME	COMMON NAME	FEDERAL STATUS	STATE STATUS	REGIONAL STATUS	GRANK	SRANK	DATE OBSERVED	IDENT.
*** Vertebrates								
ACCIPITER COOPERII	COOPER'S HAWK		E		G4	S2	1988-04-27	Y
CLEMMYS INSCULPTA	WOOD TURTLE		T		G5	s3	1981-06-29	Y
CLEMMYS MUHLENBERGII	BOG TURTLE	c2	E		G3	s2	1981-05-26	Y
CLEMMYS MUHLENBERGII	BOG TURTLE	c2	E		G3	s2	1977-06-15	
STRIX VARIA	BARRED OWL		T/T		G5	s3	1986-05-??	Y
*** Ecosystems								
CAVE AQUATIC COMMUNITY	CAVE AQUATIC COMMUNITY				G4?	S2	19??-??-??	Y
CAVE TERRESTRIAL COMMUNITY	CAVE TERRESTRIAL COMMUNITY				G4?	S3	19??-??-??	Y
*** Vascular plants								
AGROPYRON TRACHYCAULUM VAR GLAUCUM	SLENDER WHEATGRASS		E		G5T5	81	1885-07-28	Y
ATHYRIUM PYCNOCARPON	GLADEFERN		E		G5	S1	1982-06-21	Y
CAREX LEPTONERVIA	FINELY-NERVED SEDGE		E		c4	S1	1905-05-30	Y
CAREX ROSTRATA	BEAKED SEDGE				G5	s2	1907-07-10	Y
ERIOPHORUM GRACILE	SLENDER COTTONGRASS		E		G5	SH	1904-05-29	Y
GLYCERIA BOREALIS	SMALL FLOATING MANNAGRASS		E		G5	SE.1	1904-06-12	Y
MEGALODONTA BECKII	WATER-MARIGOLD		E		G4G5	S1	1938-07-16	Y
MEGALODONTA BECKII	WATER-MARIGOLD		E		G4G5	S1	1985-??-??	Y
MUHLENBERGIA CAPILLARIS	LONG-AWED SMOKE GRASS		E		G5	S1	1987-09-04	Y
MYRIOPHYLLUM VERTICILLATUM	WHORLED WATER-MILFOIL		E		G5	SB	1936-07-18	Y
PANICUM BOREALE	NORTHERN PANIC CRASS		E		G5	S1	1906-06-24	Y
PLATANTHERA HOOKERI	BOOKER'S ORCHID		E		G5	S1	1905-06-16	Y
PLATANTHERA ORBICULATA	LARGE ROUND-LEAVED ORCHID		E		G5?	S1	1907-07-21	Y
POTAMOGETON ZOSTERIFORMIS	FLAT-STEMMED PONDWEED		E		G5	S1	1867-07-04	Y
POTENTILLA PALUSTRIS	HARSH CINQUEFOIL		E		G5	S1	1943-06-06	Y
RANUNCULUS FASCICULARIS	EARLY BUTTERCUP		E		G5	S1	1987-04-??	Y
TIARELLA CORDIFOLIA	FOAMFLOWER		E		c5	S1	1979-05-21	Y

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Chapter 4

BEDROCK GEOLOGY, SURFICIAL GEOLOGY, AND SOILS

(Refer to the following maps in the Appendix of this document-- Topography, Bedrock Geology, Surficial Geology, Soil Classifications, Slopes, Surface Runoff and Floodways, Wetlands, Depth to Bedrock, Depth to Seasonal High Water Table, Septic Suitability.)

(See Chapter 5, WATER RESOURCES, for additional discussions of aquifers.)

GENERAL DESCRIPTION

Topography

Byram's topography is characterized by the northeast-southwest trend of the valleys and ridges, which parallel the dominant trend of the bedrock in the New Jersey Highlands. Relief in any localized area is seldom more than 100-200 feet; but, because of the narrowness of the valleys, the land appears more rugged. The topography ranges from 660 feet above mean sea level along Lubbers Run in Waterloo Village to 1,200 feet above mean sea level southwest of Cranberry Lake and southeast of Kofferls Pond and Lake Bottom.

Bedrock Geology

The regional bedrock consists mainly of crystalline gneissic and granitic rocks from the Pre-Cambrian era (a period extending from about 600- to about 4,500-million years ago), with a few down-faulted blocks containing rocks of Paleozoic age (from about 230- to about 600-million years ago).

With the exception of the Paleozoic Leithsville Formation, which is a dolomite, and the areas of deep glacial deposits (both marked in patterns on the Bedrock Geology Map), Byram's bedrock is relatively resistant (or impervious) and produces poor-to-moderate yields of underground drinking water. Stores of water accessible to wells are found only where the rock has fissured or fractured. Thus, the majority of the Township is underlain by rocks that exhibit limitations as aquifers; but areas underlain by Paleozoic rocks and thick glacial sediments may be more prolific.

Major faults in the bedrock also trend northeast-southwest, with less pronounced faults and cross-jointing occurring at right-angles to the major trend. Since faults can cause extensive fracturing in bedrock, rocks near the fault systems often have enhanced yields.

Magnetic ore bodies within the bedrock cause compass deviations, and this enabled early settlers to locate Byram's several mines.

Surficial Geology

Byram lies just north of the terminal moraine of the Wisconsinan (or Wisconsin) glacier, which began to retreat about 20,000 years ago. The moraine crosses the state from Belvidere to Denville, through Budd Lake, Stanhope, and Netcong, from Denville to Summit and to Perth Amboy.

Because of this glaciation, Byram's surficial deposits are predominantly glacial tills, with some stratified drift deposits occurring in valley areas and some moraine deposits along the Musconetcong River. These have been quarried to the south at Saxton Falls, where the moraine crosses the valley. Swamp deposits are scattered throughout the township, and stream deposits are found in the valleys, particularly along the Musconetcong, in the Lubbers Run area southwest of Lake Lackawanna, and in the area behind the Elementary School.

On the Surficial Geology Map, stratified drift deposits (layered sand, gravel, silt, and clay deposited by glacial meltwater) are patterned, because these deposits, along with the Leithsville bedrock, are potentially Byram's best aquifers.

Soils

Byram contains 23 soils, which may be classified into- 11 major types. The classification of soils reflects slopes as well as soil types.

The most common soils are the Rockaway soils, occurring on most of Byram's ridges and steeper slopes. These range from gravelly loams, to very stony soils, to soils having rock outcrops. In Byram, most Rockaway soils are steeply sloped (15-35%). Approximately 2/3 of Byram has slopes of 15% or more, approximately half of that being steeper than 25%.

Hibernia soils also occur on Byram's uplands. These are also often stony

or very stony, with slopes ranging up to 25%, although most of Byram's Hibernia soils are of 3-8% slope.

Riverhead soils are the third most common type in Byram. These are sandy loams occurring in and around valleys, with slopes from 3-15%.

Byram has few soils useful for agriculture.

The Soil Interpretations Records at the end of this chapter characterize the soils and also describe capabilities for agriculture, pasture, woodlands, windbreaks, and recreation, as well as limitations on site development and construction, water management, and septic systems. They also describe potential flora, as well as climate and landscaping properties.

BEDROCKGEOLOGY

Pre-Cambrian

Pre-Cambrian rocks found in Byram include:

1. Hornblende granite and syenite--the most extensive rock type found in Byram. The majority of the center of Byram, from Route 206 to Old Farm and Stag ponds and to the intersection of Amity-Lee Hill and Sparta-Stanhope roads, is hornblende syenite, although it is interrupted by several other formations. Hornblende granite occupies most of the area between Stag Pond and the Sparta border and, at the other end of the township, between Cranberry Lake and the Allamuchy border. Hornblende granite and syenite are complex units consisting of metamorphosed igneous rock.

2. Marble and skarn--marble is metamorphosed limestone, which is of sedimentary origin. It is generally crystalline, medium- to coarse-grained, massive, and white to gray in color. In Byram, marble occurs in association with skarn, a Swedish mining term for aggregates of dark silicate materials rich in iron, magnesia, and lime. Skarn is a host-rock for sulfide and magnetite deposits. At the Roseville Mine (see Historical Map), skarn was mined for magnetite. Marble and skarn also occur in a small area on the eastern shore of Cranberry Lake, in two locations along Route 206 between Cranberry Lake and Lackawanna Drive, in small belts west and south of Stag Pond, and in small areas south of Old Farm Pond, northwest of Roseville Pond, and northwest of Lake Mohawk.

3. Amphibolite--amphibolites consist of equal amounts of feldspar

and of one or more minerals such as pyroxene, hornblende, and biotite. A belt of amphibolite runs across Byram immediately above Cranberry, Johnson, and Stag lakes and to the west shore of Lake Mohawk. There are smaller bodies south and west of Jefferson Lake, in the southwestern corner of the Township, along Amity Road, and stretching from Kofferls Pond to Tomahawk Lake.

4. Gneiss--a metamorphic or metasedimentary rock which is variable in its composition; it may contain quartz, biotite, magnetite, garnet, sphene, and/or other minerals. Gneiss is found in all areas of the Township, particularly between Cranberry and Jefferson lakes, throughout the area below Jefferson and Lackawanna lakes extending to Lubbers Run, between Johnson Lake and Roseville Pond, in the area bordered by Stag Pond, Old Farm Pond and Amity-Roseville Road, and in other smaller belts.

Paleozoic

Paleozoic rocks found in Byram are limited, whereas to the west they extend almost continuously from Andover to the Delaware Water Gap and beyond. The largest exposed belt of Paleozoic rocks occurs in the flat valley depression between Roseville and Kofferls ponds. A second area lies southwest of Lake Lackawanna. Others occur in the Waterloo Village area and immediately south of Lake Mohawk.

Two types of Paleozoic rock units are found in Byram:

1. Hardyston Quartzite--composed of sandstone, pebble conglomerate, dolomitic shale and quartzite, this rock is both alluvial and marine in origin. This type is found in thin belts alongside the Leithsville formations.

2. Leithsville Formation--consisting of dolomite, dolomitic sandstone, shale and sparse quartz-pebble conglomerate, this formation is marked by mud cracks, ripple marks, graded beds. This rock unit is found in the areas described above. Unlike the rest of Byram's bedrock, which is more impervious and can store underground water only where fissured, the Leithsville formation contains limestone and so may provide aquifers where the limestone has been dissolved to form caverns. However, these Leithsville formations are probably too small to provide substantial water supplies.

Other units shown on the Bedrock Geology Map include thick unconsolidated deposits which obscure the bedrock. These include moraine deposits (the tills and sediments deposited by a glacier along its margin, generally 50-200 feet thick) in the Musconetcong River area and up toward Jefferson

TABLE IX:
MAJOR GEOLOGZC EVENTS AFFECTING BYRAM

More than I billion years ago: Pre-Cambrian rocks are crystallized; iron-rich ore-bodies, containing lead, zinc, nickel, magnesium, and manganese deposits, are formed.

About.600 million years ago: epicontinental seas advance; wave action reworks earlier alluvial deposits of sandstone and conglomerate units of Hardyston formation.

About 460-440 million years ago: compression crumbles, contorts, folds, and mildly metamorphoses rocks; the entire region -is uplifted, creating mountain ranges.

About 360 million years ago: a second mountain-building period (orogeny) lifts the Highlands region; erosion begins again.

About 240 million years ago: a third and final orogency occurs; uplifting and faulting exposes sequences of Paleozoic rocks.

About 200 million years ago: the most recent movement occurs on major northeast-southwest faults with southeasterly dips. (See the Bedrock Geology Map for fault lines.)

Several subsequent gentle uplifts followed by erosion create Byram's current topography.

About SO-100 million years ago: Byram is covered by a shallow sea; the carbonate sediments of the Leithsville Formation are deposited.

About 2 million to 17,000 years ago: three glaciations occur in New Jersey. The Wisconsinan glaciation erases the effects of the first two--retreating from this area about 20,000 years ago, it leaves its terminal moraine south of Byram, near Budd Lake, Stanhope, Netcong and Interstate-go.

Lake, and Quaternary deposits (swamp or stream deposits and glacial deposits) shown in several areas. The bedrock beneath these deposits is not always known, although in the Musconetcong-Waterloo area the underlying bedrock is limestone.

These deposits are mapped in more detail on the Surficial Geology Map, although their inclusion on the Bedrock Geology Map helps to indicate which surficial deposits continue to greater depths.

SURFICIAL GEOLOGY

Surficial geology describes the unconsolidated deposits above bedrock and on which soils form. Soils form by a process of chemical and physical alteration of the materials below the soil (parent material).

In **Byram,** surficial deposits are largely glacial, left by the Wisconsinan glaciation, which began to retreat about 20,000 years ago. The Wisconsinan either bulldozed, crushed, or scraped off most of the soil **and** rock in its path, erasing the effects of the earlier **Illinoian** and **Jerseyan glaciations** in this area.

Glacial till, a poorly-sorted, nonstratified sediment ranging in size from fine clays to large boulders, is the most common surficial deposit in **Byram.** It was deposited directly from glacial ice.

In **Byram,** the till is a sand to silty sand containing many boulders and gravel **clasts** (detached fragments from rock outcrops which have been transported and shaped by water, ice, wind, or the flow of the glacier). In large areas of **Byram,** the till is less than 10 feet thick and is interrupted by scattered outcrops of bedrock. In deeper deposits, it is generally between 10 and 30 feet thick but may be as much as 70 feet thick.

The shallow till areas are shown as white on the Surficial Geology Map, while deeper till deposits are marked by the letter B.

Till is a poor aquifer (single wells may be adequate to supply a home) and the alluvium and swamp deposits scattered throughout the Township and in its river valleys are not aquifers.

However, the stratified drift deposits (indicated by the letter A on the Surficial Geology Map and patterned with dots) **may** represent **Byram's** most prolific aquifers. This may be especially true where they overlay limestone formations (in the Musconetcong-Waterloo area and on either side of Roseville Pond) or where the deposits are thick enough to support wells and maintain a supply of water (at the east end of Cranberry Lake, below Lake Lackawanna, in the Waterloo-Musconetcong area, and in a few places along Lubbers Run). Elsewhere they are too thin to supply water wells, but serve as important recharge areas for underlying aquifers or as a source of ground-water discharge to streams.

For a complete discussion of stratified drift formations and their role as aquifers or recharge areas, see Geology of the Glacial Aquifers of New Jersey, a draft document by the New Jersey Geological Survey, in the Environmental Commission files at the Municipal Building.

This document details the various types of glacial drift deposits. Basically, these deposits are sorted layers of sand and gravel left by glacial streams, ponds, and lakes. Some have confining layers of silts and clays over them, and this confinement may affect the deposit's function as an aquifer, its connection to surrounding bedrock or surficial geology, and its vulnerability to contamination.

Because glacial aquifers are small, they are susceptible to depletion; and because they are very permeable and near the surface, they are susceptible to pollution.

SOILS

Several maps are derived from the soil classifications and interpretations, including Depth to Bedrock, Depth to Seasonal High Groundwater, Slopes, Wetlands (which are defined by the presence of ***hydric soils,**** as well as by certain kinds of vegetation and the presence of standing water). The Septic Suitability Map is based on these features.

****Hydric soils are soils that are saturated frequently enough during the growing season to become anaerobic, or oxygen depleted. Non-hydric soils***

are less frequently saturated and remain aerobic. Several other characteristics, not listed here, help to identify hydric and non-hydric soils in the field.

The Depth to Bedrock and the Seasonal High Groundwater Maps are included because the state's septic regulations (revised in 1990 and again in 1993--commonly referred to as 'Chapter 199' but officially known as New Jersey Administrative Code 7:9A) permit no systems in areas where the groundwater is shallower than 2 feet and call for a 4-foot minimum depth to bedrock. Septics are also prohibited on slopes of 25% or more and are not feasible in areas of rock outcrop because of the minimum 4-foot depth of soil required.

These environmental features were also factors in the township's environmental constraints ordinance, which called for subtracting certain percentages of constrained lands from overall density calculations. In 1992, a state Appellate Court decision (Manalapan Builders Alliance vs. Manalapan Township) invalidated a similar ordinance, leaving municipalities to seek other ways to apply a critical areas approach to density. The court ruling was based on definitions within the state's Municipal Land Use Law calling for densities to be based on gross, not net, acreage.

Some planners are questioning whether the MLUL itself should be changed to catch up with environmental planning practices.

The Depth to Bedrock Map is also useful because it points to areas that may not have adequate depth for construction of footings and laying of pipes below frost (the depth of frost is generally 3-feet). Depth to Bedrock and to Seasonal High Groundwater Maps also help indicate areas unsuitable for buildings with basements.

The Septic Suitability categories are based on ratings within the state's most recent 'Chapter 199.' Large areas of Byram are considered generally unsuitable for septics, and many other areas are severely restricted. These unsuitable-restricted areas generally occur on the Township's ridges and steep slopes. Areas rated as possibly suitable generally follow the valleys and thus the main roads. In all cases, however, site specific studies are required; even Byram's best rated areas are mixed, having some suitable locations and some restricted.

The Septic Suitability Map and its key were based on the recommendations of a soil scientist with the U.S.D.A. Soil Conservation Service, who listed each soil type within Byram according to the 'Chapter 199' ratings and described probable systems for restricted areas.

ENGINEERING PROPERTIES

Bedrock

The Pre-Cambrian crystalline rocks and the Hardyston quartzite generally have high compressive rock strengths, providing excellent foundation support. This rock strength can also be a drawback because it complicates excavations for deep foundations, trenches or buried pipes and wires, often requiring blasting. The problem is accentuated where bedrock is exposed or near the surface.

These rocks can also impede groundwater recharge, because they are impervious and often lie near the surface. This can cause high water tables and increased surface run-off. In low areas, these rocks may cause ponding.

The Paleozoic limestones allow better surface drainage and groundwater recharge. Migrating groundwater has dissolved the limestone over the millenia, leaving cavities of different sizes. However, this solubility can pose problems if the voids become large enoughto cause surface settling of soils of the collapse of the rock ceiling. When this happens, sinkholes appear on the surface, creating what is known as 'karst topography.' As yet, there are no surface indications of any extensive dissolution of Byram's limestone bedrock.

Limestone which is unweathered can also be difficult to excavate.

Glacial Deposits

Glacial tills generally pose engineering problems. Large boulders in the till can hamper excavation and may even require blasting. Tills often contain silts and clays that hamper groundwater recharge, creating poor drainage and increased run-off. Hardpan, a hard impervious layer mostly composed of clays cemented by relatively insoluble materials, is very common-to till and is sometimes found in stratified drift deposits. It also inhibits groundwater recharge and can cause perched (artificially raised)

water tables. Hardpan can be so compact and cemented that blasting is required to excavate it.

Stratified drift and some moraine deposits usually have good drainage and permeability, especially if they are sand and gravel formations. Those containing finer silts and clays are less permeable.

Some of these deposits are excavated for sale as sand and gravel.

Faults, Joints, Fractures

Faults in Byram have probably been inactive since the Triassic era (about 180 million years ago), and therefore movement along them is unlikely. Byram is located in a fairly inactive seismic zone, although occasional minor tremors may be felt.

Many of Byram's faults produce open fractures, while in other cases these have been mineralized. Non-mineralized faults may act as conduits for groundwater and so could present problems for structures such as dams or landfills, which must hold back water or segregate contaminants from groundwater.

Rocks along faults, joints or fractures may be weakened by fragmenting and fracturing and so may separate if they are-excavated or quarried. Clayey seams may also act as a lubricant, causing rocks to move during excavation.

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The Environmental Commission would like to thank Ron Witte, Scott Stanford, Richard Volkert, and Robert Canace of the N.J. Department of Environmental Protection, Geological Survey, for their help with the geology maps and text.

The Commission would also like to thank George Dan Jones and David Kingsbury of the U.S.D.A. Soil Conservation Office in Hackettstown for their help with the text on soils and the maps of Septic Suitability, Depth to Bedrock, and Depth to Seasonal High Groundwater.

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(NOTE: the next 30 pages contain Soil Interpretations Records, which give detailed information about the soils that occur in Byram.)

SOIL INTERPRETATIONS RECORD: Carlisle Series

MLRA(S): 95A, 96, 97, 98, 99, 105, 111
REV. LWP 3-92
TYPIC MEDISAPRISTS, EUIC, MESIC

THE CARLISLE SERIES CONSISTS OF VERY DEEP, VERY POORLY DRAINED SOILS FORMED IN WOODY ORGANIC DEPOSITS IN BOGS AND OTHER DEPRESSIDHAL AREAS WITHIN LAKE PLAINS OUTWASH PLAINS AND TILL PLAINS. THE SURFACE LAYER IS BLACK MUCK 8 INCHES THICK. THE UNDERLYING MATERIAL IS BLACK AND DARK REDDISH BROWN MUCK. SLOPES ARE 0 TO 2 PERCENT. CROPLAND IS THE MAIN USE.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
47-50	120-180	30-36	600-1200	VP	0-2

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-66	MUCK	PT	A-8	0	0-30					

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-66			0.13-0.23	0.2-6.0	0.35-0.45	4.5-7.8			150-250		

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KF	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-66	70-99				5	2	134	HIGH	LOW

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			+.5-1.0	APPARENT	SEP-JUN			>60		6-18	43-54	A/D	HIGH

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	SEVERE-SUBSIDES,PONDING,PERCS SLOWLY
SEWAGE LAGOON AREAS	SEVERE-SEEPAGE,EXCESS HUMUS,PONDING
SANITARY LANDFILL (TRENCH)	SEVERE-SEEPAGE,PONDING,EXCESS HUMUS
SANITARY LANDFILL (AREA)	SEVERE-SEEPAGE,PONDING
DAILY COVER FOR LANDFILL	POOR-PONDING,EXCESS HUMUS

CONSTRUCTION MATERIAL

ROADFILL ***	POOR-WETNESS,LOW STRENGTH
SAND	IMPROBABLE-EXCESS HUMUS
GRAVEL	IMPROBABLE-EXCESS HUMUS
TOPSOIL ***	POOR-EXCESS HUMUS,WETNESS

WATER MANAGEMENT

POND RESERVOIR AREA	SEVERE-SEEPAGE
EMBANKMENTS DIKES AND LEVEES	SEVERE-EXCESS HUMUS,PONDING
EXCAVATED PONDS AQUIFER FED	SEVERE-SLOW REFILL
DRAINAGE ***	PONDING,SUBSIDES,FROST ACTION
IRRIGATION ***	PONDING,SOIL BLOWING
TERRACES AND DIVERSIONS ***	PONDING,SOIL BLOWING
GRASSED WATERWAYS ***	WETNESS

BUILDING SITE DEVELOPMENT

SHALLOW EXCAVATIONS	SEVERE-EXCESS HUMUS,PONDING
DWELLINGS WITHOUT BASEMENTS	SEVERE-SUBSIDES,PONDING,LOW STRENGTH
DWELLINGS WITH BASEMENTS	SEVERE-SUBSIDES,PONDING,LOW STRENGTH
SMALL COMMERCIAL BUILDINGS	SEVERE-SUBSIDES,PONDING,LOW STRENGTH
LOCAL ROADS AND STREETS	SEVERE-SUBSIDES,PONDING,FROST ACTION
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	SEVERE-PONDING,EXCESS HUMUS

RECREATIONAL DEVELOPMENT

CAMP AREAS	SEVERE-PONDING,EXCESS HUMUS	PLAYGROUNDS	SEVERE-EXCESS HUMUS,PONDING
PICNIC AREAS	SEVERE-PONDING,EXCESS HUMUS	PATHS AND TRAILS	SEVERE-PONDING,EXCESS HUMUS

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY		CORN (BU)		CORN SILAGE (TONS)		SOYBEANS (BU)		RED CLOVER HAY (TONS)		OATS (BU)		SUGAR BEETS (TONS)			
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
DRAINED	3W		130		20		37		4.0		80		18			
UNDRAINED	5W															

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS: EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	POTENTIAL PRODUCTIVITY: COMMON TREES	SITE INDX	PROD CLAS	TREES TO PLANT
PHASE	2W	SLIGHT	SEVERE	SEVERE	SEVERE	SEVERE	RED MAPLE	56	2	
							WHITE ASH			
							GREEN ASH			
							QUAKING ASPEN			
							SWAMP WHITE OAK			
							SILVER MAPLE	82	2	

WINDBREAKS (A)

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
DRAINED,HIGH PPT	NORTHERN WHITECEDAR	20	COMMON NINEBARK	8	AMUR PRIVET	10	AMERICAN CRANBERRYBU	10
	SILKY DOGWOOD	8	NANNYBERRY VIBURNUM	15	WHITE SPRUCE	20		60
	SIBERIAN CRABAPPLE	25	EASTERN WHITE PINE	30	GREEN ASH	30	NORWAY SPRUCE	30
DRAINED,LOW PPT		60	GOLDEN WILLOW	33	WHITEBELLE HONEYSUCK	10	WHITE WILLOW	33
	BLACK WILLOW	31	AMUR PRIVET	15	SILKY DOGWOOD	8	TALL PURPLE WILLOW	23
	COMMON NINEBARK	7						

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS: GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	POTENTIAL AS HABITAT FOR: OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL	POOR	POOR	POOR	POOR	POOR		GOOD	GOOD	POOR	POOR	GOOD	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POISON SUMAC	TOVE					
REDOSIER DOGWOOD	COST4					
SPECKLED ALDER	ALRU3					
WILLOW	SALIX					
SEDGE	CAREX					
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A UNDRAINED:WINDBREAK GROUP 2(H) DRAINED:WINDBREAK GROUP 1

***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

DC0021

SOIL INTERPRETATIONS RECORD: Dumps

MLRA(S): ALL
REV. LNL, 2-86

DUMPS ARE AREAS OF SMOOTHED OR UNEVEN ACCUMULATIONS AND GENERAL REFUSE. SLOPES ARE D TO SD PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
					D-SD

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-60	VAR									

DEPTH (IN.)	LIQUID LIMIT	PLAS-TICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEA-BILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-60											

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	Kf	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-60									

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0					>60					

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	VARIABLE
SEWAGE LAGOON AREAS	VARIABLE
SANITARY LANDFILL (TRENCH)	VARIABLE
SANITARY LANDFILL (AREA)	VARIABLE
DAILY COVER FOR LANDFILL	VARIABLE

CONSTRUCTION MATERIAL

ROADFILL	VARIABLE
SAND	VARIABLE
GRAVEL	VARIABLE
TOPSOIL	VARIABLE

WATER MANAGEMENT

POND RESERVOIR AREA	VARIABLE
EMBANKMENTS DIKES AND LEVEES	VARIABLE
EXCAVATED PONDS AQUIFER FED	VARIABLE
DRAINAGE	VARIABLE
IRRIGATION	VARIABLE
TERRACES AND DIVERSIONS	VARIABLE
GRASSED WATERWAYS	VARIABLE

BUILDING SITE DEVELOPMENT

SHALLOW EXCAVATIONS	VARIABLE
DWELLINGS WITHOUT BASEMENTS	VARIABLE
DWELLINGS WITH BASEMENTS	VARIABLE
SMALL COMMERCIAL BUILDINGS	VARIABLE
LOCAL ROADS AND STREETS	VARIABLE
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	VARIABLE

RECREATIONAL DEVELOPMENT

CAMP AREAS	VARIABLE	PLAYGROUNDS	VARIABLE
PICNIC AREAS	VARIABLE	PATHS AND TRAILS	VARIABLE

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY															
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
ALL	8S															

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
							NONE			

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS		0				
NORMAL YEARS		0				
UNFAVORABLE YEARS		0				

FOOTNOTES

SOIL INTERPRETATIONS RECORD: Hibernia Series

MLRA(S): 144A, 148
REV. NJSCS-4-86
AQUIC FRAGIUDULTS, COARSE-LOAMY, MIXED, MESIC

THE HIBERNIA SERIES CONSISTS OF DEEP, SOMEWHAT POORLY DRAINED SOILS ON UPLANDS. THEY FORMED IN GLACIAL TILL AND COLLUVIAL MATERIAL. TYPICALLY THESE SOILS HAVE A VERY DARK GRAYISH-BROW, COBBLY LOAM SURFACE LAYER 5 INCHES THICK. THE SUBSOIL FROM 5 TO 25 INCHES- IS YELLOWISH-BROWN COBBLY SANDY LOAN WITH MOTTLES BELOW 9 INCHES. A FIRM AND BRITTLE MOTTLED FRAGIPAN FROM 25 TO 36 INCHES IS DARK YELLOWISH-BROWN GRAVELLY SANDY LOAM. THE SUBSTRATUM LAYERS FROM 36 TO 72 INCHES ARE GRAVELLY SANDY LOAM AND GRAVELLY LOAMY SAND. SLOPES RANGE FROM 0 TO 25 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
				SP	0-25

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-5	SIL,L	CL-ML,CL	A-4		0-5	85-95	75-90	70-85	60-75	7-15
0-5	GR-L,GR-SIL,CB-L	CL-ML,CL	A-4		5-30	70-85	55-75	50-70	40-70	7-15
5-25	CB-SL,CB-L,SL	CL-ML,SC-SM	A-4,A-2		5-15	80-95	65-90	40-80	30-60	10-18
25-36	GR-SL	SM,SC	A-2,A-1-B		0-5	75-95	65-80	40-55	20-35	5-15
36-72	GR-LS,GR-SL	SM,SC,SC-SM	A-2,A-1-B		0-10	65-90	60-80	40-70	15-25	5-10

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-5	20-30	5-10	1.22-1.35	0.6-2.0	0.12-0.16	3.6-5.5					
0-5	20-30	5-10	1.22-1.35	0.6-2.0	0.12-0.16	3.6-5.5					
5-25	20-30	5-10	1.25-1.42	0.6-2.0	0.10-0.16	4.5-5.5					
25-36	20-30	5-10	1.55-1.70	0.06-0.2	0.06-0.10	4.5-5.5					
36-72	15-25	NP-10	1.50-1.75	6.0-20.0	0.06-0.09	4.5-5.5					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KF	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-5	2-5	LOW	.37		5			MODERATE	HIGH
0-5	2-5	LOW	.32		3				
5-25		LOW	.32						
25-36		LOW	.28						
36-72		LOW	.17						

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			0.5-1.5	PERCHED	DEC-MAY			>60				C	HIGH

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	SEVERE-WETNESS,PERCS SLOWLY,POOR FILTER
SEWAGE LAGOON AREAS	0-7%:SEVERE-SEEPAGE,WETNESS 7-25%:SEVERE-SEEPAGE,SLOPE,WETNESS
SANITARY LANDFILL (TRENCH)	0-15%:SEVERE-SEEPAGE,WETNESS 15-25%:SEVERE-SEEPAGE,WETNESS,SLOPE
SANITARY LANDFILL (AREA)	0-15%:SEVERE-SEEPAGE,WETNESS 15-25%:SEVERE-SEEPAGE,WETNESS,SLOPE
DAILY COVER FOR LANDFILL	0-15%:POOR-WETNESS 15-25%:POOR-SLOPE,WETNESS

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	0-15%:SEVERE-CUTBANKS CAVE,WETNESS 15-25%:SEVERE-CUTBANKS CAVE,WETNESS,SLOPE
DWELLINGS WITHOUT BASEMENTS	0-15%:SEVERE-WETNESS 15-25%:SEVERE-WETNESS,SLOPE
DWELLINGS WITH BASEMENTS	0-15%:SEVERE-WETNESS 15-25%:SEVERE-WETNESS,SLOPE
SMALL COMMERCIAL BUILDINGS	0-8%:SEVERE-WETNESS 8-25%:SEVERE-WETNESS,SLOPE
LOCAL ROADS AND STREETS	0-15%:SEVERE-WETNESS,FROST ACTION 15-25%:SEVERE-WETNESS,SLOPE,FROST ACTION
LAWNS, LANDSCAPING AND GOLF	0-15%:SEVERE-WETNESS 15-25%:SEVERE-WETNESS,SLOPE

CONSTRUCTION MATERIAL (B)

ROADFILL	POOR-WETNESS
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	0-15%:POOR-SMALL STONES,WETNESS 15-25%:POOR-SMALL STONES,WETNESS,SLOPE

WATER MANAGEMENT (B)

POND RESERVOIR AREA	0-8%:SEVERE-SEEPAGE 8-25%:SEVERE-SEEPAGE,SLOPE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE,WETNESS
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	0-3%:PERCS SLOWLY,FROST ACTION 3-25%:PERCS SLOWLY,FROST ACTION,SLOPE
IRRIGATION ***	WETNESS,DROUGHTY,PERCS SLOWLY
TERRACES AND DIVERSIONS	0-8%GR-L,CB-L,GR-SIL:WETNESS 8-25%GR-L,CB-L,GR-SIL:SLOPE,WETNESS 0-8%SIL,L:ERODES EASILY,WETNESS 8-25%SIL,L:SLOPE,ERODES EASILY,WETNESS
GRASSED WATERWAYS	0-8%GR-L,CB-L,GR-SIL:WETNESS 8-25%GR-L,CB-L,GR-SIL:WETNESS,SLOPE 0-8%SIL,L:WETNESS,ERODES EASILY

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	0-15%:SEVERE-WETNESS 15-25%:SEVERE-SLOPE,WETNESS	PLAYGROUNDS	0-6%SIL,L:SEVERE-WETNESS 6-25%SIL,L:SEVERE-SLOPE,WETNESS 0-6%GR,CB:SEVERE-SMALL STONES,WETNESS 6-25%GR,CB:SEVERE-SLOPE,SMALL STONES,WETNESS
PICNIC AREAS	0-15%:SEVERE-WETNESS 15-25%:SEVERE-SLOPE,WETNESS	PATHS AND TRAILS	GR-L,CB-L,GR-SIL:SEVERE-WETNESS SIL,L:SEVERE-WETNESS,ERODES EASILY

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPA-BILITY		CORN (BU)		CORN SILAGE (TONS)		OATS (BU)									
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-3%	3W		110		22		80									
3-8%	3W		110		22		80									
8-15%	3E		100		20		75									
15-25%	4E		90		18		70									

WOODLAND SUITABILITY (C)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
0-15%	4W	SLIGHT	MODER.	SLIGHT	SLIGHT	SEVERE	WHITE OAK	80	4	YELLOW-POPLAR
15-25%	4R	MODER.	MODER.	SLIGHT	SLIGHT	MODER.	PIN OAK	80	4	
							WHITE ASH			
							YELLOW-POPLAR	90	6	

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-3%	FAIR	GOOD	GOOD	GOOD	GOOD		FAIR	POOR	GOOD	GOOD	POOR	
3-8%	FAIR	GOOD	GOOD	GOOD	GOOD		POOR	V. POOR	GOOD	GOOD	V. POOR	
8-15%	FAIR	GOOD	GOOD	GOOD	GOOD		V. POOR	V. POOR	GOOD	GOOD	V. POOR	
15-25%	POOR	FAIR	GOOD	GOOD	GOOD		V. POOR	V. POOR	FAIR	GOOD	V. POOR	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED ON TEST DATA OF SIMILAR SOILS.
B RATINGS BASED ON NATIONAL SOILS HANDBOOK.
C RATINGS BASED ON NATIONAL FORESTRY MANUAL
D RATINGS BASED ON SOILS MEMO 74, JANUARY 1972
***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

NJ0050

SOIL INTERPRETATIONS RECORD: Hibernia Series Stony

MLRA(S): 144A
REV. MLM-JCF, 4-86
AQUIC FRAGIUDULTS, COARSE-LOAMY, MIXED, MESIC

THE NIBERNIA SERIES CONSISTS OF DEEP, SOMEWHAT POORLY DRAINED SOILS ON UPLANDS. THEY FORMED IN GLACIAL TILL AND COLLWIAL MATERIAL. TYPICALLY, THESE SOILS HAVE A VERY DARK GRAYISH-BROWN STONY VERY STONY OR EXTREMELY STONY LOAM SURFACE LAYER 5 INCHES THICK. THE SUBSOIL FROM 5 TO 25 INCHES IS YELLOWISH-BROWN COBBLY SANDY LOAM WITH MOTTLES BELOW 9 INCHES. A FIRM AND BRITTLE MOTTLED FRAGIPAN FROM 25 TO 36 INCHES IS DARK YELLOWISH-BROWN GRAVELLY SANDY LOAM THE SUBSTRATUM LAYERS FROM 36 TO 72 IN. ARE GRAVELLY SANDY LOAM AND GRAVELLY LOAMY SAND. SLOPES RANGE FROM 0 TO 25 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
				SP	0-25

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-5	STV-L,STX-L,STV-SIL	CL-ML,CL	A-4		10-20	75-95	60-75	55-70	40-60	7-15
0-5	ST-L,ST-SIL	CL-ML,CL	A-4		5-10	80-95	75-90	65-80	50-65	7-15
5-25	CB-SL,CB-L,SL	CL-ML,SC-SM	A-4,A-2		5-15	80-95	65-90	40-80	30-60	10-18
25-36	GR-SL	SC-SM	A-2,A-1-B		0-5	75-95	65-80	40-55	20-35	5-15
36-72	GR-LS,GR-SL	SM,SC,SC-SM	A-2,A-1-B		0-10	65-90	60-80	40-70	15-25	5-10

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-5	20-30	5-10	1.22-1.35	0.6-2.0	0.10-0.16	3.6-5.5					
0-5	20-30	5-10	1.22-1.35	0.6-2.0	0.10-0.16	3.6-5.5					
5-25	20-30	5-10	1.25-1.42	0.6-2.0	0.10-0.16	4.5-5.5					
25-36	20-30	5-10	1.55-1.70	0.06-0.2	0.06-0.10	4.5-5.5					
36-72	15-25	NP-10	1.50-1.75	6.0-20	0.06-0.09	4.5-5.5					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KT	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-5	2-5	LOW	.28		5			MODERATE	HIGH
0-5	2-5	LOW	.32		3				
5-25		LOW	.32						
25-36		LOW	.28						
36-72		LOW	.17						

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			0.5-1.5	PERCHED	DEC-MAY			>60				C	HIGH

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	SEVERE-WETNESS,PERCS SLOWLY,POOR FILTER
SEWAGE LAGOON AREAS	0-7%:SEVERE-SEEPAGE,WETNESS 7-25%:SEVERE-SEEPAGE,SLOPE,WETNESS
SANITARY LANDFILL <TRENCH)	0-15%:SEVERE-SEEPAGE,WETNESS 15-25%:SEVERE-SEEPAGE,WETNESS,SLOPE
SANITARY LANDFILL (AREA)	0-15%:SEVERE-SEEPAGE,WETNESS 15-25%:SEVERE-SEEPAGE,WETNESS,SLOPE
DAILY COVER FOR LANDFILL	0-15%:POOR-WETNESS 15-25%:POOR-SLOPE,WETNESS

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	0-15%:SEVERE-CUTBANKS CAVE,WETNESS 15-25%:SEVERE-CUTBANKS CAVE,WETNESS,SLOPE
DWELLINGS WITHOUT BASEMENTS	0-15%:SEVERE-WETNESS 15-25%:SEVERE-WETNESS,SLOPE
DWELLINGS WITH BASEMENTS	0-15%:SEVERE-WETNESS 15-25%:SEVERE-WETNESS,SLOPE
SMALL COMMERCIAL BUILDINGS	0-8%:SEVERE-WETNESS 8-25%:SEVERE-WETNESS,SLOPE
LOCAL ROADS AND STREETS	0-15%:SEVERE-WETNESS,FROST ACTION 15-25%:SEVERE-WETNESS,SLOPE,FROST ACTION
LAWNS, LANDSCAPING AND GOLF	0-15%:SEVERE-WETNESS 15-25%:SEVERE-WETNESS,SLOPE

CONSTRUCTION MATERIAL (B)

ROADFILL	POOR-WETNESS
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	0-15%:POOR-SMALL STONES,WETNESS 15-25%:POOR-SMALL STONES,WETNESS,SLOPE

WATER MANAGEMENT (B)

POND RESERVOIR AREA	0-8%:SEVERE-SEEPAGE 8-25%:SEVERE-SEEPAGE,SLOPE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE,WETNESS
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	0-3%:PERCS SLOWLY,FROST ACTION 3-25%:PERCS SLOWLY,FROST ACTION,SLOPE
IRRIGATION ***	WETNESS,DROUGHTY,PERCS SLOWLY
TERRACES AND DIVERSIONS	0-8%:WETNESS,ROOTING DEPTH 8-25%:SLOPE,WETNESS,ROOTING DEPTH
GRASSED WATERWAYS	0-8%:WETNESS,DROUGHTY 8-25%:WETNESS,SLOPE,DROUGHTY

Hibernia Series Stony

NJ0050

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	0-15%:SEVERE-WETNESS 15-25%:SEVERE-SLOPE,WETNESS	PLAYGROUNDS ***	0-6%:SEVERE-SMALL STONES 6-25%:SEVERE-SMALL STONES,SLOPE
PICNIC AREAS	0-15%:SEVERE-WETNESS 15-25%:SEVERE-SLOPE,WETNESS	PATHS AND TRAILS	SEVERE-WETNESS

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPA-BILITY		CORN SILAGE (TONS)		GRASS-LEGUME HAY (TONS)											
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-3% ST	2S		20		3.0											
3-8% ST	3S		18		2.8											
8-15% ST	4S		16		2.5											
0-3% STV	6S															
3-25% STV	6S															
0-15% STX	7S															
15-25% STX	7S															

WOODLAND SUITABILITY (C)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
0-15% ST,STV	4W	SLIGHT	MODER.	SLIGHT	SLIGHT		WHITE OAK	80	4	
15-25% ST,STV	4R	MODER.	MODER.	SLIGHT	SLIGHT		PIN OAK	80	4	
0-15% STX	4X	SLIGHT	MODER.	SLIGHT	SLIGHT		WHITE ASH			
15-25% STX	4R	SLIGHT	MODER.	SLIGHT	SLIGHT		YELLOW-POPLAR	90	6	

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
3-8% ST	POOR	FAIR	GOOD	GOOD	GOOD		POOR	V. POOR	FAIR	GOOD	V. POOR	
8-25% ST	POOR	POOR	GOOD	GOOD	GOOD		V. POOR	V. POOR	FAIR	GOOD	V. POOR	
3-8% STV,STX	V. POOR	V. POOR	GOOD	GOOD	GOOD		POOR	V. POOR	POOR	GOOD	V. POOR	
8-25% STV,STX	V. POOR	V. POOR	GOOD	GOOD	GOOD		V. POOR	V. POOR	POOR	GOOD	V. POOR	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS NORMAL YEARS UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED OR TEST DATA OF SIMILAR SOILS.
B RATINGS BASED ON NATIONAL SOILS HANDBOOK, SECTION 603
C RATINGS BASED ON NATIONAL FORESTRY MANUAL
D RATINGS BASED DN SOILS MEMO 74, JANUARY 1972
***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

NJ0301

SOIL INTERPRETATIONS RECORD: Humaquepts Frequently Flooded

MLRA(S): 144
REV. SG,UCK, 4-84
HUMAQUEPTS

HUMAQUEPTS FREQUENTLY FLOODED CONSISTS OF DEEP, SOMEWHAT POORLY DRAINED TO VERY POORLY DRAINED SOILS ADJACENT TO PERENNIAL STREAMS IN THE COASTAL PLAIN PROVINCE THAT ARE SUBJECT TO FREQUENT STREAM OVERFLOW. THESE SOILS FORMED IN SEDIMENTS THAT ARE QUITE VARIABLE IN TEXTURE. SLOPES RANGE FROM 0 TO 1 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
				SP	0-1

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-10	L,S,C	SP,SM,ML,MH	A-1,A-2,A-4,A-7		0-1	90-100	85-100	50-100	5-95	2-40
10-60	L,S,C	SP,SM,ML,MH	A-1,A-2,A-4,A-7		0-1	90-100	85-100	50-100	5-95	2-40

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-10	15-55	NP-25	1.10-1.40	0.2-6.0	0.06-0.18	3.6-5.5					
10-60	15-55	NP-25	1.20-1.40	0.2-6.0	0.06-0.18	3.6-5.5					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KT	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-10	4-20	MODERATE	.20		4			HIGH	HIGH
10-60		MODERATE							

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
FREQ	BRIEF	SEP-JUN	0.5-2.5	APPARENT	NOV-JUN			>60				D	HIGH

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	SEVERE-FLOODING,WETNESS,PERCS SLOWLY
SEWAGE LAGOON AREAS	SEVERE-SEEPAGE,FLOODING,WETNESS
SANITARY LANDFILL (TRENCH)	SEVERE-FLOODING,SEEPAGE,WETNESS
SANITARY LANDFILL (AREA)	SEVERE-FLOODING,SEEPAGE,WETNESS
DAILY COVER FOR LANDFILL	POOR-SEEPAGE,TOO CLAYEY,TOO SANDY

CONSTRUCTION MATERIAL

ROADFILL	POOR-WETNESS
SAND	PROBABLE
GRAVEL	IMPROBABLE-TOO SANDY
TOPSOIL ***	L,C:POOR-WETNESS S:POOR-TOO SANDY,WETNESS

BUILDING SITE DEVELOPMENT

SHALLOW EXCAVATIONS	SEVERE-CUTBANKS CAVE,WETNESS
DWELLINGS WITHOUT BASEMENTS	SEVERE-FLOODING,WETNESS
DWELLINGS WITH BASEMENTS	SEVERE-FLOODING,WETNESS
SMALL COMMERCIAL BUILDINGS	SEVERE-FLOODING,WETNESS
LOCAL ROADS AND STREETS	SEVERE-WETNESS,FLOODING,FROST ACTION
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	L,S:SEVERE-WETNESS,FLOODING C:SEVERE-WETNESS,FLOODING,TOO CLAYEY

WATER MANAGEMENT

POND RESERVOIR AREA	SEVERE-SEEPAGE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE,PIPING,HARD TO PACK
EXCAVATED PONDS AQUIFER FED	SEVERE-SLOW REFILL,CUTBANKS CAVE
DRAINAGE	FLOODING,FROST ACTION,CUTBANKS CAVE
IRRIGATION	L,C:WETNESS,DROUGHTY S:WETNESS,DROUGHTY,FAST INTAKE
TERRACES AND DIVERSIONS	WETNESS,TOO SANDY
GRASSED WATERWAYS	WETNESS,DROUGHTY

Humaquepts Frequently Flooded

N JO301

RECREATIONAL DEVELOPMENT

CAMP AREAS	L,S:SEVERE-FLOODING,WETNESS C:SEVERE-FLOODING,WETNESS,TOO CLAYEY	PLAYGROUNDS	L,S:SEVERE-WETNESS,FLOODING C:SEVERE-TOO CLAYEY,WETNESS,FLOODING
PICNIC AREAS	L,S:SEVERE-WETNESS C:SEVERE-WETNESS,TOO CLAYEY	PATHS AND TRAILS	L,S:SEVERE-WETNESS C:SEVERE-WETNESS,TOO CLAYEY

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY		GRASS HAY (TONS)													
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
ALL	5W		2.0													

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
ALL	2W	SLIGHT	SEVERE	SEVERE	MODER.		PIN OAK RED MAPLE SWEETGUM			PIN OAK SWEETGUM

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL	POOR	FAIR	FAIR	FAIR	FAIR		GOOD	FAIR	FAIR	FAIR	FAIR	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				

[illegible] WT):
FAVORABLE YEARS
NORMAL YEARS
UNFAVORABLE YEARS

FOOTNOTES

***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

SOIL INTERPRETATIONS RECORD: Otisville Series

MLRA(S): 100, 101, 139, 140, 144A, 148
REV. NEW: JEH 8-88
TYPIC UDORTHENTS, SANDY-SKELETAL, MIXED, MESIC

THE OTISVILLE SERIES CONSISTS OF VERY DEEP EXCESSIVELY DRAINED SOILS ON OUTWASH TERRACES, KAMES ESKERS AND BEACHES. THEY FORMED IN WATER-SORTED MATERIAL. TYPICALLY THESE SOILS HAVE A DARK GRAYISH BRDUN GRAVELLY SANDY LOAM SURFACE LAYER 6 INCHES THICK. THE YELLOWISH BROWN SUBSOIL FROM 6 TO 22 INCHES IS GRAVELLY LOAMY SAND AND FROM 22 TO 28 INCHES IS VERY GRAVELLY BAND. THE SUBSTRATUM FROM 28 TO 72 INCHES IS GRAYISH-BROWN LOOSE, VERY GRAVELLY SAND. SLOPES RANGE FROM 0 TO 50 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
				E	0-50

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-6	SL,LS	SM,SW-SM,SP-SM	A-1,A-2		0-5	80-95	75-90	35-65	10-35	1-10
0-6	GR-LFS,GR-LS,GR-LCOS	SM,GM,SW-SM,GW-GM	A-1,A-2		0-10	55-80	50-75	25-50	10-30	1-10
0-6	GR-SL	SM,GM,GW-GM	A-1,A-2		0-10	55-80	50-75	30-50	15-30	1-10
6-28	GRV-S,GRV-LS,GRX-S	SM,SP,GP,GM	A-1		0-10	45-65	25-55	20-50	3-25	1-5
28-60	GRV-S,GRV-LS	GP,SP,GW-GM,SP-SM	A-1		0-10	35-60	30-55	15-40	0-10	1-5

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-6		NP	1.10-1.40	6.0-20.0	0.07-0.15	3.6-5.5					
0-6		NP	1.10-1.40	6.0-20.0	0.05-0.10	3.6-5.5					
0-6		NP	1.10-1.40	6.0-20.0	0.09-0.12	3.6-5.5					
6-28		NP	1.25-1.55	6.0-20.0	0.02-0.05	3.6-5.5					
28-60		NP	1.45-1.65	6.0-20.0	0.01-0.02	4.5-6.0					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KT	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-6	2-4	LOW	.17		3-2			LOW	HIGH
0-6	2-4	LOW	.17		3-2				
0-6	2-4	LOW	.17		3-2				
6-28		LOW	.17						
28-60		LOW	.17						

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0					>60				A	LOW

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	0-15%:SEVERE-POOR FILTER 15-50%:SEVERE-POOR FILTER,SLOPE
SEWAGE LAGOON AREAS	0-7%:SEVERE-SEEPAGE 7-50%:SEVERE-SLOPE,SEEPAGE
SANITARY LANDFILL (TRENCH)	0-15%:SEVERE-SEEPAGE,TOO SANDY 15-50%:SEVERE-SLOPE,SEEPAGE,TOO SANDY
SANITARY LANDFILL (AREA)	0-15%:SEVERE-SEEPAGE 15-50%:SEVERE-SLOPE,SEEPAGE
DAILY COVER FOR LANDFILL	POOR-SEEPAGE,TOO SANDY,SMALL STONES

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	0-15%:SEVERE-CUTBANKS CAVE 15-50%:SEVERE-SLOPE,CUTBANKS CAVE
DWELLINGS WITHOUT BASEMENTS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-50%:SEVERE-SLOPE
DWELLINGS WITH BASEMENTS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-50%:SEVERE-SLOPE
COMMERCIAL BUILDINGS	0-8%:SLIGHT 8-50%:SEVERE-SLOPE
LOCAL ROADS AND STREETS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-50%:SEVERE-SLOPE
LAWNS, LANDSCAPING AND GOLF	0-15%:SEVERE-DROUGHTY 15-50%:SEVERE-SLOPE,DROUGHTY

CONSTRUCTION MATERIAL (B)

ROADFILL	0-15%:GOOD 15-25%:FAIR-SLOPE 25-50%:POOR-SLOPE
SAND	PROBABLE
GRAVEL	PROBABLE
TOPSOIL ***	0-15%:POOR-SMALL STONES,AREA RECLAIM 15-50%:POOR-SMALL STONES,AREA RECLAIM,SLOPE

WATER MANAGEMENT (B)

POND RESERVOIR AREA	0-8%:SEVERE-SEEPAGE 8-50%:SEVERE-SEEPAGE,SLOPE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	DEEP TO WATER
IRRIGATION ***	0-3%SL,GR-SL:DROUGHTY 0-3%LS,GR-LS,GR-LCOS:DROUGHTY,FAST INTAKE 3-50%LS,GR-LS,GR-LCOS:DROUGHTY,FAST INTAKE, SLOPE
TERRACES AND DIVERSIONS	0-8%:TOO SANDY 8-50%:SLOPE,TOO SANDY
GRASSED WATERWAYS	0-8%:DROUGHTY 8-50%:SLOPE,DROUGHTY

Otisville Series

NY0085

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	0-8%SL,LS:SLIGHT 8-15%SL,LS:MODERATE-SLOPE 0-8%GR:MODERATE-SMALL STONES 8-15%GR:MODERATE-SLOPE, SMALL STONES 15-50%:SEVERE-SLOPE	PLAYGRWNDS	0-2%SL,LS:MODERATE-SMALL STONES 2-6%SL,LS:MODERATE-SLOPE,SMALL STORES 0-6%GR:SEVERE-SMALL STONES 6-50%SL,LS:SEVERE-SLOPE 6-50%GR:SEVERE-SLOPE,SMALL STONES
PICNIC AREAS ***	0-8%SL,LS:SLIGHT 8-15%SL,LS:MODERATE-SLOPE 0-8%GR:MODERATE-SMALL STONES 8-15%GR:MODERATE-SLOPE,SMALL STDNES 15-50%:SEVERE-SLOPE	PATHS AND TRAILS	0-15%:SLIGHT 15-25%:MODERATE-SLOPE 25-50%:SEVERE-SLOPE

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPA-BILITY		CORN SILAGE (TONS)		OATS (BU)		GRASS-LEGUME HAY (TONS)									
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-15%	4S		12		45		2.5									
15-25%	6S															
25-50%	7S															

WOODLAND SUITABILITY (C)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
0-15%	8S	SLIGHT	SLIGHT	SEVERE	SLIGHT		EASTERN WHITE PINE	65	8	EASTERN WHITE PINE
15-35%	8S	SLIGHT	MODER.	SEVERE	SLIGHT		NORTHERN RED OAK	60	3	EUROPEAN LARCH
35-50%	8R	MODER.	SEVERE	SEVERE	SLIGHT		SUGAR MAPLE	55	2	RED PINE
							WHITE OAK	60	3	
							BLACK OAK	60	3	

WOODBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
ALL	SIBERIAN PEASHRUB	7	TATARIAN HONEYSUCKLE	8	AMUR HONEYSUCKLE	8	LILAC	8
	AUTUMN OLIVE	9	WASHINGTON HAWTHORN	10	RADIANT CRABAPPLE	12	EASTERN REDCEDAR	14
	JACK PINE	16	AAUSTRIANPINE	18	RED PINE	18	EASTERN WHITE PINE	20

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-25%	POOR	POOR	POOR	POOR	POOR		V. POOR	V. POOR	POOR	POOR	V. POOR	
25-50%	V. POOR	POOR	POOR	POOR	POOR		V. POOR	V. POOR	POOR	POOR	V. POOR	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSTION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATED ENGINEERING PROPERTIES BASED ON TEST DATA OF 1 PEDON, WASHINGTON CO., N.Y.
B RATINGS BASED ON NHS, SECTION 603.
C RATINGS BASED ON NATIONAL FORESTRY MANUAL
D RATINGS BASED ON SOILS MEMO 74, JANUARY 1972
***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

DC0029

SOIL INTERPRETATIONS RECORD: Pits Sandy

MLRA(S): ALL
REV. LNL, 8-81

SAND PITS ARE OPEN EXCAVATIONS FROM WHICH SOIL AND THE UNDERLYING SANDY MATERIAL RAVE BEEN REMOVED, EXPOSING SANDY MATERIAL. SLOPES ARE 0 TO 3 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
					0-3

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-10	COS,S	SP,SW	A-1,A-3	0	0	100	80-100	30-60	0-5	0-1
0-10	GR-COS,GR-S	SP,SW	A-1	0	0	80-100	50-75	20-50	0-5	0-1
10-60	COS,S,GR-COS	SP,SW	A-1,A-3	0	0	80-100	50-100	20-60	0-5	0-1

DEPTH (IN.)	LIQUID LIMIT	PLAS-TICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEA-BILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-10		NP		6.0-20.0	0.03-0.05						
0-10		NP		6.0-20.0	0.02-0.03						
10-60		NP		6.0-20.0	0.02-0.05						

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	Kf	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-10	0-.1	LOW	.17		5	2	134		
0-10	0-.1	LOW	.10		5	6	48		
10-60		LOW	.15						

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0					>60				A	

SANITARY FACILITIES

SEPTIC TANK ABSORPTION FIELDS	SEVERE-POOR FILTER
SEWAGE LAGOON AREAS	SEVERE-SEEPAGE
SANITARY LANDFILL (TRENCH)	SEVERE-SEEPAGE,TOO SANDY
SANITARY LANDFILL (AREA)	SEVERE-SEEPAGE
DAILY COVER FOR LANDFILL	POOR-SEEPAGE,TOO SANDY

CONSTRUCTION MATERIAL

ROADFILL	GOOD
SAND	PROBABLE
GRAVEL	IMPROBABLE-TOO SANDY
TOPSOIL	POOR-TOO SANDY,SMALL STONES

WATER MANAGEMENT

POND RESERVOIR AREA	SEVERE-SEEPAGE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE,PIPING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	DEEP TO WATER
IRRIGATION	GR-COS,GR-S:DROUGHTY,FAST INTAKE COS,S:DROUGHTY,FAST INTAKE,SOIL BLOWING
TERRACES AND DIVERSIONS	GR-COS,GR-S:TOO SANDY COS,S:TOO SANDY,SOIL BLOWING
GRASSED WATERWAYS	DROUGH

WILDING SITE DEVELOPMENT

SHALLOW EXCAVATIONS	SEVERE-CUTBANKS CAVE
DWELLINGS WITHOUT BASEMENTS	SLIGHT
DWELLINGS WITH BASEMENTS	SLIGHT
SMALL COMMERCIAL BUILDINGS	SLIGHT
LOCAL ROADS AND STREETS	SLIGHT
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	S,GR-S:SEVERE-DROUGHTY COS,GR-COS:SEVERE-DROUGHTY,TOO SANDY

RECREATIONAL DEVELOPMENT

CAMP AREAS	SEVERE-TOO SANDY	PLAYGRWNDS	COS,S:SEVERE-TOO SANDY GR:SEVERE-SMALL STONES,TOO SANDY
PICNIC AREAS	SEVERE-TOO SANDY	PATHS AND TRAILS	SEVERE-TOO SANDY

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY															
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
ALL	8S															

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
							NONE			

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR	V. POOR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
		ALL				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS		0				
NORMAL YEARS		0				
UNFAVORABLE YEARS		0				

FOOTNOTES

NJ0058

SOIL INTERPRETATIONS RECORD: Pompton Series

MLRA(S): 144A, 145, 149B
REV. SCS-NJ-58
AQUIC DYSTROCHREPTS, COARSE-LOAMY, MIXED, MESIC

POMPTON SOILS ARE VERY DEEP, SOMEWHAT POORLY-DRAINED, MODERATELY COARSE SOILS OF THE UPLANDS AND OUTWASH PLAINS. THEY FORMED IN INTERMEDIATE POSITIONS IN THE LANDSCAPE. TYPICALLY THESE SOILS HAVE A VERY FINE SANDY LOAM PLOW LAYER 7 IN. THICK. THE SUBSOIL FROM 7 TO 34 INCHES IS MOTTLED FINE SANDY LOAM SANDY LOAM AND GRAVELLY SAND LOAM. THE SUBSTRATUM, FROM 34 TO 72 INCHES, IS GRAVELLY LOAMY SAND. SLOPES RANGE FROM 0 TO 8 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
				SP	0-8

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-7	FSL,SL,SIL	SM,SC,ML	A-4,A-2	0	0	85-95	85-95	65-75	35-60	8-18
0-7	GR-FSL,GR-SL,GR-SIL	SM,ML,GM	A-2-4,A-4,A-1-B	0	0	55-80	50-75	30-70	15-60	8-18
7-34	FSL,SL,GR-SL	SM,SC,SC-SM	A-2,A-4		0-5	80-100	50-100	45-75	30-50	10-18
34-72	SR-GR-LS-S	SM,GP-GM,GM,SP-SM	A-1		0-10	35-80	20-80	20-40	5-15	2-12

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-7	20-30	3-10	1.15-1.45	0.6-6.0	0.14-0.18	4.5-6.0					
0-7	20-30	3-10	1.15-1.45	0.6-6.0	0.09-0.14	4.5-6.0					
7-34	20-30	3-10	1.50-1.65	0.6-6.0	0.12-0.16	4.5-5.5					
34-72	20-	NP	1.45-1.70	6.0-20.0	0.05-0.10	4.5-5.5					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KF	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-7	2-4	LOW	.24		3			MODERATE	HIGH
0-7	2-4	LOW	.24		3				
7-34		LOW	.24						
34-72		LOW	.17						

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE- RARE			0.5-2.0	APPARENT	OCT-MAY			>60				B	HIGH

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	SEVERE-WETNESS,POOR FILTER
SEWAGE LAGOON AREAS ***	0-7%NONE:SEVERE-SEEPAGE,WETNESS 7-8%NONE:SEVERE-SEEPAGE,SLOPE,WETNESS 0-7%RARE:SEVERE-SEEPAGE,FLOODING 7-8%RARE:SEVERE-SEEPAGE,FLOODING,SLOPE
SANITARY LANDFILL (TRENCH)	SEVERE-SEEPAGE,WETNESS,TOO SANDY
SANITARY LANDFILL (AREA)	SEVERE-SEEPAGE,WETNESS
DAILY COVER FOR LANDFILL ***	POOR-SEEPAGE,SMALL STONES,WETNESS

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	SEVERE-CUTBANKS CAVE,WETNESS
DWELLINGS WITHOUT BASEMENTS	NONE:SEVERE-WETNESS RARE:SEVERE-FLOODING,WETNESS
DWELLINGS WITH BASEMENTS	NONE:SEVERE-WETNESS RARE:SEVERE-FLOODING,WETNESS
SMALL COMMERCIAL BUILDINGS	NONE:SEVERE-WETNESS RARE:SEVERE-FLOODING,WETNESS
LOCAL ROADS AND STREETS ***	SEVERE-FROST ACTION
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	MODERATE-WETNESS GR:MODERATE-WETNESS,SMALL STONES

CONSTRUCTION MATERIAL (B)

ROADFILL	POOR-WETNESS
SAND	PROBABLE
GRAVEL	PROBABLE
TOPSOIL	POOR-SMALL STONES,AREA RECLAIM,WETNESS

WATER MANAGEMENT (B)

POND RESERVOIR AREA	SEVERE-SEEPAGE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE,WETNESS
EXCAVATED PONDS AQUIFER FED	SEVERE-CUTBANKS CAVE
DRAINAGE	0-3%:FROST ACTION,CUTBANKS CAVE 3-8%:FROST ACTION,SLOPE,CUTBANKS CAVE
IRRIGATION	0-3%:WETNESS 3-8%:WETNESS,SLOPE
TERRACES AND DIVERSIONS	WETNESS,TOO SANDY
GRASSED WATERWAYS	WETNESS

SOIL INTERPRETATIONS RECORD: Preakness Series

MLRA(S): W A 148
REV. MJM CEF 7-88
TYPIC HUMAQUEPTS, COARSE-LOAMY, MIXED, ACID, MESIC

THE PREAKNESS SERIES CONSISTS OF DEEP, POORLY AND VERY POORLY DRAINED SOILS ON OUTWASH PLAINS AND OUTWASH TERRACES. THEY FORMED IN WATER-SORTED MATERIAL. TYPICALLY THESE SOILS HAVE A VERY DARK GRAY SANDY LOAM SURFACE LAYER 12 INCHES THICK. THE MOTTLED SUBSOIL FROM 12 TO 30 INCHES IS GRAYISH-BROWN SANDY LOAM. THE SUBSTRATUM FROM 30 TO 60 INCHES IS GRAYISH BROWN GRAVELLY LOAMY SAND. SLOPES RANGE FROM 0 TO 4 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
				P,VP	-

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-12	SL,SIL,L	SC-SM,CL-ML,ML	A-2-4,A-4		0-5	95-100	95-100	70-85	30-80	5-10
12-30	SL,GR-SL,GR-LS	SC-SM,SP-SM	A-2-4,A-4		0-5	85-100	70-100	55-85	10-40	5-10
30-60	SR-S-GR-SL	SM,SP-SM	A-1,A-2,A-3		0-10	65-90	50-85	30-70	10-30	2-10

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-12	20-30	5-10	1.20-1.35	0.6-6.0	0.14-0.24	4.5-5.5					
12-30	10-15	NP-3	1.35-1.60	2.0-6.0	0.12-0.16	4.5-5.5					
30-60	15-20	NP-5	1.40-1.60	6.0-20.0	0.03-0.10	4.5-6.0					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	Kf	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-12	3-5	LOW	.32		5			HIGH	HIGH
12-30		LOW	.24						
30-60		LOW	.17						

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE- FREQ	BRIEF	FEB-APR	0-1.0	APPARENT	OCT-MAY			>60				B/D	HIGH

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	NONE,RARE:SEVERE-WETNESS,POOR FILTER COMMON:SEVERE-FLOODING,WETNESS,POOR FILTER
SEWAGE LAGOON AREAS ***	NONE:SEVERE-SEEPAGE,WETNESS RARE,COMMON:SEVERE-SEEPAGE,FLOODING,WETNESS
SANITARY LANDFILL (TRENCH)	NONE,RARE:SEVERE-SEEPAGE,WETNESS COMMON:SEVERE-FLOODING,SEEPAGE,WETNESS
SANITARY LANDFILL (AREA)	NONE,RARE:SEVERE-SEEPAGE,WETNESS COMMON:SEVERE-FLOODING,SEEPAGE,WETNESS
DAILY COVER FOR LANDFILL	POOR-SEEPAGE,TOO SANDY,SMALL STONES

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	SEVERE-CUTBANKS CAVE,WETNESS
DWELLINGS WITHOUT BASEMENTS	NONE:SEVERE-WETNESS RARE,COMMON:SEVERE-FLOODING,WETNESS
DWELLINGS WITH BASEMENTS	NONE:SEVERE-WETNESS RARE,COMMON:SEVERE-FLOODING,WETNESS
SMALL COMMERCIAL BUILDINGS	NONE:SEVERE-WETNESS RARE,COMMON:SEVERE-FLOODING,WETNESS
LOCAL ROADS AND STREETS	NONE,RARE:SEVERE-WETNESS,FROST ACTION COMMON:SEVERE-WETNESS,FLOODING,FROST ACTION
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	NONE,RARE,OCCAS:SEVERE-WETNESS FREQ:SEVERE-WETNESS,FLOODING

CONSTRUCTION MATERIAL (B)

ROADFILL	POOR-WETNESS
SAND	PROBABLE
GRAVEL	PROBABLE
TOPSOIL	POOR-SMALL STONES,AREA RECLAIM,WETNESS

WATER MANAGEMENT (B)

POND RESERVOIR AREA	SEVERE-SEEPAGE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE,WETNESS
EXCAVATED PONDS AQUIFER FED	SEVERE-CUTBANKS CAVE
DRAINAGE	0-3%NONE,RARE:FROST ACTION 3-4%NONE,RARE:FROST ACTION,SLOPE 0-3%COMMON:FLOODING,FROST ACTION 3-4%COMMON:FLOODING,FROST ACTION,SLOPE
IRRIGATION	0-3%NONE,RARE:WETNESS 3-4%NONE,RARE:WETNESS,SLOPE 0-3%COMMON:WETNESS,FLOODING 3-4%COMMON:WETNESS,SLOPE,FLOODING
TERRACES AND DIVERSIONS	WETNESS,TOO SANDY
GRASSED WATERWAYS	WETNESS

Preakness Series

NJ0059

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	RARE,COMMON:SEVERE-FLOODING,WETNESS	PLAYGROUNDS	NONE,RARE,OCCAS:SEVERE-WETNESS FREQ:SEVERE-WETNESS,FLOODING
PICNIC AREAS	SEVERE-WETNESS	PATHS AND TRAILS	SEVERE-WETNESS

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY		CORN (BU)		CORN SILAGE (TONS		GRASS-LEGUME HAY (TONS)		PASTURE (AUM)							
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
NONE,RARE,OCCAS	4W		85				3.5		5.0							
FREQ	6W															

4

WOODLAND SUITABILITY (C)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
ALL	4W	SLIGHT	SEVERE	SEVERE	MODER.	SEVERE	PIN OAK	80	4	
							WHITE OAK	80	4	
							RED MAPLE	75	3	

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL	V. POOR	POOR	POOR	POOR	POOR		GOOD	GOOD	POOR	POOR	GOOD	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POTENTIAL PRODUCTION (LBS./A ...Gm. DRY WT) FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED ON TEST DATA OF SIMILAR SOILS.
B RATINGS BASED ON NATIONAL SOILS HANDBOOK, SECTION 603.
C RATINGS BASED ON NATIONAL FORESTRY MANUAL
D RATINGS BASED ON SOILS MEMO 74, JANUARY 1972
***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

SOIL INTERPRETATIONS RECORD: Riverhead Series

MLRA(S): 144A, 148, 149B, 140
REV. WWKAU 9-86
TYPIC DYSTROCHREPTS, COARSE-LOAMY, MIXED, NESIC

THE RIVERHEAD SERIES CONSISTS OF DEEP, WELL DRAINED SOILS ON OUTWASH PLAINS AND VALLEY TRAINS. THEY FORMED IN RELATIVELY GRAVEL FREE DEPOSITS OVERLYING STRATIFIED SAND AND GRAVEL. TYPICALLY THESE SOILS HAVE BROWN TO DARK BROWN SANDY LOAM SURFACE LAYERS 12 INCHES THICK. THE SUBSOIL FROM 12 TO 27 INCHES IS STRONG BROWN SANDY LOAM AND FROM 27 TO 35 INCHES IT IS YELLOWISH BROWN LOAMY SAND THAT IS GRAVELLY BELOW 32 INCHES. THE SUBSTRATUM FROM 35 TO 65 INCHES IS BROWN AND VERY PALE BROWN STATIFIED SAND CONTAINING THIN GRAVEL LAYERS. SLOPES RANGE FROM 0 TO 50 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	CLASS	PCT
				W	

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	MSHTO	RACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-12	SL,FSL,L	SM,ML	A-2,A-4		0-5	95-100	90-100	55-95	30-75	3-10
0-12	GR-SL,GR-FSL,GR-L	SM,ML,GM	A-2,A-4,A-1		0-5	60-80	55-75	35-70	20-55	3-10
12-27	SL,FSL,GR-SL	SM,GM	A-2,A-4,A-1		0-5	65-100	60-95	40-80	20-45	1-8
27-35	LS,GR-LS,FSL	SM,SP-SM,GM,GP-GM	A-1,A-2,A-4		0-5	60-90	55-85	30-70	10-45	1-8
35-65	SR-SG	SP,SW,SP-SM,GP	A-1		0-10	40-95	35-90	25-50	0-10	1-8

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-12	14-18	1-3	1.10-1.40	2.0-6.0	0.14-0.20	3.6-6.0					
0-12	14-18	1-3	1.10-1.40	2.0-6.0	0.09-0.14	3.6-6.0					
12-27	14-18	1-3	1.25-1.55	2.0-6.0	0.09-0.13	3.6-6.0					
27-35		NP	1.25-1.55	2.0-6.0	0.04-0.13	4.5-6.0					
35-65		NP	1.45-1.65	20-20.0	0.02-0.04	4.5-7.3					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KT	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-12	2-4	LOW	.28		5			LOW	HIGH
0-12	2-4	LOW	.20		3				
12-27		LOW	.28						
27-35		LOW	.17						
35-65		LOW	.17						

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0					>60				B	MODERATE

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	0-15%:SEVERE-POOR FILTER 15-50%:SEVERE-POOR FILTER,SLOPE
SEWAGE LAGOON AREAS	0-7%:SEVERE-SEEPAGE 7-50%:SEVERE-SLOPE,SEEPAGE
SANITARY LANDFILL (TRENCH)	0-15%:SEVERE-SEEPAGE,TOO SANDY 15-50%:SEVERE-SLOPE,SEEPAGE,TOO SANDY
SANITARY LANDFILL (AREA)	0-15%:SEVERE-SEEPAGE 15-50%:SEVERE-SLOPE,SEEPAGE
DAILY COVER FOR LANDFILL ***	0-15%:POOR-SEEPAGE,TOO SANDY 15-50%:POOR-SEEPAGE,TOO SANDY,SLOPE

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	0-15%:SEVERE-CUTBANKS CAVE 15-50%:SEVERE-SLOPE,CUTBANKS CAVE
DWELLINGS WITHOUT BASEMENTS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-50%:SEVERE-SLOPE
DWELLINGS WITH BASEMENTS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-50%:SEVERE-SLOPE
SMALL COMMERCIAL BUILDINGS	0-4%:SLIGHT 4-8%:MODERATE-SLOPE 8-50%:SEVERE-SLOPE
LOCAL ROADS AND STREETS	0-8%:MODERATE-FROST ACTION 8-15%:MODERATE-SLOPE,FROST ACTION 15-50%:SEVERE-SLOPE
LAWNS, LANDSCAPING AND GOLF	0-8%SL,FSL,L:SLIGHT 8-15%SL,FSL,L:MODERATE-SLOPE 0-8%GR:MODERATE-SMALL STONES,DROUGHTY

CONSTRUCTION MATERIAL (B)

ROADFILL	0-15%:GOOD 15-25%:FAIR-SLOPE 25-50%:POOR-SLOPE
SAND	PROBABLE
GRAVEL	PROBABLE
TOPSOIL ***	0-15%:POOR-SMALL STONES 15-50%:POOR-SMALL STONES,SLOPE

WATER MANAGEMENT (B)

POND RESERVOIR AREA	0-8%:SEVERE-SEEPAGE 8-50%:SEVERE-SEEPAGE,SLOPE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	DEEP TO WATER
IRRIGATION	0-3%SL,FSL,L:FAVORABLE 3-50%SL,FSL,L:SLOPE 0-3%GR:DROUGHTY 3-50%GR:DROUGHTY,SLOPE
TERRACES AND DIVERSIONS	0-8%:TOO SANDY 8-50%:SLOPE,TOO SANDY
GRASSED WATERWAYS	0-8%SL,FSL,L:FAVORABLE 8-50%SL,FSL,L:SLOPE 0-8%GR:DROUGHTY

SOIL INTERPRETATIONS RECORD: **Rockaway** Series

MLRA(S): 144A, 148
REV. JJP 7-88
TYPIC FRAGIUDULTS, COARSE-LOAMY, MIXED, MESIC

THE ROCKAWAY SERIES CONSISTS OF DEEP MODERATELY WELL-DRAINED AND WELL-DRAINED SOILS ON UPLANDS. THEY FORMED IN GLACIAL TILL. TYPICALLY THESE SOILS HAVE A VERY DARK GRAYISH-BROWN GRAVELLY SANDY LOAM SURFACE LAYER ABOUT 4 INCHES THICK. THE SUBSOIL FROM 4 TO 22 IN., IS YELLOWISH-BROWN GRAVELLY LOAM. THE FRAGIPAN FROM 22 TO 38 IN., IS YELLOWISH-BROWN GRAVELLY SANDY LOAM THAT IS MOTTLED. IT IS VERY FIRM AND BRITTLE. THE SUBSTRATUM FROM 38 TO 73 INCHES IS VARIEGATED GRAVELLY SANDY LOAM AND GRAVELLY LOAMY SAND THAT IS WEAKLY BRITTLE, WHEN DRY, IN THE UPPER PART. SLOPES RANGE FROM 3 TO 50 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
				MW	3-50

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-4	SL,FSL,L	SM,SC-SM,ML,CL-ML	A-2-4,A-4		0-5	90-95	80-90	50-80	25-60	5-15
0-4	GR-SL,GR-FSL,GR-L	SM,SC-SM,ML,CL-ML	A-2-4,A-4,A-1-B		0-10	85-90	60-80	40-70	20-60	5-15
0-4	CB-SL,CB-FSL,CB-L	SM,SC-SM,ML,CL-ML	A-2-4,A-4,A-1-B		10-20	85-90	60-80	40-70	20-60	5-15
4-22	CB-SL,GR-FSL,L	SM,SC-SM,ML,CL-ML	A-2-4,A-4,A-1-B		0-10	80-95	60-85	40-75	20-60	5-15
22-38	CB-SL,GR-FSL,L	SM,SC-SM,ML,CL-ML	A-2-4,A-4,A-1-B		0-10	80-95	40-75	20-60	20-60	5-10
38-72	ST-LS,CB-LS,GR-SL	SM,SC-SM	A-1-B,A-2-4		5-10	70-80	60-75	35-50	10-25	2-10

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-4	20-25	3-7	1.15-1.35	0.6-2.0	0.14-0.16	4.5-5.5					
0-4	20-25	3-7	1.15-1.35	0.6-2.0	0.11-0.16	4.5-5.5					
0-4	20-25	3-7	1.15-1.35	0.6-2.0	0.11-0.16	4.5-5.5					
4-22	20-25	3-7	1.24-1.47	0.6-2.0	0.09-0.14	4.5-5.5					
22-38	20-26	3-7	1.55-1.75	0.06-0.2	0.01-0.02	4.5-5.5					
38-72	10-20	NP-5	1.20-1.55	0.6-6.0	0.01-0.02	4.5-5.5					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	Kf	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-4	1-3	LOW	.24		3			LOW	HIGH
0-4	1-3	LOW	.17		3				
0-4	1-3	LOW	.17		3				
4-22		LOW	.17						
22-38		LOW	.17						
38-72		LOW	.17						

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
NONE			2.0-4.0	PERCHED	FEB-MAY			>60				C	MODERATE

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS ***	3-15%:SEVERE-WETNESS 15-50%:SEVERE-WETNESS,SLOPE
SEWAGE LAGOON AREAS	3-7%:SEVERE-SEEPAGE,WETNESS 7-50%:SEVERE-SEEPAGE,SLOPE,WETNESS
SANITARY LANDFILL (TRENCH)	3-15%:SEVERE-SEEPAGE 15-50%:SEVERE-SEEPAGE,SLOPE
SANITARY LANDFILL (AREA)	3-15%:SEVERE-SEEPAGE 15-50%:SEVERE-SEEPAGE,SLOPE
DAILY COVER FOR LANDFILL	3-8%:FAIR-TOO SANDY,SMALL STONES 8-15%:FAIR-TOO SANDY,SMALL STONES,SLOPE 15-50%:POOR-SLOPE

CONSTRUCTION MATERIAL (B)

ROADFILL	3-15%:FAIR-WETNESS 15-25%:FAIR-WETNESS,SLOPE 25-50%:POOR-SLOPE
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	3-15%:POOR-SMALL STONES 15-50%:POOR-SMALL STONES,SLOPE

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	3-15%:SEVERE-CUTBANKS CAVE,WETNESS 15-50%:SEVERE-CUTBANKS CAVE,WETNESS,SLOPE
DWELLINGS WITHOUT BASEMENTS	3-8%:MODERATE-WETNESS 8-15%:MODERATE-WETNESS,SLOPE 15-50%:SEVERE-SLOPE
DWELLINGS WITH BASEMENTS	3-15%:SEVERE-WETNESS 15-50%:SEVERE-WETNESS,SLOPE
SMALL COMMERCIAL BUILDINGS	3-4%:MODERATE-WETNESS 4-8%:MODERATE-WETNESS,SLOPE 8-50%:SEVERE-SLOPE
LOCAL ROADS AND STREETS	3-8%:MODERATE-WETNESS,FROST ACTION 8-15%:MODERATE-WETNESS,SLOPE,FROST ACTION 15-50%:SEVERE-SLOPE
LAWNS, LANDSCAPING AND GOLF	3-8%:SLOPE,MODERATE-DROUGHTY 8-15%:SLOPE,MODERATE-DROUGHTY,SLOPE 3-8%CR,GR,CB:MODERATE-SMALL STONES

WATER MANAGEMENT (B)

POND RESERVOIR AREA	3-8%:SEVERE-SEEPAGE 8-50%:SEVERE-SEEPAGE,SLOPE
EMBANKMENTS DIKES AND LEVEES ***	SEVERE-SEEPAGE,PIPING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE ***	SLOPE,CUTBANKS CAVE
IRRIGATION	SLOPE,WETNESS,DROUGHTY
TERRACES AND DIVERSIONS	3-8%:WETNESS,ROOTING DEPTH 8-50%:SLOPE,WETNESS,ROOTING DEPTH
GRASSED WATERWAYS	3-8%:DROUGHTY,ROOTING DEPTH 8-50%:SLOPE,DROUGHTY,ROOTING DEPTH

Rockaway Series

NJ0060

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS ***	3-8%SL,FSL,L,CR,GR:MODERATE-WETNESS 8-15%SL,FSL,L,CR,GR:MODERATE-SLOPE 3-8%CB:MODERATE-LARGE STONES,WETNESS 8-15%CB:MODERATE-SLOPE,LARGE STONES,WETNESS 15-50%:SEVERE-SLOPE	PLAYGROUNDS ***	3-8%SL,FSL,L:MODERATE-SLOPE,SMALL STONES,WETNESS 6-50%SL,FSL,L:SEVERE-SLOPE 3-8%CR,GR,:SEVERE-SMALL STONES 6-50%CR,GR,CB:SEVERE-SLOPE,SMALL STONES
PICNIC AREAS ***	3-8%SL,FSL,L,CR,GR:MODERATE-WETNESS 8-15%SL,FSL,L,CR,GR:MODERATE-SLOPE 3-8%CB:MODERATE-WETNESS,LARGE STONES 8-15%CB:MODERATE-SLOPE,WETNESS,LARGE STONES 15-50%:SEVERE-SLOPE	PATHS AND TRAILS	3-15%:SLIGHT 15-25%:MODERATE-SLOPE 25-50%:SEVERE-SLOPE

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY	CORN (BU)		CORN SILAGE (TONS)		GRASS-LEGUME HAY (TONS)		OATS (BU)		SOYBEANS (BU)		WHEAT (BU)		ALFALFA HAY (TONS)	
		NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
3-8%	2E	100		20		3.2		70		35		35		4.5	
8-15%	3E	90		18		3.0		70		30		30		4.0	
15-25%	4E	80		16		2.8		60				25		3.5	
25-35%	6E														
35-50%	7E														

WOODLAND SUITABILITY (C)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
3-15%	4A	SLIGHT	SLIGHT	SLIGHT	SLIGHT		NORTHERN RED OAK	70	4	EASTERN WHITE PINE
15-35%	4R	SLIGHT	MODER.	SLIGHT	SLIGHT		WHITE OAK	70	4	AUSTRIAN PINE
35-50%	4R	MODER.	SEVERE	SLIGHT	SLIGHT		BLACK OAK	70	4	NORWAY SPRUCE
							SCARLET OAK	70	4	
							YELLOW-POPLAR	75	4	
							WHITE ASH	65	3	

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
3-8%	GOOD	GOOD	GOOD	GOOD	GOOD		POOR	V. POOR	GOOD	GOOD	V. POOR	
8-15%	FAIR	GOOD	GOOD	GOOD	GOOD		V. POOR	V. POOR	GOOD	GOOD	V. POOR	
15-25%	POOR	FAIR	GOOD	GOOD	GOOD		V. POOR	V. POOR	FAIR	GOOD	V. POOR	
25-50%	V. POOR	FAIR	GOOD	GOOD	GOOD		V. POOR	V. POOR	FAIR	GOOD	V. POOR	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POTENTIAL PRODUCTION (LBS./AC DRY WT):						
FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED ON TEST DATA OF 6 PEDONS FROM MORRIS, PASSAIC AND SUSSEX COUNTIES.
B RATINGS BASED ON NSH PART 603.
C RATINGS BASED ON NATIONAL FORESTRY MANUAL
D RATINGS BASED ON SOILS MEMO 74, JANUARY 1972
***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

NJ0061

SOIL INTERPRETATIONS RECORD: Rockaway Series Stony

MLRA(S): 144A, 1 4 8
REV. CEF 7-88
TYPIC FRAGIUDULTS, COARSE-LOAMY, MIXED, MESIC

THE ROCKAWAY SERIES CONSISTS OF DEEP, MODERATELY WELL-DRAINED AND WELL-DRAINED SOILS ON UPLANDS. THEY FORMED IN GLACIAL TILL. TYPICALLY, THESE SOILS HAVE A VERY DARK GRAYISH-BROWN VERY STONY OR EXTREMELY STONY SANDY LOAM SURFACE LAYER 4 INCHES THICK. THE SUBSOIL FROM 4 TO 22 INCHES IS YELLOWISH BROWN GRAVELLY SANDY LOAM. A MOTTLED VERY FIRM AND BRITTLE FRAGIPAN FROM 22 TO 38 INCHES IS GRAVELLY SANDY LOAM. THE SUBSTRATUM FROM 38 TO 72 IN. IS VARIEGATED STONY SANDY LOAM AND GRAVELLY LOAMY SAND THAT IS WEAKLY BRITTLE, WHEN DRY, IN THE UPPER PART. SLOPES RANGE FROM 3 TO 50 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
				MW	3-50

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-4	STV-SL,STV-FSL,STV-L	SM,SC-SM,ML,CL-ML	A-2-4,A-4		5-10	70-90	50-85	30-65	15-55	5-15
0-4	STX-SL,STX-FSL,STX-L	SM,SC-SM,ML,CL-ML	A-2-4,A-4,A-1-B		10-15	60-80	45-75	25-70	15-55	5-15
4-22	CB-SL,GR-FSL,GR-L	SM,SC-SM,ML,CL-ML	A-2-4,A-4,A-1-B		1-10	80-95	60-85	40-75	20-60	5-15
22-38	CB-SL,GR-FSL,GR-L	SM,SC-SM,ML,CL-ML	A-2-4,A-4,A-1-B		1-10	80-95	60-85	40-75	20-60	5-10
38-72	GR-LS,CB-LS,ST-SL	SM,SC-SM	A-1-B,A-2-4		5-40	60-78	40-75	20-50	10-25	2-10

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-4	20-25	3-7	1.15-1.35	0.6-2.0	0.09-0.13	4.5-5.5					
0-4	20-25	3-7	1.15-1.35	0.6-2.0	0.08-0.12	4.5-5.5					
4-22	20-25	3-7	1.24-1.47	0.6-2.0	0.09-0.14	4.5-5.5					
22-38	20-25	3-7	1.55-1.75	0.06-0.2	0.01-0.02	4.5-5.5					
38-72	10-20	NP-5	1.20-1.55	0.6-6.0	0.01-0.02	4.5-5.5					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KF	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-4	2-5	LOW	.17		5			LOW	HIGH
0-4	2-5	LOW	.17		3				
4-22		LOW	.17		3				
22-38		LOW	.17						
38-72		LOW	.17						

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			2.0-4.0	PERCHED	FEB-MAY			48-72	HARD			C	MODERATE

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS ***	SEVERE-WETNESS,PERCS SLOWLY,POOR FILTER
SEWAGE LAGOON AREAS	3-7%:SEVERE-SEEPAGE,WETNESS 7-50%:SEVERE-SEEPAGE,SLOPE,WETNESS
SANITARY LANDFILL (TRENCH)	3-15%:SEVERE-DEPTH TO ROCK,SEEPAGE 15-50%:SEVERE-DEPTH TO ROCK,SEEPAGE,SLOPE
SANITARY LANDFILL (AREA)	3-15%:SEVERE-SEEPAGE 15-50%:SEVERE-SEEPAGE,SLOPE
DAILY COVER FOR LANDFILL	3-15%:POOR-SMALL STONES 15-50%:POOR-SMALL STONES,SLOPE

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	3-15%:SEVERE-CUTBANKS CAVE,WETNESS 15-50%:SEVERE-CUTBANKS CAVE,WETNESS,SLOPE
DWELLINGS WITHOUT BASEMENTS	3-8%:MODERATE-WETNESS 8-15%:MODERATE-WETNESS,SLOPE 15-50%:SEVERE-SLOPE
DWELLINGS WITH BASEMENTS	3-15%:SEVERE-WETNESS 15-50%:SEVERE-WETNESS,SLOPE
SMALL COMMERCIAL BUILDINGS	3-4%:MODERATE-WETNESS 4-8%:MODERATE-WETNESS,SLOPE 8-50%:SEVERE-SLOPE
LOCAL ROADS AND STREETS	3-8%:MODERATE-WETNESS,FROST ACTION 8-15%:MODERATE-WETNESS,SLOPE,FROST ACTION 15-50%:SEVERE-SLOPE
LAWNS, LANDSCAPING AND GOLF	3-8%STV:MODERATE-SMALL STONES,LARGE STONES 8-15%STV:MODERATE-SMALL STONE&LARGE STONES 15-50%STV:SEVERE-SLOPE

CONSTRUCTION MATERIAL (B)

ROADFILL	3-15%:FAIR-DEPTH TO ROCK,WETNESS 15-25%:FAIR-DEPTH TO ROCK,WETNESS,SLOPE 25-50%:POOR-SLOPE
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	3-15%:POOR-SMALL STONES,AREA RECLAIM 15-50%:POOR-SMALL STONE&AREA RECLAIM,SLOPE

WATER MANAGEMENT (B)

POND RESERVOIR AREA	3-8%:SEVERE-SEEPAGE 8-50%:SEVERE-SEEPAGE,SLOPE
EMBANKMENTS DIKES AND LEVEES ***	SEVERE-SEEPAGE,PIPING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	PERCS SLOWLY,LARGE STONES,SLOPE
IRRIGATION	SLOPE,WETNESS,DROUGHTY
TERRACES AND DIVERSIONS	3-8%:WETNESS,ROOTING DEPTH 8-50%:SLOPE,WETNESS,ROOTING DEPTH
GRASSED WATERWAYS	3-8%:DROUGHTY,ROOTING DEPTH 8-50%:SLOPE,DROUGHTY,ROOTING DEPTH

Rockaway Series Stony

NJ0061

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	3-8%STV:MODERATE-LARGE STONES,WETNESS 8-15%STV:MODERATE-SLOPE,LARGE STONES,WETNESS 15-50%STV:SEVERE-SLOPE 3-15%STX:SEVERE-LARGE STONES 15-50%STX:SEVERE-SLOPE,LARGE STONES	PLAYGROUNDS	3-6%:SEVERE-LARGE STONES,SMALL STONES 6-50%:SEVERE-LARGE STONES,SLOPE,SMALL STONES
PICNIC AREAS	3-8%STV:MODERATE-WETNESS,LARGE STONES 8-15%STV:MODERATE-SLOPE,WETNESS,LARGE STONES 15-50%STV:SEVERE-SLOPE 3-15%STX:SEVERE-LARGE STONES 15-50%STX:SEVERE-SLOPE,LARGE STONES	PATHS AND TRAILS	3-15%:SLIGHT 15-25%:MODERATE-SLOPE 25-50%:SEVERE-SLOPE

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY		PASTURE (AUM)													
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
3-25%	6S		5.0													
25-50% STV	7S		4.5													
STX	7S		4.5													

WOODLAND SUITABILITY (C)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
3-15% STV	4A	SLIGHT	SLIGHT	SLIGHT	SLIGHT	SLIGHT	NORTHERN RED OAK	70	4	EASTERN WHITE PINE
15-35% STV	4R	SLIGHT	MODER.	SLIGHT	SLIGHT	SLIGHT	WHITE OAK	70	4	AUSTRIAN PINE
3-15% STX	4X	SLIGHT	MODER.	SLIGHT	SLIGHT	SLIGHT	BLACK OAK	70	4	NORWAY SPRUCE
15-35% STX	4X	SLIGHT	MODER.	SLIGHT	SLIGHT	SLIGHT	SCARLET OAK	70	4	
35-50%	4R	MODER.	SEVERE	SLIGHT	SLIGHT	SLIGHT	YELLOW-POPLAR	75	4	
							WHITE ASH	65	3	

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
STV	V. POOR	POOR	GOOD	GOOD	GOOD		POOR	V. POOR	POOR	GOOD	V. POOR	
STX	V. POOR	V. POOR	GOOD	GOOD	GOOD		V. POOR	V. POOR	POOR	FAIR	V. POOR	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED ON TEST DATA OF 6 PEDONS FROM MORRIS, PASSAIC AND SUSSEX COUNTIES.
B RATINGS BASED ON NSN PART 603.
C RATINGS BASED ON NATIONAL FORESTRY MANUAL
D RATINGS BASED ON SOILS MEMO 74, JANUARY 1972
***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

SOIL INTERPRETATIONS RECORD: Washington Series

MLRA(S): 147 148 144A
REV. WCK/DDL/1.02
ULTIC HAPLUDALFS, FINE-LOAMY, MIXED, MESIC

THE WASHINGTON SERIES CONSISTS OF VERY DEEP WELL DRAINED SOILS ON UPLANDS. THEY FORMED IN GLACIAL TILL. TYPICALLY THESE SOILS HAVE A DARK YELLOWISH BROWN LOAM SURFACE LAYER 9 INCHES THICK. THE STRONG BROWN SUBSOIL FROM 9 TO 17 INCHES IS LOAM AND FROM 17 TO 52 INCHES IS CLAY LOAM. THE SUBSTRATUM FROM 52 TO 72 INCHES IS BRCUNISH YELLOW LOAM GRADING TO GRAVELLY SILT LOAM WITH DEPTH. BEDROCK IS AT 72 INCHES. SLOPES RANGE FROM 0 TO 35 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
50-55	160-190	40-48		W	0-35

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-9	L,SCL,CL	CL,CL-ML	A-4,A-6	0	0-5	90-100	85-95	75-85	60-80	15-30
9-52	CL,SCL,L	CL	A-6		0-5	90-100	85-95	80-90	75-85	25-35
52-72	CL,L,GR-SIL	CL,CL-ML	A-4,A-6	8	0-10	75-95	60-80	55-75	50-70	15-30
72-76	WB									

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-9	25-35	6-12	1.25-1.45	0.6-2.0	0.18-0.22	5.6-7.3			10-20		
9-52	30-40	10-15	1.35-1.60	0.6-2.0	0.16-0.20	5.6-7.3			10-16		
52-72	25-35	6-12	1.25-1.45	0.6-6.0	0.12-0.16	5.6-7.3			7-13		
72-76				0.06-20							

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KT	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-9	2-4	LOW	.37		4	6	48	MODERATE	LOW
9-52	0-.5	LOW	.43						
52-72	0-.5	LOW	.37						
72-76									

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0					>60				B	MODERATE

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS *** 1	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-35%:SEVERE-SLOPE
SEWAGE LAGOON AREAS 1	0-7%:SEVERE-SEEPAGE 7-35%:SEVERE-SEEPAGE,SLOPE
SANITARY LANDFILL (TRENCH) 1	0-15%:SEVERE-SEEPAGE 15-35%:SEVERE-SEEPAGE,SLOPE
SANITARY LANDFILL (AREA) 1	0-15%:SEVERE-SEEPAGE 15-35%:SEVERE-SLOPE,SEEPAGE
DAILY COVER FOR LANDFILL	0-8%:FAIR-TOO CLAYEY 8-15%:FAIR-TOO CLAYEY,SLOPE 15-35%:POOR-SLOPE

CONSTRUCTION MATERIAL (B)

ROADFILL ***	0-15%:FAIR-FROST ACTION,SHRINK-SWELL 15-25%:FAIR-SLOPE,FROST ACTION,SHRINK-SWELL
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	0-8%:FAIR-SMALL STONES,TOO CLAYEY 8-15%:FAIR-SLOPE,SMALL STONES,TOO CLAYEY 15-35%:POOR-SLOPE 0-15%GR:POOR-SMALL STONES 15-35%GR:POOR-SLOPE,SMALL STONES

WATER MANAGEMENT (B)

POND RESERVOIR AREA ***	0-3%:MODERATE-SEEPAGE 3-8%:MODERATE-SLOPE,SEEPAGE 8-35%:SEVERE-SLOPE
EMBANKMENTS DIKES AND LEVEES ***	MODERATE-PIPING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE ***	0-3%:FAVORABLE 3-35%:SLOPE
IRRIGATION	0-3%:ERODES EASILY 3-35%:SLOPE,ERODES EASILY
TERRACES AND DIVERSIONS	0-8%:ERODES EASILY 8-35%:SLOPE,ERODES EASILY
GRASSED WATERWAYS	0-8%:ERODES EASILY 8-35%:SLOPE,ERODES EASILY

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-35%:SEVERE-SLOPE
DWELLINGS WITHOUT BASEMENTS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-35%:SEVERE-SLOPE
DWELLINGS WITH BASEMENTS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-35%:SEVERE-SLOPE
SMALL COMMERCIAL BUILDINGS	0-4%:SLIGHT 4-8%:MODERATE-SLOPE 8-35%:SEVERE-SLOPE
LOCAL ROADS AND STREETS	0-15%:SEVERE-LOW STRENGTH 15-35%:SEVERE-LOW STRENGTH,SLOPE
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 15-35%:SEVERE-SLOPE 0-8%GR:MODERATE-SMALL STONES

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS ***	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 0-8%GR:MODERATE-SMALL STONES 8-15%GR:MODERATE-SLOPE,SMALL STONES 15-35%:SEVERE-SLOPE	PLAYGROUNDS ***	0-2%:MODERATE-SMALL STONES 2-6%:MODERATE-SLOPE,SMALL STONES 6-35%:SEVERE-SLOPE 0-6%GR:SEVERE-SMALL STONES 6-35%GR:SEVERE-SLOPE,SMALL STONES
PICNIC AREAS ***	0-8%:SLIGHT 8-15%:MODERATE-SLOPE 0-8%GR:MODERATE-SMALL STONES 8-15%GR:MODERATE-SLOPE,SMALL STONES 15-35%:SEVERE-SLOPE	PATHS AND TRAILS ***	0-15%:SLIGHT 15-25%:MODERATE-SLOPE 0-15%GR:MODERATE-SMALL STONES 15-25%GR:MODERATE-SLOPE,SMALL STONES 25-35%:SEVERE-SLOPE

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPA-BILITY	CORN (BU)		CORN SILAGE (TONS)		OATS (BU)		GRASS-LEGUME HAY (TONS)		PASTURE (AUM)		WHEAT (BU)			
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	IRR	IRR.
0-3%	1		140		28		80		5.0		8.0		50			
3 - a	2E		140		28		80		5.0		8.0		50			
8-15%	3E		130		26		80		5.0		8.0		45			
15-253	4E		120		24		75		4.5		7.5		40			
25-35%	6E										6.5					

WOODLAND SUITABILITY (C)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
0-15%	4A	SLIGHT	SLIGHT	SLIGHT	SLIGHT		NORTHERN RED OAK	80	4	EASTERN WHITE PINE
15-35%	4R	SLIGHT	MODER.	SLIGHT	SLIGHT		YELLOW-POPLAR	80	5	EUROPEAN LARCH
							WHITE ASH	85	4	BLACK WALNUT
										YELLOW-POPLAR
										NORUAY SPRUCE

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-3%	GOOD	GOOD	GOOD	GOOD	GOOD		POOR	V. POOR	GOOD	GOOD	V. POOR	
3-8%	FAIR	GOOD	GOOD	GOOD	GOOD		POOR	V. POOR	GOOD	GOOD	V. POOR	
8-15%	FAIR	GOOD	GOOD	GOOD	GOOD		V. POOR	V. POOR	GOOD	GOOD	V. POOR	
15-25%	POOR	FAIR	GOOD	GOOD	GOOD		V. POOR	V. POOR	FAIR	GOOD	V. POOR	
25-35%	V. POOR	POOR	GOOD	GOOD	GOOD		V. POOR	V. POOR	POOR	GOOD	V. POOR	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED ON TEST DATA OF 10 PEDONS FROM PENNSYLVANIA
8 RATINGS BASED ON [illegible] PART 603.
C RATINGS BASED ON NATIONAL FORESTRY MANUAL
0 WILDLIFE RATINGS BASED ON SOILS MEMORANDUM 71 JAN. 1972.
● **THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

NY0151

SOIL INTERPRETATIONS RECORD: Wassaic Series

MLRA(S): 101, 144A, 140
REV. NEW TMG 1-92
GLOSSOBORIC HAPLUDALFS, FINE-LOAMY, MIXED, MESIC

THE WASSAIC SERIES CONSISTS OF MODERATELY DEEP WELL AND MODERATELY WELL-DRAINED SOILS ON UPLANDS. THEY FORMED IN GLACIAL TILL. TYPICALLY, THESE SOILS HAVE A VERY DARK GRAYISH-BROWN SILT LOAM SURFACE LAYER 9 IN. THICK OVER 1 INCH OF GRAYISH-BROWN LOAM. THE BROWN SUBSOIL LAYERS ARE SILT LOAM FROM 10 TO 14 INCHES AND GRAVELLY SILT LOAM FROM 14 TO 23 INCHES. THE SUBSTRATUM FROM 23 TO 28 INCHES IS BROWN GRAVELLY LOAM. HARD BEDROCK IS AT 28 INCHES. SLOPES RANGE FROM 0 TO 70 PERCENT.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
45-50	140-200	30-42	800-1750	MW,W	0-70

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-10	SIL,L,FSL	GM,ML,SM	A-2,A-4	0	0	80-100	75-100	60-95	40-90	10-27
0-10	GR-SIL,GR-L,GR-FSL	GM,ML,SM	A-2,A-4	0	0-10	55-85	50-80	35-70	25-65	10-27
10-23	L,GR-SIL,SICL	GM,GC,SM,CL	A-2,A-4	0-1	0-10	60-100	55-95	45-95	25-85	18-35
23-28	FSL,GR-SIL,SICL	GM,GC,SM,CL	A-2,A-4	0-1	0-15	55-100	50-95	35-90	25-75	15-30
28-32	UWB									

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-10	25-35	2-10	1.10-1.40	0.6-2.0	0.13-0.21	5.6-7.3					
0-10	25-35	2-10	1.10-1.40	0.6-2.0	0.08-0.17	5.6-7.3					
10-23	15-25	2-10	1.20-1.50	0.2-2.0	0.09-0.19	5.6-7.3					
23-28	15-35	2-10	1.10-1.50	0.2-2.0	0.09-0.19	5.6-7.8					
28-32											

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KF	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-10	2-6	LOW	.32	.32	3	5	56	MODERATE	LOW
0-10	2-6	LOW	.24	.32	3	5	56		
10-23	0-2	LOW	.32	.32					
23-28	0-1	LOW	.32	.32					
28-32									

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
NONE			2.0-3.0	PERCHED	MAR-APR			20-40	HARD			B	MODERATE

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	SEVERE-DEPTH TO ROCK,WETNESS,PERCS SLOWLY
SEWAGE LAGOON AREAS	0-7%:SEVERE-DEPTH TO ROCK,WETNESS 7-70%:SEVERE-DEPTH TO ROCK,SLOPE,WETNESS
SANITARY LANDFILL (TRENCH)	0-15%:SEVERE-DEPTH TO ROCK 15-70%:SEVERE-DEPTH TO ROCK,SLOPE
SANITARY LANDFILL (AREA)	0-15%:SEVERE-DEPTH TO ROCK 15-70%:SEVERE-DEPTH TO ROCK,SLOPE
DAILY COVER FOR LANDFILL	0-15%:POOR-DEPTH TO ROCK,SMALL STONES 15-70%:POOR-DEPTH TO ROCK,SMALL STONES,SLOPE

CONSTRUCTION MATERIAL (B)

ROADFILL	0-25%:POOR-DEPTH TO ROCK 25-70%:POOR-DEPTH TO ROCK,SLOPE
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	0-15%:POOR-SMALL STONES 15-70%:POOR-SMALL STONES,SLOPE

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	0-15%:SEVERE-DEPTH TO ROCK,WETNESS 15-70%:SEVERE-DEPTH TO ROCK,WETNESS,SLOPE
DWELLINGS WITHOUT BASEMENTS	0-8%:MODERATE-WETNESS,DEPTH TO ROCK 8-15%:MODERATE-WETNESS,SLOPE,DEPTH TO ROCK 15-70%:SEVERE-SLOPE
DWELLINGS WITH BASEMENTS	0-15%:SEVERE-WETNESS,DEPTH TO ROCK 15-70%:SEVERE-WETNESS,DEPTH TO ROCK,SLOPE
SMALL COMMERCIAL BUILDINGS	0-4%:MODERATE-WETNESS,DEPTH TO ROCK 4-8%:MODERATE-WETNESS,SLOPE,DEPTH TO ROCK 8-70%:SEVERE-SLOPE
LOCAL ROADS AND STREETS	0-8%:MODERATE-DEPTH TO ROCK,WETNESS 8-15%:MODERATE-DEPTH TO ROCK,WETNESS,SLOPE 15-70%:SEVERE-SLOPE
LAWNS, LANDSCAPING AND GOLF	0-8%SIL,L,FSL:MODERATE-DEPTH TO ROCK 8-15%SIL,L,FSL:MODERATE-SLOPE,DEPTH TO ROCK 0-8%GR:MODERATE-SMALL STONES,DEPTH TO ROCK

WATER MANAGEMENT (B)

POND RESERVOIR AREA	0-3%:MODERATE-SEEPAGE,DEPTH TO ROCK 3-8%:MODERATE-SEEPAGE,DEPTH TO ROCK,SLOPE 8-70%:SEVERE-SLOPE
EMBANKMENTS DIKES AND LEVEES	SEVERE-PIPING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	0-3%:DEPTH TO ROCK 3-70%:DEPTH TO ROCK,SLOPE
IRRIGATION	0-3%SIL,L,FSL:WETNESS 3-70%SIL,L,FSL:SLOPE,WETNESS 0-3%GR-SIL,GR-L,GR-FSL:WETNESS,DROUGHTY 3-70%GR-SIL,GR-L,GR-FSL:SLOPE,WETNESS,DROUGHTY
TERRACES AND DIVERSIONS	0-8%:DEPTH TO ROCK,WETNESS 8-70%:SLOPE,DEPTH TO ROCK,WETNESS
GRASSED WATERWAYS	0-8%SIL,L,FSL:DEPTH TO ROCK 8-70%SIL,L,FSL:SLOPE,DEPTH TO ROCK 0-8%GR-SIL,GR-L,GR-FSL:DROUGHTY,DEPTH TO ROCK

Wassaic Series

NY0151

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	0-8%SIL,L,FSL:MODERATE-WETNESS 8-15%SIL,L,FSL:MODERATE-SLOPE,WETNESS 0-8%GR:MODERATE-SMALL STONES,WETNESS 8-15%GR:MODERATE-SLOPE,SMALL STONES,WETNESS 15-70%:SEVERE-SLOPE	PLAYGROUNDS	0-2%SIL,L,FSL:MODERATE-SMALL STONES,WETNESS 2-6%SIL,L,FSL:MODERATE-SLOPE,SMALL STONES 6-70%SIL,L,FSL:SEVERE-SLOPE 0-6%GR:SEVERE-SMALL STONES 6-70%GR:SEVERE-SLOPE,SMALL STONES
PICNIC AREAS	0-8%SIL,L,FSL:MODERATE-WETNESS 8-15%SIL,L,FSL:MODERATE-SLOPE,WETNESS 0-8%GR:MODERATE-WETNESS,SMALL STONES 8-15%GR:MODERATE-SLOPE,WETNESS,SMALL STONES 15-70%:SEVERE-SLOPE	PATHS AND TRAILS	0-15%:SLIGHT 15-25%:MODERATE-SLOPE 25-70%:SEVERE-SLOPE

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY	CORN (BU)		CORN SILAGE (TONS)		OATS (BU)		WHEAT, WINTER (BU)		GRASS-LEGUME HAY (TONS)		PASTURE (AUM)			
		NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-3%	2S	105		21		75		45		4.5		8.5			
3-8%	2E	105		21		75		45		4.5		8.5			
8-15%	3E	95		19		70		40		4.0		7.5			
15-25%	4E	85		17		65		35		4.0		7.5			
25-35%	6E											5.5			
35-70%	7E														

WOODLAND SUITABILITY (C)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX.	PROD CLAS.	
0-15%	3A	SLIGHT	SLIGHT	SLIGHT	SLIGHT		SUGAR MAPLE	73	3	EASTERN WHITE PINE
15-35%	3R	SLIGHT	MODER.	SLIGHT	SLIGHT		NORTHERN RED OAK	80	4	RED PINE
35-70%	3R	SLIGHT	SEVERE	SLIGHT	SLIGHT		WHITE ASH	85	4	EUROPEAN LARCH NORWAY SPRUCE

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-8%	FAIR	GOOD	GOOD	GOOD	GOOD		POOR	V. POOR	GOOD	GOOD	V. POOR	
8-15%	FAIR	GOOD	GOOD	GOOD	GOOD		V. POOR	V. POOR	GOOD	GOOD	V. POOR	
15-25%	POOR	FAIR	GOOD	GOOD	GOOD		V. POOR	V. POOR	FAIR	GOOD	V. POOR	
25-35%	V. POOR	FAIR	GOOD	GOOD	GOOD		V. POOR	V. POOR	FAIR	GOOD	V. POOR	
35-70%	V. POOR	POOR	GOOD	GOOD	GOOD		V. POOR	V. POOR	POOR	GOOD		

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATED ENGINEERING PROPERTIES BASED ON TEST DATA OF 1 PEDON, ORLEANS CO. N.Y.
B RATINGS BASED ON NSH SECTION 603.
C RATINGS BASED ON NATIONAL FORESTRY MANUAL
D RATINGS BASED ON SOILS MEMO 74, JANUARY 1972

MA0021

SOIL INTERPRETATIONS RECORD: Whitman Series Stony

MLRA(S): 142, 144A, 144B, 145, 149B, 148
REV. DCC 6-87
TYPIC HUMAQUEPTS, COARSE-LOAMY, MIXED, NDNACID, MESIC

THE WHITEMAN SERIES CONSISTS OF VERY DEEP, VERY POORLY DRAINED SOILS ON UPLANDS. THEY FORMED IN GLACIAL TILL. TYPICALLY, THESE SOILS HAVE A SLACK VERY STONY OR EXTREMELY STONY FINE SANDY LOAM SURFACE LAYER 8 IN. THICK. THE MOTTLED SUBSOIL FROM 8 TO 15 INCHES IS GRAY SANDY LOAM. FROM 15 TO 35 INCHES. THE MOTTLED SUBSTRATUM IS A VERY FIRM GRAY AND OLIVE GRAY SANDY LOAM. FROM 35'70 65 INCHES THE SUBSTRATUM IS OLIVE GRAY LOAMY SAND.

LANDSCAPE AND CLIMATE PROPERTIES

ANNUAL AIR TEMPERATURE	FROST FREE DAYS	ANNUAL PRECIPITATION	ELEVATION (FT)	DRAINAGE CLASS	SLOPE (PCT)
45-52	100-195	28-45	0-2100	VP	0-8

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. >10 IN (PCT)	FRACT. 3-10IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	CLAY (PCT)
0-8	STV-FSL,STV-SL,STV-L	ML,SM,CL-ML	A-1,A-2,A-4		5-15	65-80	60-75	35-70	20-65	5-8
0-8	STX-FSL,STX-SL,STX-L	ML,SM,CL-ML	A-1,A-2,A-4		10-40	65-80	60-75	35-70	20-65	5-8
8-15	SL,GR-FSL,GR-SIL	ML,SM,CL-ML	A-1,A-2,A-4		0-10	65-95	60-90	35-85	20-60	2-4
15-35	SL,GR-FSL,L	ML,SM,CL-ML	A-1,A-2,A-4		0-10	65-95	60-90	35-85	20-60	1-3
35-65	LS,GR-LS,GR-SL	SM	A-1,A-2		0-10	65-95	60-90	30-65	15-35	1-6

DEPTH (IN.)	LIQUID LIMIT	PLASTICITY INDEX	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SAR	CEC (ME/100G)	CACO3 (PCT)	GYPSUM (PCT)
0-8	16-35	NP-10	1.10-1.30	0.6-6.0	0.15-0.25	4.5-6.5					
0-8	16-35	NP-10	1.10-1.30	0.6-6.0	0.12-0.24	4.5-6.5					
8-15	16-35	NP-10	1.60-1.85	0.6-6.0	0.10-0.17	4.5-6.5					
15-35	16-32	NP-8	1.85-2.00	0.0-0.2	0.03-0.04	4.5-6.5					
35-65		NP	1.90-2.10	0.0-0.2	0.02-0.03	4.5-6.5					

DEPTH (IN.)	ORGANIC MATTER (PCT)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	KF	T	WIND EROD. GROUP	WIND EROD. INDEX	CORROSIVITY STEEL	CONCRETE
0-8		LOW	.20		5	8		HIGH	HIGH
0-8		LOW	.20		3	8			
8-15		LOW	.32						
15-35		LOW	.24						
35-65		LOW	.24						

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			+1-0.5	PERCHED	SEP-JUN			>60				D	HIGH

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	SEVERE-PERCS SLOWLY,PONDING
SEWAGE LAGOON AREAS ***	0-2%:SLIGHT 2-7%:MODERATE-SLOPE 7-8%:SEVERE-SLOPE
SANITARY LANDFILL (TRENCH)	SEVERE-PONDING
SANITARY LANDFILL <AREA)	SEVERE-PONDING
DAILY COVER FOR LANDFILL	POOR-PONDING

CONSTRUCTION MATERIAL (B)

ROADFILL	POOR-WETNESS
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL ***	POOR-WETNESS,LARGE STONES,AREA RECLAIM

WATER MANAGEMENT (B)

POND RESERVOIR AREA	0-3%:SLIGHT 3-8%:MODERATE-SLOPE
EMBANKMENTS DIKES AND LEVEES ***	SEVERE-PIPING,PONDING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE ***	0-3%:PERCS SLOWLY,FROST ACTION 3-8%:PERCS SLOWLY,FROST ACTION,SLOPE
IRRIGATION ***	0-3%:PONDING,PERCS SLOWLY,ROOTING DEPTH 3-8%:SLOPE,PONDING,PERCS SLOWLY
TERRACES AND DIVERSIONS	WETNESS,PERCS SLOWLY,LARGE STONES
GRASSED WATERWAYS	STV:WETNESS,PERCS SLOWLY,ROOTING DEPTH STX:LARGE STONES,WETNESS,PERCS SLOWLY

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS ***	SEVERE-PONDING
DWELLINGS WITHOUT BASEMENTS	SEVERE-PONDING
DWELLINGS WITH BASEMENTS	SEVERE-PONDING
SMALL COMMERCIAL BUILDINGS	SEVERE-PONDING
LOCAL ROADS AND STREETS	SEVERE-FROST ACTION,PONDING
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	STV:SEVERE-PONDING STX:SEVERE-LARGE STONES,PONDING

Whitman Series Stony

MA0021

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	STV:SEVERE-PONDING STX:SEVERE-LARGE STONES,PONDING	PLAYGRDUNDS	0-6%:SEVERE-PONDING,LARGE STONES 6-8%:SEVERE-SLOPE,LARGE STONES,PONDING
PICNIC AREAS	STV:SEVERE-PONDING STX:SEVERE-LARGE STONES,PONDING	PATHS AND TRAILS	SEVERE-PONDING

REGIONAL INTERPRETATIONS

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY															
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
ALL	/S															

WOODLAND SUITABILITY (D)

CLASS-DETERMINING PHASE	ORD SYM	MANAGEMENT PROBLEMS					POTENTIAL PRODUCTIVITY			TREES TO PLANT
		EROS'N HAZARD	EQUIP. LIMIT	SEEDL. MORT'Y	WINDTH HAZARD	PLANT COMPET	COMMON TREES	SITE INDX	PROD CLAS	
ALL	2W	SLIGHT	SEVERE	SEVERE	SEVERE		RED MAPLE	55	2	
							EASTERN WHITE PINE	56	7	
							RED SPRUCE	44	6	

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (E)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-2% STV	V. POOR	POOR	POOR	POOR	POOR		GOOD	FAIR	POOR	POOR	FAIR	
2-3% STV	V. POOR	POOR	POOR	POOR	POOR		GOOD	POOR	POOR	POOR	FAIR	
3-8% STV	V. POOR	POOR	POOR	POOR	POOR		POOR	V. POOR	POOR	POOR	V. POOR	
0-2% STX	V. POOR	V. POOR	POOR	POOR	POOR		GOOD	FAIR	V. POOR	POOR	FAIR	
2-3% STX	V. POOR	V. POOR	POOR	POOR	POOR		GOOD	POOR	V. POOR	POOR	FAIR	
3-8% STX	V. POOR	V. POOR	POOR	POOR	POOR		POOR	V. POOR	V. POOR	POOR	V. POOR	

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE				
ALDER	ALNUS					
SEDGE	CAREX					
SKUNK CABBAGE	SYFO					
CINNAMON FERN	OSCI					
SPHAGNUM MOSS	SPHAG*					
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS						
NORMAL YEARS						
UNFAVORABLE YEARS						

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES ARE BASED ON TEST DATA FROM SIMILAR SOILS.
B RATINGS BASED ON ..ISH PART 2 SECTION 403, MARCH 1978.
D RATINGS BASED ON NATIONAL FORESTRY MANUAL
E UILOLIFE RATINGS BASED DN SOILS MEMORANDUM 74..JAN. 1972.
***THIS IS A RATING OVERRIDE. SEE THE INTERPRETATION OVERRIDE FILE FOR AN EXPLANATION OF THIS OVERRIDE.

Chapter 5

WATER RESOURCES

(Refer to the following maps in the Appendix of this document-- Groundwater Recharge, Wetlands, Water Companies, Surface Runoff and Floodways.)

BYRAM: RICH AND POOR IN WATER

The 'Township of Lakes' has more than two dozen lakes and ponds, numerous small streams, two sizable rivers, and many wetlands. But while **Byram** is rich in surface water, the Township's geology provides very limited aquifers to supply drinking water. Unlike much of the rest of Sussex County, **Byram** has few aquifers that are extremely prolific. Those that **exist** occur principally in the Musconetcong Valley, in the southwest corner of the Township.

Over the past 40 years, **Byram** has evolved from a lake resort community to a suburbanized township. As it continues to grow, both its **surface-** and **ground-waters** will come under increasing stress. Lakes, streams and wetlands are susceptible to contamination, siltation and flooding; aquifers are susceptible to contamination and overuse. Building on the land can alter groundwater recharge, which can affect the quantity and quality of both surface- and ground-water.

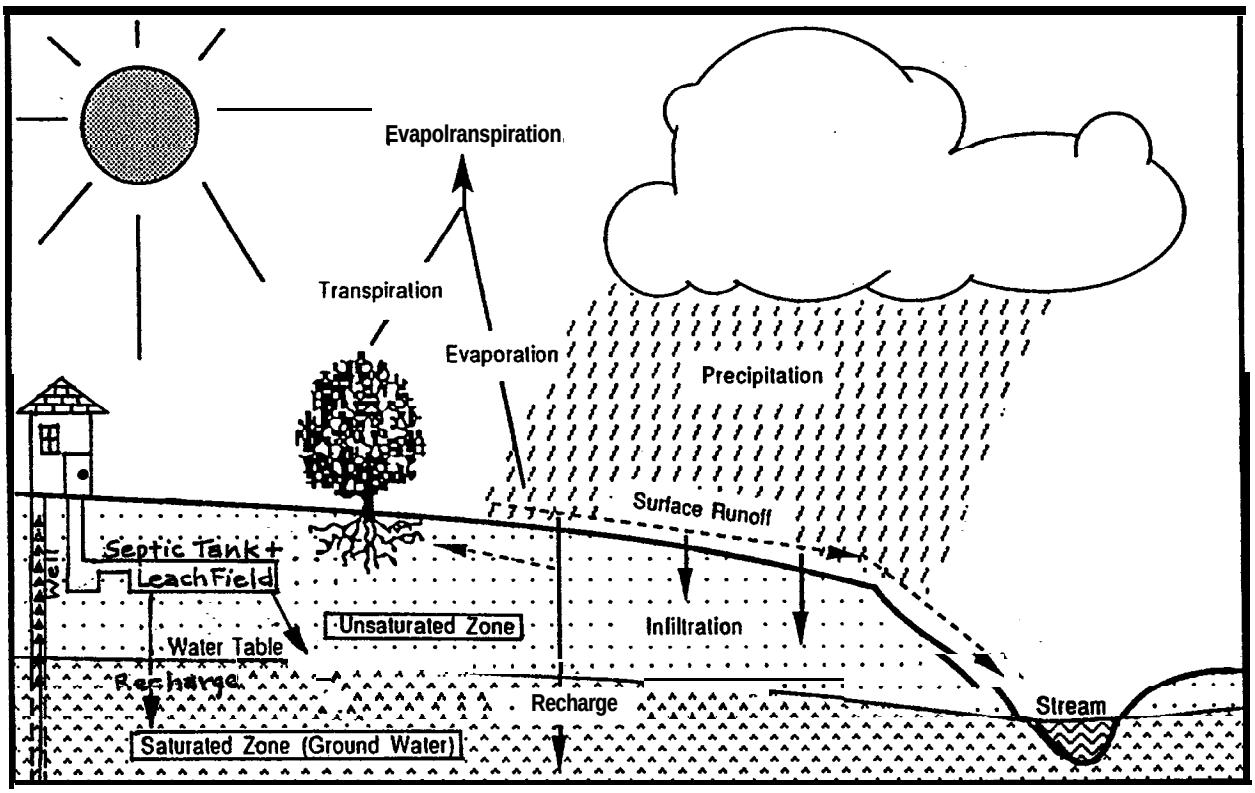
All of the Township's water is tied into one large natural system known as the hydrologic cycle.

THE HYDROLOGIC CYCLE

The illustration on the next page explains the hydrologic cycle, which transforms water from one form and place to another. The sum of water involved in all parts of this cycle is an area's water. budget. Disturbing one part of the cycle through natural or human events, such as drought,

THE HYDROLOGIC CYCLE

a solar-driven continuous system
that transfers water from one form and place to another



Precipitation *occurs when water vapor is transformed into rain, sleet, hail or snow Precipitation may flow into streams and lakes, may evaporate, or may infiltrate into the ground.*

Some ***infiltrated wafer*** *is used by plants. The remainder percolates deeper into the ground--some of it, known as* ***base flow,*** *discharges into lakes or streams or appears as springs; some recharges* ***aquifers.***

Aquifers are underground reservoirs that store and transmit water and ***supply*** *water for wells. Properly functioning* ***septic systems*** *help recharge aquifers by cleansing wastewater and returning it to the ground.*

Some precipitation evaporates, becoming water vapor. Water taken up by plants also becomes water vapor after the plants use it and return it to the atmosphere, a process known as transpiration. ***Evapotranspiration*** *accounts for about 30-60 percent of all precipitation, leaving 40-70 percent for surface water and groundwater recharge.*

depletion of aquifers, paving or compacting of critical recharge areas, affects the rest of the cycle.

To start the cycle, water as precipitation falls either directly into lakes, streams and wetlands or onto the land. Precipitation that falls on the land may travel to surface water bodies as surface runoff, or it may evaporate, or it may seep into the soil. Water that infiltrates the soil may be used by plants and returned to the atmosphere as vapor (transpiration) or it may travel below the root zone as groundwater recharge. It is estimated that between 30-60 % of precipitation is lost as evapotranspiration.

Groundwater recharge supplies the water table (the saturation zone of the soil) and underground water reservoirs (aquifers). From either the saturation zone or aquifers it may discharge into lakes, streams and wetlands--or lakes, streams and wetlands may discharge into the ground and aquifers.

Evaporation from land or from water bodies and transpiration from plants returns to the atmosphere where, depending on weather conditions, it is condensed again as precipitation, completing the cycle.

The Effect of Septics and Sewers on the Hydrologic Cycle

Sewers and septic systems can affect the water budget. Septics return their effluent to the ground, after bacterial action and filtration in the soils cleanses it (in a properly working system). Thus **septics** contribute to recharge. Sewers, however, carry large amounts of water out of the **sewered** area. If recharge from other sources is not adequate to replace this gallonage, aquifers may become depleted and this may affect the water table and the amount of water in streams or lakes.

Byram's *Sewer Line*

In early 1992, **Byram** was granted 60,000 gallons per day in sewer allotment **from** the Musconetcong Sewer Authority in Mt. Olive, with another 40,000 GPD promised when the plant is successfully re-rated for higher effluent discharge. At the total 100,000 GPD, the sewer line (which would serve only a small part of the township, initially along the lower portion of Route 206, a short distance on Lackawanna Drive, and as far as the Intermediate School on Mansfield Drive) would take 36.5 million gallons per year out of the aquifers serving those areas of the township.

Monitoring the Effects of Sewers on Byam's Groundwater

Quantifying the safe yield of aquifers is a very complicated process. Unlike most of the rest of Sussex County, Byram has few extremely prolific aquifers. For both these reasons, the Commission requested that monitoring wells and stream or staff gauges be installed to provide data about the effect of the sewer line on aquifers and the water table. The Commission made this request on the advice of hydrogeologists from the New Jersey Department of Environmental Protection, who recommended that monitoring begin well before the sewer became operable, in order to obtain good baseline data. The Township Council agreed to this monitoring program.

For further discussion of Byram's aquifers, see later sections in this chapter and also Chapters 4, BEDROCK GEOLOGY, SURFICIAL GEOLOGY, AND SOILS, and 6, COMPOSITE ENVIRONMENTAL CONSTRAINTS.

GROUNDWATER RECHARGE

The Recharge Map

The Groundwater Recharge Map was prepared by the Environmental Commission according to instructions in a draft document from the N.J. Department of Environmental Protection's Geological Survey.

The factors influencing recharge are climate, soils (which include slopes), natural land cover, and developed areas.

The resulting map estimates how many inches of precipitation each year infiltrate below the root zone--that is, precipitation that does not run off, evaporate from the land surface, or transpirate through plants.

How much of this recharge travels horizontally through the ground as 'base flow', discharging into surface waters, and how much of the recharge resupplies aquifers is not explained by the map (N.J.D.E.P. hopes to publish a methodology for this by 1994 or 1995). The limitations of the groundwater recharge mapping process are described on pages 63-67 of the N.J.D.E.P. draft document.

The Commission's work documents, including the various map overlays and the final recharge calculations, are on file at the Municipal Building.

The Commission conferred with Township Planner Eric Snyder in delineating land use categories and 'used the table on page 79 of the N.J.D.E.P. draft

document to calculate recharge. A small change was made in the formula upon publication of the final N.J.D.E.P. document, and the Commission recalculated all the recharge numbers according to that new formula.

In October 1993, N.J.D.E.P. officials in charge of the groundwater recharge mapping project reviewed and approved the Commission's work. Those officials were planning to calculate the volumes of recharge in different areas of the Township, based on the inches per year shown on the Commission's map.

Groundwater Recharge in Byram

Byram receives an annaul average of 44 inches of precipitation (rain and snow converted to rain). At best, only about 1/3 of this precipitation soaks into the ground below the level of the root zone. How much of that 1/3 is then available to recharge aquifers is not known.

In Byram, groundwater recharge falls largely into two categories--minimal (O-7 inches per year, almost all of this category being zero recharge, occurring in RvE soils) and high (20 inches and above). The acreage covered by these two categories is roughly the same, and together they cover most of the township. Because so much of the township is marked by minimal (mostly zero) recharge, the Environmental Commission recommends maximum protection for areas of high recharge.

These mapping categories were established by the Commission based on a natural grouping of recharge numbers derived during the mapping process. The Commission's results were also verified by comparing them to numbers and recharge categories derived by the N.J.D.E.P. in two other pilot mapping projects.

The Role of Wetlands, Lakes and Streams in Recharge

Wetlands are not categorized on the recharge map, because, like lakes and streams, their role in groundwater and aquifer recharge is complex. These surface water bodies may be important recharge areas, or they may be areas where groundwater or aquifers discharge, or they may be areas where no water is exchanged.

Generally, upland wetlands are more likely to be recharge areas, and valley wetlands are more likely to be an expression of the water table.

(Wetlands are also discussed in Chapter 3, NATURAL HABITATS AND ENDANGERED SPECIES.)

Recharge as an Environmental Constraint

The Commission used the information gathered from the Groundwater Recharge Map in two ways:

1. Areas where high recharge overlies either limestone bedrock or stratified drift deposits (both possible important aquifers for **Byram**) were categorized by the Commission as critical on the Composite Environmental Constraints Map.

2. The key for the Composite Environmental Constraints Map refers to the Groundwater Recharge Map, noting **that all areas** of high recharge, whether shown in critical, semi-critical, or non-critical areas on the Constraints map, must be given special protection. Soil and plant disturbance (including soil compaction), impervious coverage, and stormwater management (surface runoff) all affect recharge rates.

The Effects of Development on Recharge

Changes in land use can have a striking effect on recharge. A good example of this in **Byram** can be illustrated by studying recharge in wooded areas (the most typical land cover in **Byram,** designated as category **R**-50 in the N.J.D.E.P. draft document) with **Rockaway** soils (the most common soil group in **Byram,** designated as soil type G in the draft document) and calculating recharge based on various land uses:

1.Left undeveloped, these areas have a high recharge of about 20 inches per year.

2. When developed as **1/2** acre residential, the recharge drops by about **1/3** to about 14 inches.

3. When developed as landscaped commercial industrial (category U-31 in the draft document, defined as having about 5-15% vegetated, including highways and large parking lots), the recharge drops precipitously to less than 3 inches.

The adverse effects of development on recharge can be ameliorated by landscaping practices and good stormwater management; but tree removal and other changes in vegetation, soil compaction, and the addition of impervious coverage all will reduce recharge.

AQUIFERS

Most of Byram is underlain by Pre-Cambrian gneisses and granitic bedrock, which are generally poor aquifers. These otherwise impermeable formations contain water only in faults, joints or fractures. Well yields depend on the numbers and sizes of these openings, which vary by location and decrease at greater depths, with the most extensive fracturing and weathering generally occurring at depths less than 150 feet.

Generally, well production in this kind of bedrock ranges from 2 to 50 gallons per minute and is sufficient for residential use. Yields are more reliable when wells are near fracture zones. Areas near major faults may supply high well yields because the bedrock is often more fractured in these locations. Sites close to lakes or streams, which can help recharge the aquifer, may also exhibit enchanced yields.

The Hardyston Quartzite bedrock of Paleozoic age found in Byram is similar to the Pre-Cambrian formations in being a poor aquifer. It is found only in small belts in a few areas of Byram.

The Leithsville Formation, also a Paleozoic Carbonate rock, contains limestone. It has a better potential as an aquifer, because limestone can become weathered and cavernous by being dissolved in mild acids, such as carbonic acid, a product of precipitation leaching through soil. The Leithsville Formation occurs in only three small areas in Byram--between Roseville and Kofferls ponds; west of Lake Lackawanna; west of Lake Waterloo. Well yields may reach a couple hundred gallons per minute. Solution channels are more commonly found in valleys, depressions, and near streams and rivers; but, as with fissures in pre-Cambrian rock, the location of solution channels in limestone is unpredictable.

Byram's best possible aquifers may lie in the glacial stratified drift formations found intermittently along Route 206; along the Musconetcong and Lubbers Run; and beginning southeast of Lake Lackawanna and extending up past Roseville Pond toward Stag Lake. These formations are mapped in detail on the Surficial Geology Map; the deeper glacial deposits shown on the Bedrock Geology Map may indicate where the surficial formations have enough depth to be useful aquifers. Where stratified drift formations lie over Leithsville bedrock may also indicate possible good aquifers.

Some of these aquifers are extensive enough to supply large municipal water systems, according to N.J.D.E.P. geologists. Elsewhere, N.J.D.E.P. geologists estimate these deposits are too thin to be aquifers, although, because of their permeability, they may readily transmit surface water into bedrock aquifers.

Both limestone and stratified drift formations are very susceptible to contamination from the surface.

According to the N.J.D.E.P. draft document on glacial (stratified drift) aquifers, "the sources and flow paths of recharge for a given aquifer are difficult to document with certainty" (page 37 of Geology of the Glacial Aquifers of New Jersey). However, the document makes some tentative conclusions:

1. Direct precipitation is probably a significant source of recharge for glacial aquifers with large permeable outcrop areas (that is, areas exposed to the surface). Most of Byram's surficial stratified drift formations are minor in size.

2. Infiltration from streams, lakes, and wetlands is a primary source of recharge for glacial aquifers with relatively small outcrop areas in narrow valleys with large streams and for aquifers in contact with large lakes. The document cites the Musconetcong valley as an example.

3. Stratified drift formations that are partially confined (or overlain) by less-permeable layers of fine-sand-to-silt (another type of glacial deposit) can be readily recharged through those confining layers. If the confining layers are clay and silt, recharge is minimal.

4. Confined glacial aquifers may receive significant recharge from contiguous permeable bedrock. The initial source of the recharge to the bedrock may be precipitation or water from lakes, streams, and wetlands.

How each of these kinds of recharge may affect Byram's minor stratified drift formations would require more detailed study.

Safe Aquifer Yields and Carrying Capacity

In 1973, the Miller-Vecchioli Tocks Island study calculated safe aquifer yields for various geological formations. Those safe yields for Byram's geological formations ranged from 200,000 gallons per day (normal rainfall) to100,000 gallons per day (drought) for Pre-Cambrian rocks, and from 500,000-200,000 gallons per day for stratified drift deposits.

The Miller-Vecchioli methodolgy is now considered outdated and the numbers somewhat conservative. New methods for calculating safe yields have been tried, relying more on groundwater recharge and also on discharge from groundwater into lakes and streams (base flow). However, N.J.D.E.P. hydrogeologists caution against depending on such general methods to estimate available water supplies in a specific area or township. They caution against using recharge or base flow numbers as representing the available water supply, since only a certain percent of recharge can safely be taken for human use before aquifer depletion can begin to occur. The current state Water Supply Master Plan sets this percentage at 10-30%, using 20% as the figure for the Highlands area within which Byram lies.

The Environmental Commission wants water supply issues to be made a primary factor in zoning and development decisions and wants those decisions to be based on a 'carrying capacity' approach. 'Carrying capacity' assumes that a township's natural resources, especially water supply, can safely support only a limited number of people. Other factors, including man-made infrastructure such as roads, can be used to help set carrying capacities.

WELL COMPANIES

Most of Byram's residences are supplied by 11 water companies, the smallest serving 16 homes and the largest serving 400 homes in Byram (with additional customers in Sparta). Many other homes, all businesses, the schools, and the municipal complex have individual wells.

The tables on pages 103 and 104 list the companies, their addresses and phone numbers, officers' names, the numbers of hookups and wells, the pumping rates, and how the water is treated.

The 1984 amendments to the N.J. Safe Drinking Water Act (known as A-280) established periodic testing requirements for all community water systems. In 1989 standards were established for organic chemicals and maximum contaminant levels (MCL) were set.

Under the law, MCLs for carcinogens "shall permit cancer in no more than one in a million persons ingesting that chemical for a lifetime. The

WATER COMPANIES SERVING BYRAM

COMPANY	AREA SERVED	NO. WELLS	NO. HOOKUPS	PUMPING RATE IN MGD
1. Brookwood Musconetcong River Property Owners Association	West Brookwood	3	400	well#1=0.1; #2=0.11; #3=0.216
2. Byram Homeowners Association Water Company	Forest West/Forest South	2	148	well#1=0.13; #2=0.15
3.. Colby Water Company	Colby Dr./Tamarack Rd.	1	19	well#1=0.003
4. East Brookwood Water Company	East Brookwood	3	175	#l-unused; #2=0.034; #3=0.043
5. Forest Lakes Water Company	Forest Lakes	2	360 in Byram 35 in Andover	well#1 =0.156; #2=0.36
6. Frenches Grove Water Association	Cranberry Lake: N. Shore Tr./Rose Tr.	3	85	(summer only; rates not listed)
7. North Shore Water Association	Cranberry Lake: N. Shore Rd. areas	2	22 year-round 40 summer	#1=0.025; #2=summer only
8. South Shore Water Association	Cranberry Lake: S. Shore Rd. areas	1	10 (summer only)	(not available)
9. Sparta Township Water Utility	Lake Mohawk/ Tomahawk Lake area/ Autumn Hill/Mohawk View	32	c.350 in Byram c.4,150 in Sparta	(not available; 3 wells in Byram but all wells serve the whole system)
10. Strawberry Point Property Owners Association	Cranberry Lake: Strawberry Point	2	30 year-round 35 summer	well#1=0.042;#2=unused
11. Willor Manor Water Company	Willor Manor	1	16	well#1=0.028

NOTE: treatment for all companies is chlorination

WATER COMPANIES SERVING BYRAM

COMPANY	*ADDRESS*	*OFFICER* (as *of 1994)*	*TELEPHONE*
1. **Brookwood** Musconetcong River Property Owners Association	P.O. Box 797, **Stanhope** 07874	Doug Stout (pres.) Karen Sloan (sec'y.)	(908) 850-7185 or 347-4 173 347-7084
2. **Byram** Homeowners Association Water Company	P.O. Box 725, Andover 07821	Marsha Godard (sec'y.)	**347-6962**
3. Colby Water Company	P.O. Box 814, Andover 07821	Bill Spichiger (pres.) Holly Livesey (treas.)	347-3258 347-7128
4. East **Brookwood** Water Company	P.O. Box **575, Stanhope 07874**	Richard **Stopa**	**347-9004**
5. Forest Lakes Water Company	P.O. Box 284, Andover 07821	Dorothy Gorman (sec'y.)	**786-6600**
6. **Frenches** Grove Water Association	P.O. Box 474, Andover 07821	Joseph Murphy Jimmy Oscovitch	514-5167 691-6334
7. North Shore Water Association	1 Katonah Trail, Andover 07821	Liz Cecere (pres.) Donna Galotta (sec'y.)	691-3341 347-6205
8. South Shore Water Association	74 South Shore Rd., Andover 07821	Karl **Mangel**	347-5906 or 857-0875
9. Sparta Township Water Utility (includes Sparta Mt. Water Co.)	65 Main Street, Sparta 07874	Richard Weifert (superint.) (billing)	729-7133 729-5 133
10. Strawberry Point Property Owners Association	200 N. Shore Rd., Andover 07821	Bill Busch (pres.)	347-0217
11. **Willor** Manor Water Company	9 **Willor** Rd., Andover 07821	Richard Markferding (pres.)	69 l-2802

MCLs for non-carcinogens shall eliminate, with the limits of practicality and feasibility, all adverse physiological effects which may result from ingestion." (See Theodore B. Shelton's Interpreting Drinking Water Quality Analysis, listed in the bibliography at the end of this chapter.) It is important to realize that the process of setting standards for drinking water is imperfect, because there is insufficient data on adverse health effects of contamination and because political factors may influence the standards.

The frequency of testing depends on the type of water system and the number of individuals it serves. Nine of Byram's 11 companies are classified as 'community public water systems,' meaning that the system has at least 15 connections or serves 25 permanent residents. Willor Manor and the South Shore Water Association are smaller.

In the 9 larger companies, coliform bacteria must be tested at least once a month; organic chemicals must be tested yearly; inorganics and nitrate, every three years. Radiological testing is required every four years. Chlorinated systems are monitored daily.

The N.J. Department of Environmental Protection is to inspect and evaluate each company for compliance with testing procedures and with mechanical requirements. Recent inspection results are in the Environmental Commission files at the municipal building under "Water Companies." Companies rated 'unacceptable' must correct the deficiencies within 30 days and file a written report. Residents who want information about any of Byram's water companies may call the company or may call the N.J.D.E.P.'s Bureau of Safe Drinking Water at (609)-292-5550.

GROUNDWATER CONTAMINATION

Specific Contamination Episodes: Volatile Organics

Within the past decade, some of Byram's water companies (North Shore, Willor Manor, East Brookwood, Sparta Mountain, with smaller and less frequent problems at Frenche's Grove, Colby, and Byram Homeowners) and wells at the Byram Consolidated School and the Municipal Building have had problems with low levels of carcinogens.

The contaminants are usually chlorinated organics (most often trichloroethane or trichloroethylene) which are found in many industrial and

household products used for cleaning and degreasing. These chemicals--including dry-cleaning fluids, metal and automotive cleaners, septic tank degreasers, spot removers and furniture cleaners, inks and correction fluids, and various adhesives-- are becoming increasingly common in well water throughout the state.

Some homes with private wells near the water companies have also reported contamination, and N.J.D.E.P. tests have also found high levels of these contaminants in some commercial and industrial wells and small traces in the Cranberry Lake Fire Department well.

Further information is available at the Municipal Building, under "Groundwater Contamination" in the Environmental Commission files. The contamination is typically managed by filtering the affected wells and by periodic testing.

Information in the Board of Health files at the Municipal Building describes the various- episodes -of contamination as follows:

1. The **Willor** Manor contamination was discovered in 1985-86 and includes trichloroethane and carbon tetrachloride, as well as traces of other chemicals. The levels of trichloroethane and carbon tetrachloride fell within Level II and Level III categories, under which the N.J.D.E.P. calls for certain levels of testing and treatment. Under Level II, periodic monitoring is required and either alternative water sources or appropriate remedial action is recommended. Under Level III, monthly monitoring is required and either alternative **water** sources or appropriate remedial action is required within one year.

2. The North Shore contamination also was discovered in 1985-86, with levels of trichloroethane requiring Level III action and **dichloroethylene** at Level I (random sampling, no recommended remediation).

3. The East Brookwood contamination was **dicovered** in 1986, with levels of tetrachloroethylene requiring Level II action and traces of trichloroethylene and trichloroethane at Level I.

4. In 1985, Colby had Level I quantities of trichloroethane; **Byram** Homeowners had Level I of ortho-xylene, meta-xylene, and **para-xylene**; and Sparta Mountain had Level I of meta-xylene and xylenes and Level II of tetrachloroethylene.

5. In 1989-90, trichloroethane (at Level I) and trichloroethylene (at

Level II), as well as traces of other volatile organics, were discovered at the Consolidated School and the Municipal Building. Tests for contaminants at the Intermediate School produced results within safe standards. In 1991, air strippers were installed at the Consolidated School and the Municipal Building; by September 1992, tests results were within safe standards.

Specific Contamination Episodes: Radon

Wells at the Autumn Hill and Mohawk View housing developments, subdivided in the late1980s, were found to have significant amounts of radon. Tests by the state Bureau of Safe Drinking Water (within the N.J.D.E.P.E.) found levels of 23,000-40,000 picocuries per litre.

Although there were no established standards for radon in water when this NRI was published, the U. S. Environmental Protection Agency had proposed a maximum contaminant level of 300 picocuries per litre. That standard was expected to be in force by 1995. The current atmospheric standard for radon is 4 picocuries per litre of air; 10,000 picocuries in water are the equivalent of 1 picocurie in air.

The superintendent of the Sparta Township Water Utility, which delivers water to about 350 Byram residents, tested 20 of the Utility's 32 wells and found that only 3 would have met the proposed radon standard. This may indicate that radon contamination could be a problem in many of Byram's water companies and individual wells.

Information about drinking water standards and well testing is contained in the Environmental Commission files at the Municipal Building under "Drinking Water. "

General Risks of Contamination

Septic systems may also cause groundwater or drinking water contamination if they are improperly designed, operated or maintained. All of Byram, except the Intermediate School, depends on septic systems rather than sewers. However, most of Byram's soils are rated unsuitable or restricted for septics. This problem is magnified by the fact that many of the septic systems in Byram's older lake communities were installed before regulations were in place. Many are also improperly used and poorly maintained.

In 1990, a septic management district was established at Cranberry Lake, covering approximately 525 systems, almost all of them residential. The district educates septic owners about proper use, requires owners to locate and map their systems and to pump at least every three years. The septic management district is described more fully in the 'Lakes' section of this chapter. The district was created as a pilot program, which may be extended to the entire Township if it works well.

Other potential risks to groundwater include the MKY facility (a former manufacturing facility on Tamarack Road which has been closed and cleaned up, with nearby well tests showing no unacceptable contamination by the lead found in nearby soils and surface water), a small dump on the southeastern shore of Wolf Lake (MKY reportedly dumped and 1993 testing by the N.J.D.E.P. found numerous contaminants, with especially high levels of lead) and an old landfill in the Cat Swamp Hill area of Route 206 (anecdotal reports say this dump was closed about 25 years ago but may have received both household and industrial waste).

Page 109 contains summaries of the N.J.D.E.P. testing and cleanup reports for MKY and Wolf Lake.

The Wolf Lake and Cat Swamp Hill sites are located over or near stratified drift deposits, which are very susceptible to contamination. The Environmental Commission is involved in trying to identify what may be dumped in these two areas. In October 1993, the Commission submitted to the N.J.D.E.P. substantial documentation on the Cat Swamp Hill site, including maps, aerial photos, and interviews with people familiar with the dump. Maps indicated that approximately 1/3 of the site was located on N.J.D.E.P. property, a 225 acre piece purchased in 1982 to add to the Allamuchy Mountain State Park. When this document went to press, the N.J.D.E.P. Site Remediation Program was in the process of testing surface refuse, soils and groundwater for contamination, using federal cleanup funds.

Some of Byram's few industries-- the township's two salvage yards (Raimo's on Route 206 and North Jersey Auto Wreckers on Lackawanna Drive), Cartridge Activated Devices on Old Indian Spring Road, and the various garages and automotive repair shops--may also use or produce substances that could, if improperly disposed of, threaten groundwater.

THE STATUS OF THE MKY/MYCALEX FACILITY AND THE RELATED WOLF LAKE SITE

Summary of documents obtained in 1993 by the Byram Township Environmental Commission from the N.J.D.E.P. and the U.S.E.P.A. The E.P.A. was the lead agency on the MKY cleanup. (Documents are in the Environmental Commission files at the municipal building under "MKY/Mycalex.")

MKY/Mycalex/Mykroy:

1. Site description. On this 5.59 acre site, known as the MKY Corporation Mycalex Facility, or as Mycalex, or as Mykroy Ceramics, electronic products involving ceramics and synthetic mica were manufactured. Lead was a waste-product, and lead-bearing sludges, sand, gravel and other miscellaneous debris were deposited at the site until 1971. After 1971, MKY continued to dump materials suspected of containing significant lead concentrations which the company brought in from other locations.

There are two vacant buildings on the property. A small stream runs besides the waste piles and discharges into a marshy area at the edge of Johnson Lake. MKY operated from 1945 to 1971.

2. Cleanup. In September 1985, the U.S.Environmental Protection Agency entered into an Administrative Consent Order (ACO) with MKY under which MKY would pay for investigation and cleanup. Between July 1989 and 1991, approximately 5300 tons of lead contaminated soil were trucked out to a licensed landfill in Illinois. The site was regraded and revegetated. The soils cleanup is considered complete, although in 1993 the stream cleanup was still being reviewed. The N.J.D.E.P. was satisfied that the stream cleanup was adequate; the U.S.E.P.A. was still questioning it.

3. Contamination. At the request of the N.J. Department of Environmental Protection and Energy, MKY took several soil and surface water samples from the Johnson Lake tributary and the marsh. All showed lead contamination, as had the soils above the marsh. Four monitoring wells on the site (which have since been removed) also showed some lead (but in levels below drinking water standards) and one of the wells showed low levels of chlorinated organics. These chlorinated organics probably did not come from MKY manufacturing activities, the U.S.E.P.A. concluded.

In October 1989, the Byram Township Health Department collected samples from 31 residential wells west and southwest of the MKY site (these homes were 2000 feet or more from the site). Trace levels of chlorinated organics were found in several wells, although the U.S.E.P..A. concluded that the aquifer supplying these wells was "not seriously degraded." These wells apparently were not tested for lead contamination, since the on-site monitoring wells only showed lead in concentrations below drinking water standards.

NOTE: One N.J.D.E.P. official interviewed by the Environmental Commission recommended that residents near this site test their wells annually for chlorinated organics (which are not uncommon in wells where septic systems are used). Residents may also want to test for lead.

Wolf Lake Site:

This 1/4-acre site is southeast of the lake between the shore and Roseville Road and is owned by the same family that operated MKY.

In the early 1990s, the Township Environmental Commission asked the state to test for contaminants dumped by MKY. An April 28, 1993 report by N.J.D.E.P. lists numerous contaminants exceeding state criteria, including a pesticide and many metals. Lead predominated, at levels up to 201,000 parts per million--cleanup criteria is 100 ppm. N.J.D.E.P. warned of potential groundwater contamination and a high potential for surface water contamination. No enforcement action was initiated. The area is still largely devoid of vegetation. Wolf Lake is a popular fishing spot.

The Township also has a small list of ECRA (Environmental Cleanup and Responsibility Act--revised in 1993) and BUST (Bureau of Underground Storage Tank) sites, where pollution problems from underground storage tanks or other commercial activities have required cleanup. This list, almost all BUST sites, includes the Township Municipal Complex, Byram Garage, A.F. Drilling, Byram Transmission, and Becks Service Station. ***Further information is in the Environmental Commission files at the Municipal Building under "BUST sites."***

STREAMS

Byram's two major streams, Lubbers Run and the Musconetcong River, are both classified as trout maintenance waters by the state. Dragon Brook (the outlet stream for Cranberry Lake) is non-trout waters. Unnamed streams and tributaries assume the classification of the first classified stream they enter.

Sewage Treatment Plants

Both Lubbers Run and the Musconetcong, which together form Byram's border with Hopatcong, Stanhope and Mt. Olive, receive effluent from wastewater treatment plants.

The small plant at the Byram Intermediate School sends approximately 4,000 gallons per day of effluent into Lubbers Run; the figure ranges from 1,500 to 8,000 gallons per day, according to consultants hired by the Township to oversee Byram's entry into the Musconetcong Sewer Authority (MSA) in the early 1990s. This 15-year-old Intermediate School plant is to be phased out when the Township connects to the MSA.

The Musconetcong Sewer Authority, located in Mt. Olive and serving Mt. Olive, Stanhope, and Roxbury, sends its effluent into the Musconetcong. The MSA plant is currently being upgraded and will seek re-rating to a capacity of 3.26 million gallons per day. From current gallonage, Byram has just been granted 60,000 GPD; from the re-rating Byram expects to receive another 40,000 GPD.

The MSA plant then plans another expansion to nearly double its capacity, but this is not expected to occur for a decade or so and will depend partly on how the doubling of effluent would affect the Musconetcong

River. The Byram Township Environmental Commission and the Musconetcong River Watershed Association will join forces to review MSA's expansion applications to the state.

Non-point Pollutants Affecting Byram's Streams

Single sources of pollution, such as sewage treatment plants, are called 'point' sources. However, pollutants may be entering Byram's streams from the many 'non-point' (general or widespread) sources in their drainage basins. Typical non-point sources are septic systems that are improperly designed or used, road and driveway runoff (petroleum products as well as siltation), erosion and siltation from unpaved areas (especially construction sites), chemical or fertilizer runoff from lawns or fields, runoff from quarrying. Byram has minimal agricultural land to cause non-point pollution, but its many homes and lawns are a major factor in both stream and lake degradation.

The lists on pages 112 and 113 describe non-point pollution, its sources and effects.

In 1973, state sampling of lakes and streams found some of the township's highest coliform counts in Lubbers Run where it passes under Route 206 and Waterloo Road. Subsequent stream testing results are not available, but residents also report the stream is flooding more quickly and more frequently and is carrying more silt, which is being deposited at various places along the stream. Stream siltation and more frequent flooding are typical results of increased development in a watershed.

Careless development near streams or in and near floodplains, wetlands, and steep slopes can also cause a see-saw effect in which streams alternately overflow and erode their banks or become dry in periods of low rainfall. This occurs when impervious surfaces (driveways, parking lots, roofs) replace vegetation and soils in the watershed, which normally filter and absorb stormwater. The water rushes off the site, eroding the soils, before it can percolate down through the ground to recharge the stream's base flow (water that soaks into the ground and then travels through soils or subsurface formations to discharge into streams, lakes or wetlands). This see-saw effect adversely affects aquatic life.

NON-POINT SOURCE WATER QUALITY IMPACTS

Pollutant	Nonpornt Source(s)	Water Quality and Associated Impacts
Sediment	cropland forestry activitia pasture streambanks construction activities roads mining operations existence of gullies livestock operation, (streambanks) other land disturbing activities	• Decrease in transmission of light through water. • Increase in primary productivity (aquatic plants and phytoplankton) upon which other species feed, cawing decrease in food supply. • Obscures sources of food, habitat. hiding places, nesting sites; also interferes with mating activities that rely on right and delays reproductive timing. • Direct effects on respiration and digestion of aquatic species (e.g.. gill abrasion). • Decrease in viability of aquatic life--decrease in survival rates of fish eggs and therefore in size of fish population affects species composition. • Increase in temperature of surface layer of water, increases stratification and reduces oxygen mixing with lower layers. therefore decreasing oxygen supply for supporting aquatic life. • Decrease in value *for* recreational and commercial activities: • Reduced aesthetic value. • Reduced sport and commercial fish populations. • Decreased boating and swimming activities. • Interference with navigation. • Increases drinking water costs.
Salts	agricultural activities mining operations urban runoff	• Favors salt-tolerant aquatic species anti affects the types and populations of fiih and aquatic wildlife. • Fluctuations in salinity may cause greater problems than absolute levels of salinity. • Reduces crop yields. • Destruction of habitat and food source plants for fish species. • Reduced suitability for recreation through higher salinity levels (skin/eye irritation) and higher evaporation rates. • Affects quality of drinking water.
Pesticides & Herbicides	all lands where pesticides are used: (cropland, forest, pastures, urban/ suburban, golf courses, waste disposal sites) sites of historical usage (organochlorides) urban runoff irrigation return flows	• Hinders photosynthesis in aquatic [illegible] • Sublethal effects lower organism's resistance and increase susceptibility to othu environmental stresses. • Can affect reproduction, respiration, growth and development in aquatic species as well as reduce food supply and destroy habitat for aquatic peciu. • By definition these chemical are poisons: if released to the aquatic environment before degradation they can kill non-target fish and othu aquatic species. • Some pesticides/herbicides can bioaccumulate in tissues and other species.

Pollutant	Nonpoint Source(s)	Water Quality and Associated Impacts
		• pesticides/herbicides are carcinogenic and mutagenic and/or teratogenic. • Reduces commercial/sport fishing and other recreational values. • Health hazard from human consumption of contaminated fish/water.
Nutrients (Phosphorus, Nitrogen)	• wion from fertilized areas urban runoff septic systems animal production operations cropland or pastures where manure is	• Promotion of premature aging of lakes and estuaries--eutrophication. • Algal blooms and decay of organic materials create turbid conditions that eliminate submerged aquatic vegetation and destroy habitat and food source for aquatic animals and waterfowl. • Blooms of toxic algae can affect health of swimmers and aesthetic qualities of waterbodies (odor and murkiness). • Favors survival of less desirable fish species ovu commercially/recreationally more desirable/sensitive species. • Interference with boating and fishing activities. • Reduced quality of water supplies. • Reduced dissolved oxygen levels can suffocate fish species. • Reduction of waterfront property values. • NO_3 (Nitrates) can cause infant health problems.
Metals	urban runoff mining operations	• Accumulates in bottom sediments, posing risk to bottom-feeding organisms and their predators. • Can bioaccumulate in animal tissues. • affect reproduction rates and life spans of aquatic species. • Disrupts food chain of aquatic environment. • Can affect recreational and commercial fishing. • affect water supplies.
Bacteria	animal operations cropland or pastures where manure is spread - M C - urban runoff wildlife	• Introduction of pathogens--disease-bearing organisms--to surface waters. • Reduced recreational usage. * Increase in treatment costs for drinking water. •
Sulfates	mining operations	• Significant changes in acidity of streams. • Leaching of toxic metals from soils and rock surfaces. • Elevated levels of acidity and metals can be lethal to fish and eliminate entire aquatic communities. • Severely limits domestic and industrial water use.

Source: U.S. EPA. 1984 and 1987

LAKES

Of Byram's more than two dozen lakes, approximately half are located in undeveloped or only slightly developed areas and surrounded by substantial forested tracts. These are mostly the smaller lakes, many of them man-made and shallow.

Most of the larger lakes, however, are heavily developed. These are also man-made or have been enlarged by damming and are often shallow. The larger man-made or enlarged lakes include: Cranberry, Frenche's, Waterloo, Jefferson, Johnson, Lackawanna, Mohawk. Of these, Cranberry (190 acres) and Lackawanna (110 acres) are the largest lakes lying completely within Byram and are the most heavily developed. A small part of Mohawk lies within Byram and is also heavily developed. Johnson, Panther and Forest are also developed, although building is not as intensive near the shoreline as it is around Cranberry, Lackawanna and Mohawk.

Eutrophication: Lake Degradation

Several studies h-ave been made of these developed lakes, and all show the lakes suffering from varying degrees of eutrophication. Eutrophication is the natural aging process by which a lake fills in and dies. This process usually takes hundreds or thousands of years, but it can be significantly accelerated by human activity within the watershed, including construction, an increase in impervious surface such as driveways, roads and roofs, septic contamination, fertilizer and pesticide runoff from lawns and gardens, contamination from road runoff and from phosphorous in detergents used in or outside the home, and silt runoff from roads and soils which gradually reduce lake depths.

In extreme cases, this process can occur within a few decades. Shallow lakes are more susceptible because sunlight can penetrate to the bottom; encouraging weed growth.

The Pytlar Thesis: A Study of Six of Byram's Lakes

In 1976, a Rutgers graduate student, Theodore S. Pytlar, Jr., studied and ranked six of Byram's lakes: Cranberry, Lackawanna, Forest, Roseville, Stag, and Panther.. Pytlar concluded that all six lakes were 'mildly eutrophic,' with Lackawanna being the most eutrophic, Cranberry and

Roseville being next, and Panther, Stag and Forest being in slightly better condition. Lackawanna, Cranberry and Roseville were characterized as being the most susceptible to further rapid eutrophication, because of their depths, development along their shores (although Roseville is not heavily developed), and conditions within the lakes themselves. The rate at which these six lakes further decline, Pytlar points out, is largely dependent upon 'cultural influences,' meaning the impact of human activity in the watershed and the lake.

At the end of this chapter are 17 pages from Mr. Pytlar's thesis, and other exerpts may be found in the Environmental. Commission files at the Municipal Building.

The 1982 Lakes Study by the Environmental Commission

In 1982, members of the township Environmental Commission again studied four of **Byram's** lakes: Cranberry, Lackawanna, Forest and Mohawk, the four most heavily developed. Their testing of eight chemical (phosphorous, dissolved oxygen, alkalinity, hardness, **pH,** nitrate, nitrite, chloride) and three physical (temperature, depth, turbidity) parameters f on four dates during 1982 showed Lackawanna to be the 'cleanest,' having the most consistent results on water entering and leaving the lake, with Cranberry also showing little discrepancy on feeder and drainage points. Forest had the highest readings in phosphorous, alkalinity, nitrate and chloride; and Mohawk was characterized as acting as a 'sink' for phosphorous and especially nitrate.

These results for Lackawanna, Cranberry, and Forest are somewhat contradictory to Pytlar's conclusions. In his 1991 Natural Resources update, Township Planner Eric Snyder describes Forest Lake as "the lake least affected by eutrophication in **Byram...** It is also the most recent lake development, subject to greater controls on septic system construction and maintenance."

Mr. Snyder also notes, however, that Forest has "the greatest degree of topographic relief of any lake community in the Township. . ..the effects of development on Forest Lake may be expected to be dramatic and more clear-cut than anywhere else in the Township."

In the 1982 study, Environmental Commission members suggested that Forest "is almost completely surrounded by ridges, most of which have

been built upon. The high reading for phosphorous and nitrate could be caused by fertilizer run-off, and the exceptionally high readings for chloride from network of roads. This view seems to be reinforced by the fact that the levels tended to increase as the season progressed. ***The complete 1982 study is in the Environmental Commission files at the Municipal Building.***

The 1992 Study of Cranberry Lake

Another two-year study of Cranberry Lake was completed in April 1992 by Coastal Environmental Services, Inc., a Princeton consulting firm. This $50,000 Cranberry Lake Diagnostic Feasibility Study was funded half by the state and half by the township (partly in cash and partly in kind). Environmental Commission members volunteered for testing and the Commission helped administer the study. ***A copy of this document is in the Environmental Commission files at the Municipal Building.***

Based on conclusions and management recommendations in that study, a three-year $200,000 grant from the U.S. Environmental Protection Agency was obtained in 1992 to begin working on drainage improvements, weed harvesting, community education, and a sensitive land use plan. The township is supplying $200,000 in-kind, and Commission members are actively involved in the work.

The 1990 Cranberry Lake Septic Management District

In 1990, a Township Board of Health ordinance also established a septic management district at Cranberry Lake, including its approximately 520 homeowners and few businesses nearby on Route 206. Each septic owner is required to pay $15 for a septic permit, to be renewed every three years. At the first renewal, a map must be submitted to the township showing the location of the septic and proof that it has been pumped; pumping is then required on a three-year schedule.

The Cranberry Lake Septic Management District was one of four pilot programs initiated in Sussex County under a 1988 $400,000 state grant to the Sussex County Planning Department. The other three were in Frankford (Culver's Lake), Sparta (the Germany Flats aquifer area), and Hopatcong (most of the developed areas). Only Frankford's and Byram's programs led to the creation of management districts. Frankford's requires full inspection and repair of septic systems when houses are sold. The County Planning Department was also to establish a county-wide licensing

Roseville being next, and Panther, Stag and Forest being in slightly better condition. Lackawanna, Cranberry and Roseville were characterized as being the most susceptible to further rapid eutrophication, because of their depths, development along their shores (although Roseville is not heavily developed), and conditions within the lakes themselves. The rate at which these six lakes further decline, Pytlar points out, is largely dependent upon 'cultural influences,' meaning the impact of human activity in the watershed and the lake.

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program for new septics, as required by 1990 revisions to the state's septic code, but the state licensing requirement was removed in 1993.

Coliform Testing at Public Swimming Areas

Public swimming areas at the Township's various lakes are tested regularly during the summer months by the Township's Health Officer (currently a sanitarian from the Sussex County Department of Health and Public Safety). In the 15 years during which this testing has occurred, most of the swimming areas have occasionally shown excessive coliform counts. Coliform is the bacteria associated with animal or human fecal matter. Total coliform counts must be below 200 (per milliliter); if they exceed 200 in two consecutive samples, the beach must be closed.

Private lakes which charge a fee for swimming, such as Tomahawk, do their own testing, with only occasional spot-checks by a public health official.

The Environmental Commission files at the Municipal Building contain lists of high readings at the various beaches, under "Beach Testing."

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NOTE: The packet of educational information given to all Cranberry Lake homeowners and the few businesses included in the 1990 Cranberry Lake Septic Management District is on file at the municipal building. This packet would be useful for any Township resident, as it details the design, construction, and proper use and maintenance of septic systems.

(NOTE: the next 17 pages contain exerpts from Theodore Pytlar's 1976 thesis on six of Byram's lakes.)

AN ASSESSMENT AND RANKING OF SIX LAKES IN BYRAM TOWNSHIP, NEW JERSEY

by Theodore S. Pytlar, Jr.

June 1, 7976

I. LAKE PROBLEMS

Lake problems are a result of human presence. Natural lake conditions which are undesirable to man are defined by him as a problem, and the alteration of natural conditions by human activities can also cause lake problems. Lakes are subject to multiple uses such as water supply, recreation, aesthetics, lake industries, and housing. Undesirable lake conditions such as algal blooms, algal decomposition, large standing crops of aquatic macrophytes (water weeds), other manifestations of eutrophication, sedimentation, and bacterial contamination may interfere with these multiple uses. Figure A-l illustrates various lake zones and their importance, and may be a useful aid in understanding the discussion to follow.

A. Major Causes

The three major causes of lake problems are accelerated eutrophication, sedimentation, and bacterial contamination. Accelerated eutrophication results from lake nutrient enrichment usually due to development in a lake basin. The increased nutrient concentrations in the lake system cause the production of organic matter to increase, the quality of the water to decrease, and the overall aesthetic quality of the lake to decrease. The principal undesirable features of eutrophication are the increased production of algae and aquatic macrophytes and the change in the types'present to those which result in obnoxious blooms. The presence of algal mats and dense growths

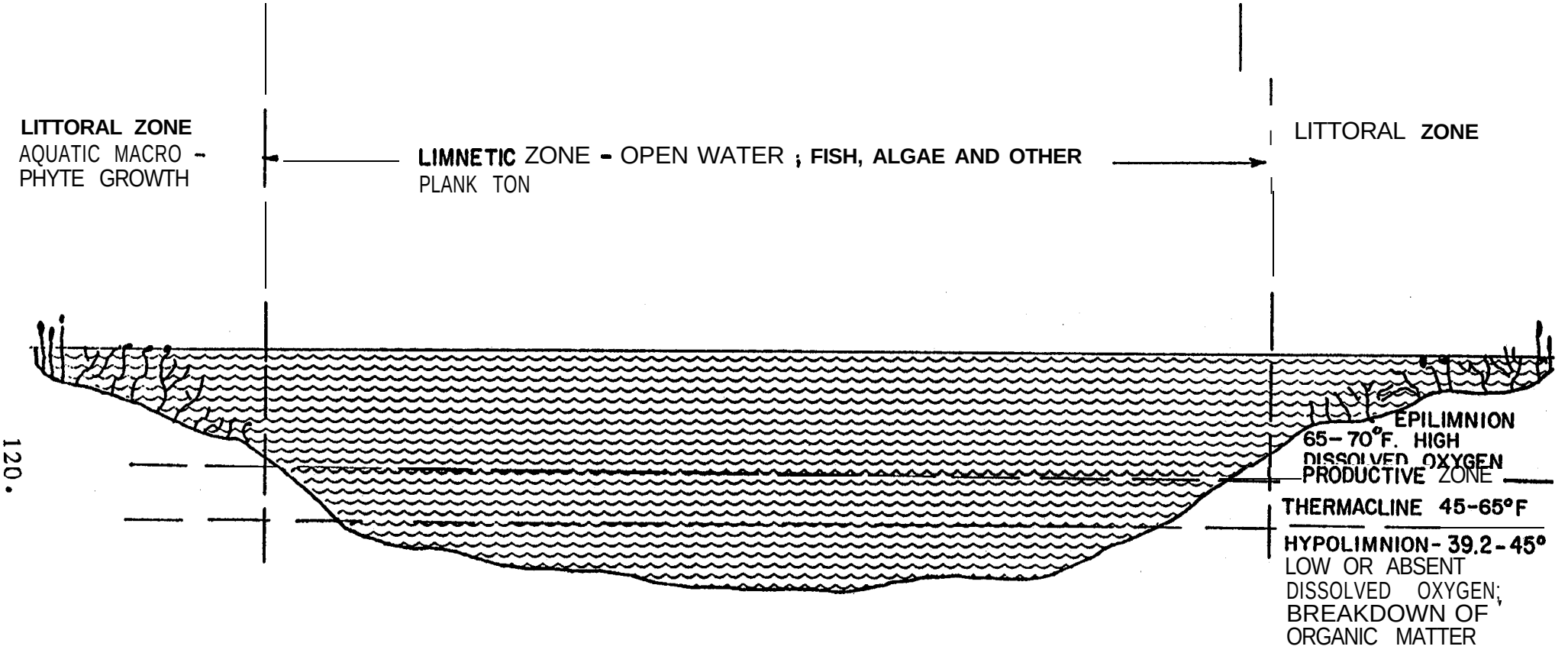


FIGURE **A.-I. ZONES OF TYPICAL LAKE IN SUMMER. IN SHALLOW LAKES** CHARACTERISTIC OF **BYRAM** TOWNSHIP, THE **EPILIMNION** AND LITTORAL **ZONE** WOULD BE INCREASED, WITH LITTLE OR NO HYPOLIMNION.

of macrophytes may make lakes less attractive for swimming and water skiing and may cause a shift away from desirable game and pan-fish species. Where lakefront housing values are dependent upon lake quality, these values may decline.

The primary nutrients of interest with regard to lake eutrophication are nitrogen and phosphorus, particularly phosphorus. They have been found to be limiting factors controlling productivity in many lakes. Different land uses in a lake's drainage basin contribute different amounts of nitrogen and phosphorus to the lake. Natural forest runoff generally provides the lowest amounts, while urban, and agricultural runoff and septic tank seepage provide the greatest amounts. Nutrients contributed from various land uses may cause eutrophication or increase its severity where it already exists.

Sedimentation has been called the nation's number one pollution problem. The erosion of the land in a lake's drainage basin causes sediment to be washed into the lake. Suspended sediments can give the water a muddy appearance and decrease the amount of light available for plant growth. Sediments also serve to decrease the depth of the lake,, increasing the amount of nutrients available for plant growth in the productive, lighted, upper water layers. The eutrophication is due to the overlapping of the zones of growth and decomposition resulting from the decreased depth.

Land under natural forest cover has the lowest amount of erosion per unit area and contributes the least to sedimentation. When the natural cover is changed or removed by man, the amount of erosion from the land increases. Erosion is most intense when the soil is laid bare, usually during construction. The amount of sediment contributed from land under construction may be 20 to 40,000 times that from farms or forest land.

Bacterial contamination of lake water may be caused by pathogenic organisms from fecal material. The prominent sources with respect to housing and recreational lakes is domestic drainage, particularly from septic systems, and storm water runoff. Septic systems improperly installed, located in unsatisfactory locations, such as waterlogged, shallow, or coarse soils, or which have failed can contribute large amounts of pathogenic fecal organisms to a lake. Locating a house on the shore of a lake puts the building's septic system in proximity to the water, creating the danger of fecal contamination of the lake. Channeling storm water runoff into the lake may also cause bacterial contamination. If bacterial contamination becomes so great that state or federal standards for total and/or fecal coliforms are violated, recreational use of the lake may be stopped.

Increased overland runoff due to a greater percentage of impervious surface (roads, roofs, etc.) due to land development may cause greater fluctuations in lake water temperature

than would naturally occur, and a lowered lake level due to a lowered water table. This may have an adverse effect on the lake's plant and animal life, as well as aesthetic qualities.

Enlargement of a lake's surface area for the purpose of increasing available lakefront housing, or aesthetic and recreational opportunities may create a shallow lake, which is susceptible to eutrophication. These enlarged lakes will tend to fill with organic and inorganic sediments more rapidly than natural lakes if they interrupt extensive, natural drainage systems.

B. Important System Characteristics Associated with Lake Problems

The complexity of lake dynamics makes it important that all of the elements which comprise the total lake system (water, lake organisms, land, human activities) be considered in assessing the condition of a lake. This will enable the researcher to more accurately understand the characteristics of the water body itself.

1. Physical Characteristics - The important physical characteristics of the lake are the total lake volume, mean depth, the volumes of the epilimnion and hypolimnion, and the shape of the basin in which the water is held.

Eutrophic conditions are closely related to shallowness in this region. Small, shallow lakes which do not undergo

thermal stratification are most susceptible to eutrophying influences than are large, deep lakes which do stratify. Therefore, nutrient contributions from human land uses can be very effective in promoting eutrophication in small, shallow lakes. The entire bottom area of these lakes, or large parts of them, may support aquatic macrophyte growth where the shallow depths permit sunlight to penetrate to the bottom.

2. Water Quality Characteristics - The important water quality characteristics are buffer capacity (alkalinity), pH, hardness, nutrient supply, water temperature, turbidity (cloudiness of the water), and dissolved gases present. Of these water quality characteristics, those most influential in determining the conditions of lakes are dissolved gases present, nutrient supply, and turbidity.

The primary dissolved gas of interest in lake water is oxygen. It is necessary for animal life, and it is produced by plants. Supersaturation (concentrations greater than those which the water can normally hold) may occur in the epilimnion or surface layer of the lake in the presence of large concentrations of algae or aquatic macrophytes. Complete depletion may occur in the hypolimnion when large quantities of organic matter cause oxygen to be depleted during their decomposition.

Accompanying decreasing or depleting oxygen levels in the hypolimnion are increases in carbon dioxide concentrations. In addition, ammonium, hydrogen sulfide and possibly

methane may be produced in the hypolimnion when oxygen is absent. Complete oxygen depletion may also occur in shallow, unstratified, plant filled waters at night due to the decomposition which occurs at that time when no oxygen is being produced by photosynthesis. These are the conditions with respect to dissolved gases which occur under eutrophic lake conditions.

Nutrient availability is considered to be the most important single factor in determining lake productivity. Phosphorus seems to be the key nutrient determining biological productivity, nitrogen being important only when there is adequate phosphorus. Complex cycles linking the biological, geological, and chemical elements of a lake govern the availability of these nutrients for use by organisms. During the growing season, nutrients are incorporated into the algae and aquatic macrophytes in the lake, and are released upon decay. In addition, these nutrients cycle between the lake bottom sediments and the water, and enter the lake in surface water flows, groundwater movement and from the atmosphere.

The nutrients entering a lake through surface waters such as streams are measured in terms of area1 loading, which is the amount added to the lake per unit time, per unit of lake surface area. This is often considered to be the best measure of nutrient status of the lake. Water flowing into a lake usually has little phosphorus unless polluted by man. The

area1 nutrient loadings for a lake can be related to the mean depth of the lake and the amount of time which water remains in the lake before it flows out in order to determine'whether undesirable, eutrophic conditions may exist in the lake.

Turbidity is caused by the presence of suspended material in the water. Such things as clay, silt, fine particles of organic and inorganic matter, and plankton, and other microscopic organisms contribute to turbidity. Increasing turbidity is associated with decreasing water quality and increasing eutrophication. Erosion of soil particles from the land into the water and organic particulate matter from aquatic organisms are two of the primary causes of increased turbidity.

3. Biology - The type of organisms present in a lake may give a reliable indication of the condition of the lake. The two main groups of photosynthetic organisms of concern are the aquatic macrophytes and algae. Extensive aquatic macrophyte growth over a large area of lake is associated with high productivity and eutrophication. High levels of algal growth are also an indication of eutrophic conditions, and may represent a more advanced stage of eutrophication than heavy macrophyte growth in some cases. Blue-green algae are the form which usually receive most attention as an index of eutrophication. They are objectionable due to their ability to float and form scums on the surface of the lake.

4. Drainge Basin Characteristics - The size of a lake's drainage basin may influence lake productivity in that a larger basin may provide greater opportunity for nutrients from the land to fertilize the lake. Small drainage basins are usually associated with less productive conditions. A basin with steep slopes may be more susceptible to erosion and sedimentation of the lake. The frequency with which water in the lake is renewed (flushing rate) is important to lake condition. Higher flushing rates are associated with less productive conditions due to rapid removal of nutrients from the lake. High drainage basin to lake surface area ratios combined with low total volume and mean depths may indicate high flushing rates.

The mode of water input and output may have a significant impact on a lake's condition. The areas of interest here are the relative amount of surface and groundwater flowing into and out of the lake, and the pattern of water inputs and outputs in a lake. The greater the groundwater inflow into a lake, the lower the expected nutrient contributions because most of the phosphorus in groundwater is taken up and retained by the soil. Lakes may supply water to the ground as well as receive it from the ground. In some lakes, groundwater and surface water may flow into the lake in certain locations, and they may flow away from the lake in other locations. It would be best to build on land where the water flows away from the lake so nutrients from such things as septic tanks and lawns will not flow into the lake.

5. Man's Activities - The impact which human activities will have on a lake depends on the natural characteristics of the system and the extent of these activities. A positive relationship has been found between lake condition and the land use in the drainage basin. Urban and agricultural land uses and septic systems are generally believed to contribute the greatest amounts of nutrients to a lake. The location of these nutrient sources adjacent to a lake or its feeder streams will generally lead to higher nutrient contributions than if these land uses are in remote basin locations with respect to the lake.

The hydrology of urban or densely developed areas contributes to the rapid transport of dissolved and suspended materials and nutrients into nearby waters. Runoff from crop and pasture lands contributes nutrients, sediment, and pathogenic bacteria to lake water. Septic systems are a point of controversy in lake regions. While they have been responsible for the nutrient enrichment and bacterial contamination of lakes, the potential exists for their effective use under conditions of close supervision and maintenance.

Human manipulations of the lake itself may also cause deterioration of the lake. Lake enlargement, as previously mentioned, may create impoundments with high productivity potentials which are subject to rapid eutrophication. In addition, management of plant growth in lakes may lead to undesirable effects. The killing of aquatic macrophytes using

chemical treatment may cause release of nutrients in forms available for algal growth.

II. DATA COLLECTION, ANALYSIS AND LAKE RANKING

On the basis of the literature review of the major problems associated with housing and recreational lakes and observations of the Byram Township lakes under study, a list of data necessary to assess the condition of lakes was compiled. Six lakes were chosen on which to collect this data. These lakes were Cranberry, Forest, Lackawanna, Panther, Roseville and Stag. Data on the chemical, biological, morphological, hydrological, geological, geographical and cultural characteristics of the lakes were collected. However, it was not possible to acquire all of the data included in the list of data.

Assessing the condition of each of the six lakes and ranking the lakes on the basis of their trophic status (oligo-trophic-mesotrophic-eutrophic) with respect to one another was accomplished by analyzing all of the data collected, as well as interpretive parameters of lake condition calculated from the data.

It was found that some elements of the data were most useful in illustrating the fact that the lakes in Byram Township have many similar characteristics, and they vary with respect to trophic status only within a restricted range on the total scale extending from oligotrophy to eutrophy. These unifying data

elements include the climatic regime under which all the lakes exist, their geographic location in proximity to one another, and the relatively small size and shallow depth of all the lakes. In addition, such water quality characteristics such as pH, temperature, hardness, dissolved oxygen levels, Secchi depth (depth of light extinction), and alkalinity were indicative of similar conditions. The presence of aquatic macrophytes in the shallow areas of all the lakes also indicated the similarity in their trophic states. Finally, the fact that most of these lakes have been artificially enlarged gives them similar characteristics. These six lakes group around a mildly eutrophic condition, varying from those which seem to border between mesotrophy and eutrophy to those which are moderately eutrophic.

Just as there were those elements of the data which were illustrative of the similarities among the lakes, there were elements which showed the differences among the lakes. These elements were the existence of thermal stratification in some of the lakes, total and fecal coliform counts, the extent and intensity of aquatic macrophyte growth, the variations in Secchi depths, the ratio of the sum of drainage basin area and lake surface area to lake volume (Schindler's ratio), the relative amount of groundwater input to the lakes, and the intensity of nutrient contributing land uses. Both area1 and volumetric (amount of nutrient per unit time, per unit volume) nutrient

loadings were estimated by measuring the land areas under the types of land uses identified in the direct drainage basin of each lake. Coefficients for nitrogen and phosphorus contributions from each land use were used to determine the total mass of nutrients being contributed to the lakes each year, including that from septic tanks. Masses of nutrients per year were divided by lake surface area and lake volume to determine area1 and volumetric loadings respectively. The assessments of lake condition based on the consideration of each individual data element and interpretive parameter discussed above corresponded closely with one another, giving firm support for the final lake rankings.

Figure 2 is a spatial distribution of the lakes studied along a line running from ultraoligotrophic to hypereutrophic states, based on the overall indications given by all the factors considered in this study. All indicators suggest that Lake Lackawanna is in the most advanced state of eutrophication of the lakes studied. Cranberry Lake and Roseville Pond exemplify a situation of two lakes which are similar on the basis of objective rating parameters but dissimilar in other respects. Roseville would appear to be a lake which should be at a lower trophic status than Cranberry. However, its large total drainage area, small surface area, relatively small volume, and upstream agricultural land use cause its status to be comparable to that of Cranberry Lake, Stag, Panther and Forest Lakes group closely together on the basis of their values or area1 and volumetric nutrient loadings, Schindler's ratio , secchi depth, and total

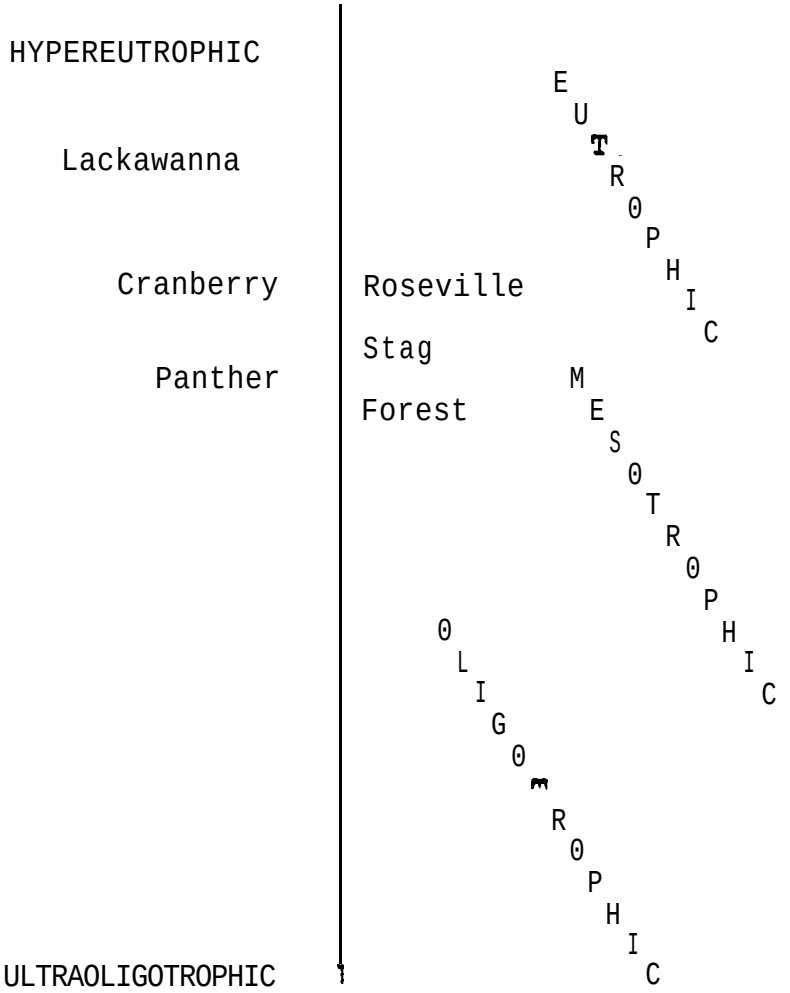


Figure A-2 Relative trophic status of Byram Township lakes.

direct drainage areas. Stag's larger drainage area, smaller volume and extensive shallow zone seem to make it somewhat more eutrophic than Panther whose seemingly large groundwater supply seems to reduce its nutrient input. Forest Lake is surprising in that the relatively high degree of development in its basin would be expected to make it more eutrophic than otherwise would be. However, its small drainage area, large volume and housing setback from the lakeshore seem to be maintaining its relatively low degree of eutrophication up to this point.

III. Future Conditions of Byram Township Lakes

The most important factors influencing the future lake conditions and rates of eutrophication of lakes due to nutrient or sediment loadings are the amount of existing high nutrient contributing land uses, the amount of new construction, the amount of new high nutrient contributing land uses added to a basin, and the adequacy of practices, if any, employed to control nutrient and sediment contributions from developed land and land under construction.

The land draining directly into the lake has the greatest potential for contributing nutrients and sediments to the lake. Therefore, lakes with large direct drainage areas would be susceptible to accelerated eutrophication. The lakes most susceptible to accelerated eutrophication are those which are presently the most eutrophic: Lackawanna, Cranberry, and Roseville. Stag, Panther and Forest Lakes would seem to be the least susceptible. (Forest Lake may experience accelerated eutrophication

if current efforts to maintain the quality of the lake are discontinued). This is in no way meant to suggest that these latter three lakes are safe from accelerated eutrophication. Increased amounts of nutrient and sediment contributing land uses in these basins could have adverse impacts on lake quality.

Barring any major additional development in the lake basins, the next five to twenty years should see no large changes in the status of the lakes relative to one another, although the presently more eutrophic lakes may progress more rapidly into further eutrophication. Major subdividion development or any other types of high nutrient contributing land *uses* in any of the lake basins could result in accelerated eutrophication of the lakes in which this development occurs, if the potential impacts are not assessed and accomodated with sound environmental planning.

Chapter 6

COMPOSITE ENVIRONMENTAL CONSTRAINTS

(Refer to the Composite Environmental Constraints Map in the Appendix of this document.)

BYRAM'S SENSITIVE LANDS

With few exceptions, all of Byram's land is marked by one or more serious environmental constraints. Many areas are characterized by two or three constraints. These constraints impose various limits on how the land can be used and on what kinds of development should be permitted.

For some features, such as steep slopes, septic suitability, wetlands or depth to bedrock, the restrictions are obvious, because conventional construction clearly is not workable. These features are already protected, at least to some degree, by Township and state regulations.

For other features, especially those that affect Byram's surface and groundwater supplies, the potential problems are not as apparent and adequate protection is not in place to prevent damage or depletion. These features include lakes and ponds, stream corridors, aquifers or geological formations likely to contain important aquifers, and groundwater recharge.

All these features are shown on individual maps and then brought together on the Composite Constraints Map, which is described in this chapter. Recommendations for proper land use and for better protection of these environmental features are found in this chapter and in Chapter 7.

Byram Township's 1975 Master Plan concluded from its mapping of Environmentally Sensitive Areas (page 11-14): "Most of Byram is not well suited for intensive development, which is consistent with the findings of the Sussex County Land Use Study which classified most of Byram for either 'no development' or for minimum lots of 2-1/4 to 3-1/2 acres."

Other studies call for minimum lot sizes of 2.9 to 5.6 acres (the Sussex County '208' Plan, the Sussex County Carrying Capacity Manual, the Tocks Island studies in the 1960s, Byram's 1976 Public Water Supply Study).

ENVIRONMENTAL CONSTRAINTS

Steep slopes and septic restrictions are the two most prevalent of Byram's natural constaints. Two-thirds of the Township is marked by slopes of 15% or more. The majority of Byram's land is rated unsuitable for septics, and very little land is without some septic restrictions.

These two constraints and several others have been discussed in preceding chapters and are briefly summarized here.

Steep slopes of more than 15% are found in approximately 2/3 of the Township; half of those areas have slopes of 25% or greater. Typically, those areas are also marked by shallow depth to bedrock, as well as rock ledges and outcrops.

Wetlands are scattered throughout the Township, as are many other areas where water tables may be seasonally high.

Most land is either unsuitable or restricted for septic systems.

Limestone bedrock overlain by glacial stratified drift formations are found in three locations, providing possible important aquifers for Byram. Most of the rest of Byram's subsurface geology is very impermeable and a poor source of drinking water supplies.

Stratified drift is underlain by deep glacial deposits in other areas, again possibly indicating Byram's better aquifers.

All of these glacial formations, as well as limestone bedrock, can be highly permeable and need protection against contamination from underground sources and also from surface runoff.

Large sections of the township are areas of high groundwater recharge, an integral part of Byram's water budget which affects water levels in its lakes, ponds, and streams, as well as in its aquifers.

*Critical **natural habitats** for flora and fauna are discussed and mapped in Chapter 3, **NATURAL HABITATS AND ENDANGERED SPECIES,** but are not included in this Composite Environmental Constraints Map.*

THE COMPOSITE ENVIRONMENTAL CONSTRAINTS MAP

The Commission used the Environmental Constraints Composite (Figure IV-9) from the township's 1989 Master Plan as a base map. This composite map is based on wetlands, steep slopes, and septic restrictions, reflecting a concern largely with construction problems.

The Environmental Commission has added several other constraints to the map, which are aimed at protecting lakes, streams, and especially aquifers (underground drinking water supplies). The result is that many areas have been shifted out of the non-critical classification shown on the Master Plan map and that many other areas have been redefined, either being categorized as critical under certain circumstances or as requiring special precautions.

Stream corridors, which are too small to show on the map, should also be considered critical areas.

The Commission has added the following constraints to the Composite Environmental Constraints map:

1. groundwater recharge--areas of high recharge require caution regarding soil disturbance or compaction, impervious coverage, stormwater management (including control of surface runoff contamination), and plant and tree removal.
2. stratified drift deposits (possible aquifers and very susceptible to contamination).
3. limestone bedrock (also possible aquifers and especially important when overlain by stratified drift).
4. deep glacial deposits (beneath stratified drift deposits, also possible important aquifers and very susceptible to contamination).

LAND USE RECOMMENDATIONS

Recommendations by the Township Planner and the Environmental Commission are contained in Chapter 7.

Septic recommendations are given on the page facing the Septic Suitability Map in the Appendix.

Soil Interpretations Records at the end of Chapter 4 describe the following characteristics and limitations of each soil type in Byram:

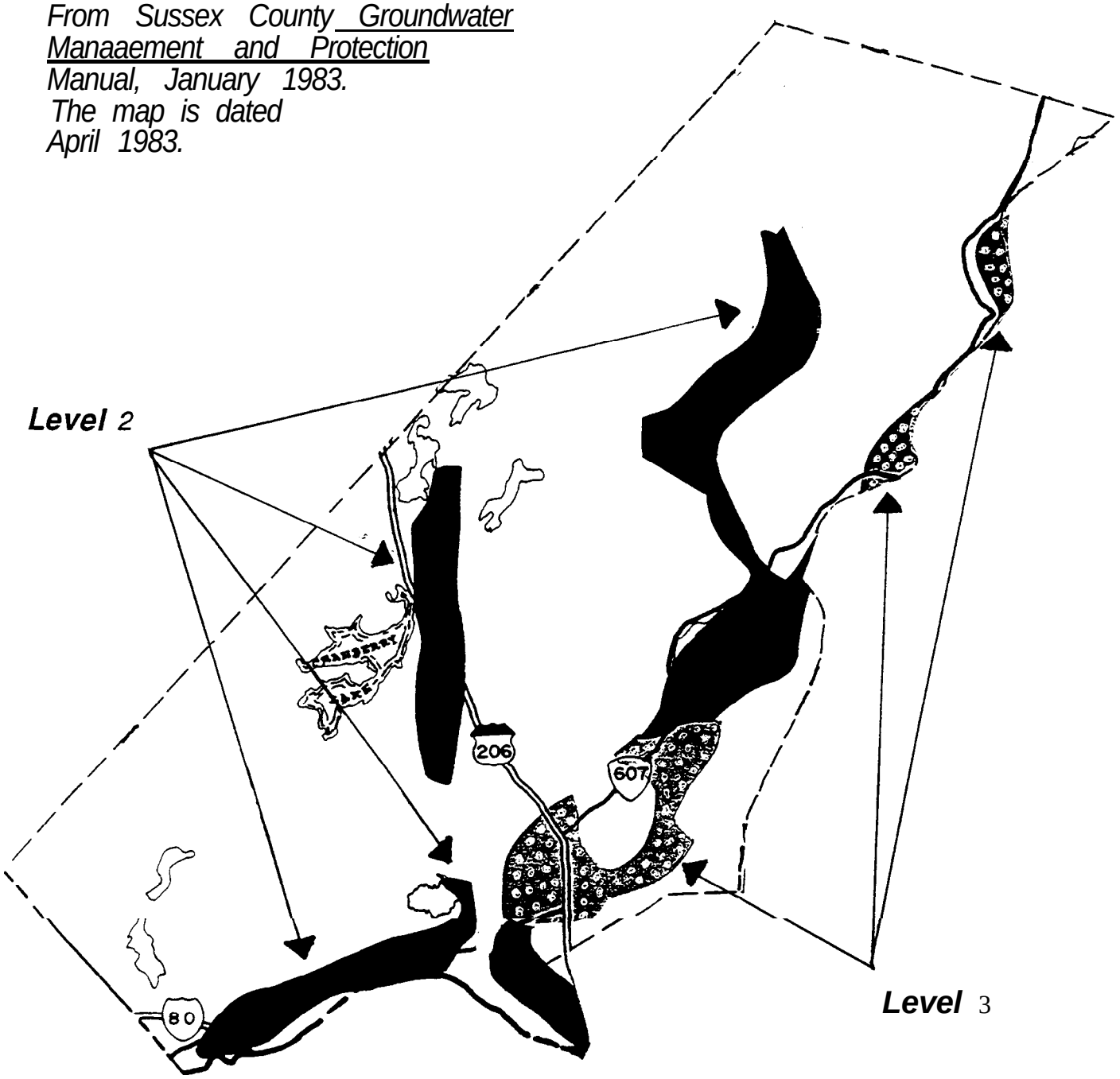
-landscape and climate properties (including drainage, permeability, erodability, flooding, water tables, depth to bedrock, and others)
-limitations for septics or landfills
-construction limitations (basements, excavations, roads, landscaped areas, lawns and golfcourses)
-availability of construction materials (roadfill, sand, gravel, topsoil)
-water management (dams, ponds, drainage, grassed waterways and others)
-use for recreation
-use for agriculture
-use as woodlands (including erosion hazard, common trees and other characteristics)
-use for windbreaks
-suitability for wildlife habitat
-typical plants and small trees

In addition, at the end of this chapter on pages 142 to 162, are *copies of recommendations and best management practices pertinent to Byram from the Sussex County Groundwater Management and Protection Manual.*

The map from that manual ranks Byram's stratified drift aquifers in Levels II or III for groundwater management. *The Byram section of that map, reproduced on page* 139, is far more general than the Surficial Geology Map in this document, but serves to classify these aquifers and related recharge areas according to the Sussex County Planning Department's assessment in 1983. The areas are ranked according to possible aquifer yield as well as to susceptibility to contamination.

GROUND WATER MANAGEMENT AREAS

From Sussex County Groundwater Manaaement and Protection Manual, January 1983. The map is dated April 1983.



For more specific mapping of these areas, please see the Surficial and Bedrock Geology Maps in the last section of this document. For recommendations on land use and development in these areas, please see Chapter 6.

Byram has no Level I groundwater management areas--that is, it is lacking the extensive aquifers of high yield that occur elsewhere in Sussex County.

Levels II and III are defined as:

-Level II: isolated minor aquifers of moderate risk of contamination and related recharge areas.

-Level III: possible confined aquifers of high yield (confined means the sand and gravel deposits that are porous enough to contain water are protected by layers or more impermeable materials such as clay or silt).

Because these Level II and III aquifers are the best that Byram may have, the Environmental Commission is recommending that they be given maximum protection.

Recharge areas for stratified drift aquifers can be assumed to be located directly above them. Recharge areas for limestone, however, may be some distance away and connected through hydraulic gradients (differences in pressure, caused for instance by well pumping).

The recommendations from the county manual include the following:

-what kinds of land use and development should and should not occur in Level I, II and III areas and suggested groundwater management guidelines (based on stratified drift deposits, limestone rock aquifers, and critical recharge areas).

-best management practices for surface mine management (Byram has a large quarry off Route 206).

-best practices for woodland management (Byram's many acres that are farmland assessed usually list foresting as their agricultural activity; these tracts are required to have a forest management plan and to follow it).

-control of industrial uses through zoning to prevent groundwater contamination (based on both aquifers and critical recharge areas).

-protection of aquifers and critical recharge areas by controlling land uses, densities and land coverages.

-zoning ordinances to prohibit variances in critical recharge areas over pervious aquifers.

-establishment of densities based on proper aquifer pump tests (not simply well tests); final subdivision approval and densities would be granted only after these tests are reviewed.

-best management practices for limiting the use of road re-icing salts and storing them properly.

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Sussex County Groundwater Management and Protection Manual, by Lyn A. Dabagian and David G. Roberts, Sussex County Planning Department, January 1983.

Township of Bvram Comprehensive Master Plan, Louis Berger & Associates, East Orange, N.J., April 1989.

Township of Bvram. Master Plan Studies: Land Use and Zonina. H2M Corp., Newton, N. J., 1977.

NOTE: for more information on the impact of building over aquifers and recharge areas, as well as wide-ranging discussions about planning and zoning, see Growth Without Chaos: Reforming New Jersey's Svstem for Managing Land Development, by Robert E. Coughlin and John C. Keene, prepared for the New Jersey Conservation Foundation, May 1987.

(NOTE: the next 21 pages contain land use recommendations from the Sussex Countv Groundwater Management and Protection Manual.)

LAND USE RECOMMENDATIONS AND BEST MANAGEMENT PRACTICES FROM THE SUSSEX COUNTY GROUNDWATER MANAGEMENT AND PROTECTION MANUAL

Suitability of Land Uses To Sussex County Groundwater Management Areas

As described in an earlier section, critical groundwater areas in Sussex County have been divided into three recommended levels of stringency. The section to follow will suggest a guideline and methodology for the application of the various land uses to these groundwater management areas.

Level I

Groundwater management areas which fall into this category (represented in purple and all hashed areas on the Groundwater Management Map) are the most sensitive to contamination from the various sources mentioned during the course of this text. Therefore other than land uses such as parks and preserves which allow the land to remain in its natural state, the development of these Level I areas should be restricted to the least harmful of any land use and even then should be permitted only when compliance with stipulations geared toward preserving water quality is ensured.

A suggested approach towards achieving this end follows below: All land uses besides those listed below should be prohibited.

1. Agriculture/Silviculture - Cultivation and harvesting on Level I lands should be permitted conditioned on the strict application of all pertinent Best Management Practices. An enforcement strategy to ensure compliance is essential.

2. Office/Research - a development of this type would be limited to operations which do not involve the use or disposal of harmful chemicals involved with or supporting laboratory research. (See pg. 70 (E)). In addition, site plan requirements should specify that the artificial recharge devices used to maintain the pre-construction water budget be shown and detailed in the working drawings.

3. Residential - Because residential development in Sussex County is for the most part married to on-site wastewater treatment, the safest and simplest method of preventing the degradation of groundwater by wastewater is to only permit single family detached dwellings on lots large enough to provide for the necessary dilution and adsorption of harmful elements. (See Sussex County Carrying Capacity Manual). BMP's such as street sweeping, catch basin cleaning, and general stormwater and erosion control should be implemented in these areas as well.

Level II

Groundwater management areas which fall into this category (represented in dark blue on the Groundwater Management Map) could accommodate any of the land uses suggested for Level I plus the following recommended uses:

1. Residential - Cluster subdivisions, P.D.'s, P.R.D.'s, and P.U.D.'s may be permitted conditioned on the establishment of parameters regarding percentages of open space required relative densities of allowable housing types, site plan specifications for stormwater control retention devices, and on-site wastewater treatment. The safe removal of solid waste from the area will also become a factor due to the increased densities.

If P.U.D.'s are to be a permitted use in Level II areas, guidelines as to the kinds of commercial establishments that could be allowed in the PUD should be promulgated based first on their possible effect on groundwater quality, and then on their relative effects on the local economy. The suggested procedure is as follows:

A. Calculate housing density based on groundwater management parameters.

B. Calculate expected population generated by the PUD and breakdown into age groups.

C. Determine market demand generated by the expected population (Supportive capacity).

D. Determine the capability of local commerce to service the market demand.

E. Determine additional commercial types needed to be incorporated into the PUD to satisfy demand.

F. Of the additional commercial types needed, determine suitability for location in Level II groundwater management area.

G. Program suitable commercial types into design.

Level I II

Groundwater management areas that fall into this category (represented in aquamarine on the Groundwater Management Map) require the least amount of protection but deserve consideration because of the possible confined groundwater pockets of high yield potential that lie within the deeper subsurface strata. For that reason, the recommendation here is that the land uses with their associated conditions that were outlined for Level I and Level II be permitted uses in Level III areas. The following land uses should not be permitted :

1. Industry which uses or generates hazardous or toxic materials

2. Resource Extraction or Processing Industries

3. Landfills

4. Chemical Dumping or Storage Activities

5. Industrial Waste Lagoons

6. Hazardous Waste Disposal Sites

7. Commercial establishments using organic chemicals (e.g. dry cleaners, printing shops or other toxic or hazardous materials)

8. Pipelines and/or tanks which carry and store petroleum products and other chemicals

After applying the previously described GMA concepts into a master plan and translating them onto a zoning map, certain alterations in zoning will probably occur in most municipalities. The next section offers a hypothetical example of this application.

Zoned areas that are unaltered after applying GMA concepts will more than likely also require some re-examination since the inception of groundwater management into municipal master plans and development regulations will set the stage for a more comprehensive growth management strategy and scheme.

New considerations for areas not in GMA's may and should arise with an overall objective of providing balanced fiscal growth within the municipality and properly managing infrastructural aspects.

The following section will present groundwater management guidelines patterned after ongoing programs being conducted by regional agencies in the United States. It will then apply the ordinance to an actual situation in order to walk the user through the process.

SUGGESTED GROUNDWATER MANAGEMENT GUIDELINES

I. Purpose

In order to protect and preserve the quality and quantity of the groundwater resources of a municipality, thereby ensuring the availability of clean, safe, potable water for its present and future residents.

II. Definitions

A. Aquifer - An underground layer of porous rock, sand, etc. containing water, into which wells can be sunk.

B. Attached - A connection of two or more dwelling units, whether it be by an extension of the roof line, by a common garage, or some other means.

C. Critical Recharge Area - Any area of land which permits access of precipitation to an aquifer to a degree which is vital to the natural groundwater budget.

D. Cluster Septic System - An on site, though not necessarily "on-lot" wastewater treatment facility which serves more than one unit

E. Density - The number of dwelling units per acre of land.

F. Development - An arrangement of newly constructed residential dwelling units, and /or commercial structures, and /or industrial or office plants.

G. Groundwater - Water which has collected and is held in soil or rock below the surface and which may be available for withdrawal.

H. Groundwater Budget - The balance of water which is naturally maintained in an aquifer after compensating losses and rec ha rge .

I. Hazardous Substance - Any waste or combination of wastes which alone or in relation with other substances pose a present or potential threat to human health, living organisms or the environment, including but not limited to waste material that is toxic, carcinogenic, corrosive, irritating sensitizing, biologically infectious or flammable, and any waste so designated by the United States Environmental Protection Agency.

III. Establishment of Groundwater Management Areas

The municipality should establish Groundwater Management Areas (GMA's) which should be delineated on the official zoning map of the towns hip. The GMA's will be based on the locations of stratified drift deposits, carbonate rock aquifers and critical recharge areas.

It should also be established that wherever a GMA lies within the same area as a previously established land use zone, the regulations of the GMA shall prevail where they diverge from the existing regulations for that zone. All BMP's for respective uses (see BMP section) should be exercised in all 3 GMA's.

Level I GMA

Recommended Uses (other uses prohibited)

A. Parks, active and passive

B. Agricultural /Silviculture - Conditioned on the strict application of all pertinent Best Management Practices.

C. Office/Research - Limited to operations which do not involve the handling and use or disposal of harmful chemicals involved with or supporting laboratory research as well as the guaranteed maintenance of the pre-construction water budget.

D. Large Lot Residential - Residential dwellings developed at a density consistent with the determinations of the nitrate dilution model;[29] using the figure for drought conditions.

Level II GMA

Recommended Uses (other uses prohibited)

A. Any use recommended for L-I GMA's

B. Cluster Residential Subdivision

1. The determination of the open space ratio for a cluster subdivision in a L-2 GMA shall be made based on the following procedure:

a. Consult Table VI and/or properly performed aquifer pump test for the minimum lot size required for the entire site in order to ensure adequate dilution of wastewater.

b. Determine maximum number of units allowed on site based on minimum lot size

c. Produce cluster design according to municipal standards for open space ratios in a cluster development.

d. If no such standard exists, base open space ratio determination of 50% of the total site area.[30] Base

29. See Environmentally *Based Growth Management: The Carrying Capacity Approach* for *Sussex County, a manual prepared by the Sussex County "208", which presents the nitrate dilution model in* detail.

30. 50% *open space is significantly higher than is normally required in municipal ordinances, but the sensitivity of the area merits a comfortable safety margin in order to ensure proper dilution.*

location of open space on a site analysis which will reveal environmentally sensitive areas such as wetlands, steep slopes, or streams that should be protected. The remaining 50% of the site may be developed at double the density established in (1).

e. In the procedure outlined above, the minimum lot size is cut in half. Therefore no single lot should contain an individual wastewater treatment system. Wastewater from the clustered area should be directed to a cluster septic system to be located in the common open space sector of the site and designed to minimize its visual and olfactory impact.

2. No lot should support more than one dwelling unit.

C. Planned Developments

1. The determination of open space shall be calculated for each clustered area within the planned development individually with the cumulative amount of open space for the site to be not less than 50% of the total site area.

2. Onsite Wastewater systems will be governed for each clustered area according to the guidelines under Level II: B-l.

D. Planned Residential Development

1. The amount of open space required to be set aside for each cluster of each housing type shall be adequate to dilute the wastewater generated by the units in the cluster. (See Level I I : B-l)

E. Planned Unit Development

1. The residential components of a Planned Unit Development, as they pertain to groundwater and wastewater disposal, shall be governed as those in Level II : B-l.

2. Commercial uses shall not generate or utilize substances which are hazardous to groundwater quality. Provisions shall be made for the additional wastewater generated by commercial uses when determining appropriate wastewater treatment and disposal methods.

Level III GMA

Recommended Uses

A. All uses recommended under Level I and Level I I GMA's with associated provisions

The following should be Prohibited in Level III GMA's

A. Industries which manufacture, process or handle hazardous substances.

B. Industries which extract or process natural resources such as sand and gravel, fossil fuels, mineral deposits, etc.

C. Landfills

D. Chemical Dumping or Storage Activities

E. Industrial Waste Lagoons

F. Hazardous Waste Disposal Sites

G. Commercial establishments which handle hazardous substances such as dry cleaners, print shops, etc.

H. Pipelines and tanks which carry and store petroleum products and other chemicals below the ground's surface.

SUMMARY SHEET

category: WATER QUALITY

sub-category: SURFACE MINING/ SILVICULTURE

BMP: SURFACE MINE MANAGEMENT

OBJECTIVE

To reduce, to the maximum extent possible, any negative impact of surface mining operations on surface and groundwater resources. The greatest progress can be made by organizing BMP's and incorporating them into the Soil Erosion and Sediment Control Plan which now must be reviewed by the Soil Conservation District.

WHERE APPLICABLE

These general practices should be applied to any site currently existing or being developed as a surface mining operation.

PROS

1. These measures, when implemented, will greatly reduce the amount of sediment in stormwater that results from exposing large areas of soil.
2. The Soil Conservation District can have direct input into ensuring an effective soil erosion control system.

CONS

1. The main disadvantage of applying these practices to surface mining operations will be realized by the operator in the form of the cost of installing stormwater control structures. The fact that every operator must comply, regardless of the municipality where the operation is located, means that one is not restricted more than another.

IMPLEMENTATION CONSIDERATIONS

The basic requirements ot the regulations on surface mining operations are as follows:

1. Sequence of Construction - The proper sequencing of construction and phasing should be noted on the plan. Roads, curbs, utilities and the estimated duration of each phase should be specified.
2. Tracking - The plan should indicate means by which off-site tracking of sediment by construction vehicles will be controlled during all phases of construction.
3. Temporary stabilization - All exposed surfaces that are created as a result of construction should receive temporary stabilization. Temporary seeding mixtures and rates along with lime and fertilizer recommendations should be detailed and noted on the plan. Mulching specifications and packing should be included for application during non-seeding dates.
4. Permanent stabilization - All exposed areas which are to be permanently vegetated should be seeded within 10 days of the final grading. Permanent seeding mixtures and rates along with lime and fertilizer recommendations should be detailed and noted on the plan. Mulching specifications and packing methods should be included for application during non-seeding dates.
5. Stockpiling - All stockpiled areas should be located in plain view on the plan The means by which stockpiles will be stabilized should be specified on the plan. If excess material is to be removed from the 'site it should be so stated
6. Disturbed limits - To the maximum extent possible, all vegetated areas not needed for construction should be left undisturbed for as long as possible.
7. Written notification - The Soil Conservation District should receive written notification before the initiation of any disturbance.

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The following practices should be implemented where needed and, if their application is intended, they should be delineated on the plan:

1. Pipe outlets - Pipe outlet discharge and velocities should be calculated and noted. Adequate outlet protection should be provided and noted on plan view where velocities are expected to be erosive.
2. Rip-rap - The length of the rip-rap structure and the size of the stone to be used should be noted. Rip-rap can effectively stabilize steep slopes.
3. Diversions - Diversions slow runoff and direct it to detention or retention facilities. Any diversions should be located in plan view and cross section on the plan.
4. Grassed waterways - Grassed waterways are used to transport stormwater so as to maximize the reduction of velocity and the rate of infiltration. These structures should also be located in plan view, cross section, and profile, and included in the plan.
5. Sediment basins - Sediment basins collect stormwater and allow solid particle: to settle out of solution. These structures should be located in plan view, cross section and elevation, and the principal spillway, emergency spillway and dam should be shown in elevation as well.
   In addition to the information recommended above, the following should be provided:
   A. Design Calculations
   B. Clean-out elevations
   C. Riser details
   D. Outlet protection, if necessary, and a statement regarding stabilization of the dam.
6. Steep slopes - Slopes greater than 3.1% should be stabilized, seeded and mulched immediately after grading.
7. Agricultural lands - If the surface mining operation is located near agricultural lands there must be some means of protecting cultivated areas during their idle periods once construction on the mine site begins (i.e. temporary seeding) and after the last crop is harvested. In addition, if the situation arises where tile drains are necessitated, the system should be incorporated into existing tile or surface drainage systems so as not to interfere with the drainage conditions of the adjacent or proximate agricultural lands.

The cost of implementing and maintaining the erosion and sediment control plan will depend on the kinds of control methods needed and their dimensions and numbers. Information on unit pricing can be obtained at the county Soil Conservation District. General maintenance measures are 1) install perimeter control measures prior to clearing and grubbing, 2) avoid exposure of soils on steep slopes, 3) avoid clearing too far above highwall or below outcrop line, 4) minimize length of time that soil is exposed by clearing or grubbing, 5) carefully site and protect stockpiled topsoiling material, and 6) avoid the creation of a soil surface which impedes infiltration and/or concentrates surface runoff (e.g zipper marks or dozer cleat marks that run up 'and down slope rather than along contour).

Implementation is the responsibility of the operator, and the compliance with the requirement of a erosion and sediment control plan is mandated by New Jersey state law.

For Additional Information

1. The Soil Conservation District, Rt . 206, Andover Township, R .D. 7, Box 13, Newton, N.J. 07860. (201) 383-7315.

b

category

WATER QUALITY

SUMMARY SHEET

sub-category

SURFACE MINING / SILVICULTURE

BMP

WOODLAND MANAGEMENT

OBJECTIVE

To improve woodland management operations by minimizing erosion, siltatior and water quality contamination.

WHERE APPLICABLE

All woodlands that are harvested.

PROS

1. The use of practical and common sense practices for the management of woodlands will not only maintain the quality of the surface and groundwater, but accentuate the aesthetic quality of a valuable resource.
2. Makes operation more econanical in the long run.

CONS

1. The necessity to change some management habits may involve some additional time at the outset, but will prove much more profitable in the long run, as the life of the stand will be prolonged, and the quality of the trees and water maintained.

IMPLEMENTATION CONSIDERATIONS

Harvesting activities need to be properly planned and implemented to preventwater contamination. The following cmsiderations should be incorporated into the harvesting plan.

1. stream crossings
   a) try to avoid stream crossing if possible
   b) look for previous crossings and use them if necessary to cross
   c) new crossings should have low, stablebanks, a firm stream bottom, and gentle slopes along the approaches
   d) use temporary culverts where necessitated
2. Stream Bank Protection
   a) avoid cutting trees/vegetation on stream banks since they help keep the bank in place and provide shade.
   b) donotskidup and down stream channels (active or intermittent)
   c) keep skidders back fran the water, winch off logs that are close to banks
   d) fell trees so tops land away from streams to keep debris and skidders out of the water and further from the banks
   e) leave buffer strips around streams, lakes and ponds undisturbed
   f) properly place skid trails so as to minimize disturbance of soil
   g) schedule logging during driest periods of the year
3. steep Slopes
   a) minimize activity in steep slope areas
   b) winch off logs and minimize skid trails in steep slope areas
   c) if steep slopes can't be avoided, regrade and install diversion devices in these areas to minimize erosion
4. Skid Trails/Roads/Landing - Location
   a) keep away frunwetorpoorlydrainedareas, and tops and toes of banks and slopes
   b) avoid sharp curves

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c) set roads at least 100 to 150 feet back fran streams, ponds, and marsh es (200 feet for landings)
d) reseed if necessary when done
e) use care when skidding to protect understory vegetation
f) put in diversion 'devices if necessitated
g) use winch as much as possible

5. Waste Products
a) keep petroleum products away from water bodies - take wastes off - sit
b) pick up litter, oil cans, lunch wrappers, broken cables and other wast products daily

6. Education
a) emphasize the above to crew members/machine operators

For Additional Information

N.J. Forestry Association, N.J. Chapter
Society of American Foresters
P.O. Box 304
Pennington, N.J. 08534

N.J. Bureau of Forestry
CN 028
Trenton, N.J. 08625

U.S. Dept. of Agriculture
Soil Conservation Service
Hackettstown, N.J.

Area Forester
NJ Bureau of Forest Management
RD 1, Box 999
Franklin, New Jersey 07416

category

WATER QUALITY

SUMMARY SHEET

sub-category

INDUSTRIAL / COMMERCIAL USES

BMP

CONTROL THROUGH ZONING

OBJECTIVE

The purpose of controlling development is to prevent permanent damage to groundwater resources by contact with noxious substances which escape into the environment due to accident or negligence.

WHERE APPLICABLE

Major and minor aquifers should be inventoried and their intake areas and recharge zones delineated and catagorized as to the level of control of industrial development required to protect them. (See chapter 5 and GMA map)

PROS

1. Low public cost - the Zoning Ordinance is the instrument to implement industrial development control. Amendment of zoning and continuing administration is the most significant public cost.
2. Potentially very effective - prevention of noxious substances from escaping into the environment is a most effective method of groundwater protection.

CONS

1. Possible loss of ratables - limited industrial development on recharge area given a lack of alternate sites can result in a reduction of property tax collection.
2. Variances can be a problem if not barred. (See land use BMP's)
3. Illegal change of use - once a building is constructed, illegal modification are difficult to detect.

IMPLEMENTATION CONSIDERATIONS

By zoning map and industrial use categories, a municipality controls industrial development to protect groundwater resources. Industrial uses are prohibited from or are restricted from being developed upon aquifer intake areas because of potential harmful effect. Restrictions are particularly important for industrial uses which produce noxious substances which, if they escape into the environment, can result in permanent damage to the aquifer. (See chapter 5)

A direct cost of implementing control of industrial uses is the cost of legal fees for preparing the ordinance amendments. An indirect cost is a possible loss of municipal revenues when the land which might otherwise be developed as industrial use is shifted downward to a less valuable (from a tax perspective) use.

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There are few examples of critical recharge area zoning and industrial zone delineation is usually based on access and remoteness from residential areas. The water quality management plans of the Metro-Dade Planning Department in Florida and the Nassau-Suffolk Regional Planning Commission in Long Island, New York, offer ordinances which regulate industrial development on critical recharge areas.

An example of the consequences of neglect can be found in southern New Jersey, where industrial wastes dumped and forgotten at the' Price's Pit Landfill, near Atlantic City, are oozing into the Great Cohansey aquifer of the Pine Barrens, one of the East's purest and most plentiful groundwater supplies. The Federal government has declared it among the most serious environmental problem in the nation.

Zoning cannot be arbitrary or capricious.in its effect. Environmental considerations are a valid basis for determining zoning patterns if they are founded in fact and consistently applied.

For Additional *Information*

1. Melvin Levin , Jerome Rose, Joseph Slavet. New Approaches To State Land Use Policies; Lexington, Mass. : D. C. Health and Company. Copyright 1974

2. Strom, Fredric, ed. 1981 Zoning and Planning Law Handbook. New York, N.Y.: Clark Boardman Company, Ltd. copyright 1981.

SUMMARY SHEET

category: WATER QUALITY

sub-category: GENERAL LAND USE

BMP: LAND USE DISTRIBUTION

OBJECTIVE

To arrange land uses, densities and land coverages to give maximum protection to groundwater quantity and quality by minimizing impervious coverage over aquifers and intake areas and preventing location of pollution.

WHERE APPLICABLE

All areas of land within a municipality which oveklie major aquifers of high yield and their recharge areas, aquifers of minor yield and their recharge areas. and areas where there is a possibility of confined aquifers of high yield overlain by thin sands of low yield.

PROS

1. Helps to maintain balance of the water budget by restricting surfaces which prevent the penetration of precipitation into the ground and by maximizing recharge.
2. Arranges land uses to most appropriately accomodate the requirements for impervious surfaces in accordance with recharge requirements to ensure maintenance of natural groundwater levels with the overall determinant being the effective management of groundwater quantity and quality.

CONS

1. There may be a short term disadvantage to local planning and governing bodies because of the need to revise existing land use control ordinances or add groundwater management ordinances to their existing codes.
2. Time will need to be invested in establishing policy towards site plans and subdivision applications which arr pending for parcels located in designated protected areas.

IMPLEMENTATION CONSIDERATIONS

. Evaluation of Existing Conditions - Survey and map major and minor aquifers and their recharge areas.
2. Classification - Classify major and minor aquirers and their recharge areas into one or more levels of protection based on their relative susceptibility to contamination or depletion.
3. Conformity of Existing Ordinances - Re-evaluate master plan elements which relate economic and population growth with water supply (if any) and revise if necessary. Re-evaluate land development ordinances, revising and /or supplementing where necessary to incorporate the groundwater consideration! and to conform them to the master plan.
4. Implement the legal adoption of the zoning and subdivision revisions and amendments, including public hearings.

Design criteria and specifications for the following measures will be discusse in detail in succeeding BMP fact sheets:

1. Porous Asphalt Pavement
2. Modular Paving
3. Collection of runoff from roofs

Aside from the designation of areas to be protected or managed, specific standards relating to impervious surfaces can be incorporated into land development ordinances. An example follows below. Note : The Figures used below are hypothetical and are for illustrative purposes only.

IS=Impervious surfaces
PP=Porous pavements

GROUNDWATER MANAGEMENT AREAS

	Level I	Level 11	Level III
% Lot Coverage IS	0-3	3-5	5-10
% Lot Coverage PP	5-10	10-15	15-20
% Predevel. Recharge	100	90	80

Unfortunately, there are very few municipal ordinances which have been formulated to date using the approach described above. However the planning agencies of Metro-Date County. Florida, and Nassau and Suffolk Counties in Long Island, New York, have enacted such ordinances at the regional level. In New Jersey. counties do not possess the power to zone. That power is possessed by local municipalities alone. The procedure and composition of the ordinances mentioned are usable as models, however, and should be investigated.

Groundwater management is an integral part of the Comprehensive Management Plan developed by the Pinelands Commission, and may serve as a useful example as well.

1. Direct costs of effecting these measures would be the costs of hiring or retaining planning and legal consultation to amend the local officials.
2. Indirect costs may be incurred if less development occurs on designated areas and the tax revenue is not compensated for by an increase in development or density elsewhere.
3. Any added expense of using porous pavements will be borne by the developer. although these materials may prove to be cost effective.

Implementation takes place through the adoption of groundwater related master plans and zoning ordinances.

In general, the land use control techniques described above have gained legal acceptance. However, applying such techniques to major and minor aquifers and their critical recharge areas is still legally unproven. Dade County, Florida is fighting challenges to an ordinance of theirs which restricts development in well fields based on cones of influences. Their "overlay ordinance", which deals. with levels of protection for management areas, as described above, is yet to be adopted formally.

For Additonal Information

1. Lower Raritan /Middlesex County Water Resources Management Program. Groundwater Recharge Management Handbook. (author) , March 31, 1981.
2. Tourbier, J. Toby, Westmacott , Richard. A Handbook of Measures to Protect Water Resources in Land Development. Washington: The Urban Land Institute, 1981.

category

WATER QUALITY

SUMMARY SHEET

sub-category

GENERAL LAND USE

BMP

BAR VARIANCES

OBJECTIVE

To present a well constructed zoning ordinance which protects aquifer intake areas from being compromised by variances which corrode the effectiveness in promoting groundwater quality and quantity.

WHERE APPLICABLE

Critical recharge areas which are the most productive for replenishing groundwater supply and/or directly over pervious major aquifers such as stratified drift aquifers.

PROS

1. Low public cost-administration of the zoning ordinance is the only public cost incurred directly.
2. Potentially effective - protecting intake areas from development is a preventive measure which is more effective than corrective measures after the damage is done.

CONS

1. Untested legality- no precedent for a prohibition of variances for environmental reasons.
2. Possible loss of tax ratables- if development is turned away, the municipality may collect less property taxes than might otherwise be the case.

IMPLEMENTATION CONSIDERATION

The zoning ordinance would contain a provision which would prohibit granting of variances in the areas which are defined as critical to groundwater recharge. Especially important are prohibition of variances which would 1) introduce a potentially harmful use (e.g., toxic chemical processing) to the recharge area and/or 2) result in extensive impervious cover to the recharge area. The areas in which variances would be barred are most likely zoned for a low density or planned development. When development pressures increase, the demand for variances increases--thus the need for barring them.

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BAR VARIANCES

To present a hypothetical example: the owner of a tract of land in an area recently zoned as Maximum Protection Critical Recharge Zone (MPCR) operates a farm (a permitted use) but applies for a bulk variance in order to subdivide a portion into one acre lots. The minimum allowable lot size is five acres in the zone. If the variance is granted, a precedent will be set which will encourage other land owners to apply for similar variances. The result will be a gradual erosion of the effectiveness of the area for recharge and a greater concentration of contaminants with direct access to the aquifer below.

Prohibiting variances is an untested area of legal practice. Applications for variances which meet hardship tests must be granted according to state law. There is no provision in state law for barring variances, but environmental causes are valid reasons for creating zones and zoning regulations. By extension , it may be valid to bar variances for environmental reasons.

To implement a provision to bar variances, the cost is that of amending zoning ordinances - attorneys fees and public hearing costs.

For Additional Information

1. The Municipal Land Use Law Chapter 291, Laws of N.J. 1975. Compiled as 40: 55D - 1 et seq.

category

WATER QUALITY

SUMMARY SHEET

sub-category

RESIDENTIAL

BMP

ROAD DE-ICING

OBJECTIVE

To reduce water quality contamination by minimizing the use of de-icing materials where possible.

WHERE APPLICABLE

In regions where snow and ice on roads warrants the use of de-icing agents such as salt.

PROS

1. Realize enhanced water quality.
2. Reduce vehicle corrosion due to salt.
3. Reduce damage to roadside vegetation.

CONS

1. Icy roads cause accidents which can result in injury and death, therefore, it is difficult to draw the line between water supply degradation and vehicle-related safety.

IMPLEMENTATION CONSIDERATIONS

1. De-Icing Salts - Chloride ions from de-icing salts move rapidly into the soil and can pollute ground. and /or surface water. (5) As a result, consequences can occur such as hypertension, caused by excess sodium in water supplies; serious corrosion of vehicles and highway structures from chlorides: damage of pavement and roadside vegetation, also from excess chlorides in water: an deterioration of the soil structure.

   Since presently there are no viable alternatives for calcium or sodium chlorides for road de-icing. (pavement heating is too expensive), and because the use of abrasives, such as sand and grit, alone is often not publically acceptable and may result in excessive sediment problems, the use of these materials can probably not be eliminated altogether. However, through operator education programs and by setting clear guidelines on application rates and optimum mixes, quantities spread and frequency of spreading can be significantly reduced. Also, spreading equipment should be well maintained for best performance of even spreading. Equipment can be modified to improve application effectiveness, and new techniques such as pre-storm application of a brine solution followed by use of high speed snow blowers, should be investigated and evaluated for their effectiveness. Limiting salt application in aquifer recharge areas or directly over major aquifers to critical areas for road safety only (such as steep slopes, curves, and intersections) is a possibility worth investigation. It has also been experienced that sediment control basins which receive salt-contaminated water from snow melt can be evaporated in the spring to yield salt concentrations high enough (specific gravity of 1.178) to be reused for de-icing the next winter season (175 gals /mile) . (2)

   Salt tolerant species of vegetation should be planted on all new roads.
2. Salt Storage Piles - The leachate from stockpiles of de-icing salts can make its way into groundwater and/or surface water supplies and therefore can become a serious problem. It is necessary to properly site,construct and maintain these piles. They should be placed on impervious liners or pads that are not susceptible to breakdown from salt exposure, and covered to eliminate water infiltration and leachate leading areas should be kept clean so scattered salt is not washed away into water systems.

For Additional *Information*

1. Adams, F.S. Highway Salt: Social and Environmental Concerns. Highway Research Report 425. Ottawa, Ont. : National Research Council, 1973.

2. Walker, W.H. and Wood, F.O. Road Salt. Use and the Environment. Highway Research Record, Repor 425. Ottawa, Ont .: National Research Council, 1973.

3. Hanes, R.E. Effects of De-Icing Salts on the Environment. Highway Research Record, Report 91. Ottawa, Ont. : National Research Council.

4. Murray, D.M. A Search for New Technology for Pavement Snow and Ice Control. Washington: EPA, 1972.

5. Urban Land Institute, Water Resources Protection Technology, Tourbier, 1981.

category

WATER QUANTITY

SUMMARY SHEET

sub-category

AVOIDING OVERTAXATION

BMP

CONSUMPTIVE USE LIMITATION

OBJECTIVE

To maintain the predevelopment water budget by avoiding overtaxation of groundwater supplies through consumptive use.

WHERE APPLICABLE

Any community or region which relies upon groundwater for water supply.

PROS

1. Mds longevity to water supply
2. Reduces water quality threats by preventing concentration of contaminants
3. Minimizes deviation from natural water budget

CONS

1. May limit or restrict excessive use of a water supply well

IMPLEMENTATION CONSIDERATIONS

When a groundwater well is over pumped beyond what has been determined to be the safe yield of that particular groundwater system (See Ch. 2, p. 16 and Ch. 4, p. 49 of this manual), undesirable and costly consequences can result. To avoid overtaxation and consumptive use, proper planning and design measures should be taken prior to development to ensure that demand will be met without exceeding the groundwater budget. Also, following development, proper measures need to be implemented to ensure thatuseisaccording to thatwhichwas projected, and that necessary adjustments be made prior to adversely affecting the groundwater system.

Aquifer pump tests can be performed and calculations made to effectively estimate the localized productivity and limitations of a groundwater system or well.* This procedure can also aid in the determination of proper well depth and pump setting.

To apply this aquifer-test approach, townships could allow for flexibility in zoning, which would be based upon hydrologic criteria. For example, lot densities could be planned based upon the values derived fran a regional ground water budget analysis, but final subdivision approval could be granted only after a review of the results of an aquifer test. This approach gives the developer an approximation of allowable density, but places the burden of final

* Proper testing for well yield - For individual residences the well should be tested with a pump for a minimum of three (3) hours. Drawdown in the well should be measured. The pump setting should be in accordance with measured drawdown in the well.

(Robert Canace, New Jersey Department of Environmental Protection)

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proof of the adequacy of the water supply and compatibility with regional planning goals on the developer. In some instances the aquifer. test may demonstrate that greater densities may be permitted than indicated by the regional zoning analysis.

Where large residential developments are planned with homes relying upon individual well water supplies a phased development approach should be adopted, wherein the wells be drilled initially to determine the existence of an adequate water supply for the planned home. Zoning can restrict the options for obtaining a water supply where the first well does not encounter water. Ground water does not obey zoning restrictions. A lack of flexibility in zoning laws can limit potential solutions to water supply problems once development begins.

The phased well drilling/testing approach involves drilling and test pumping wells in the proposed development on a lot-by-lot basis, to insure the existence of a water supply for each lot and test for interference between wells located on separate lots. Such an approach permits an a priori* resolution of potential individual water supply problems.

* a priori - from the Latin meaning "derived by reasoning fran self-evident propositions"

For Additional Information

(1) New Jersey Department of Environmental Protection, Division of Water Rewources, Geologic Survey

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Chapter 7

RECOMMENDATIONS: PLANNING PRACTICES AND ORDINANCES

The recommendations in this chapter by Township Planner Eric Snyder and by the Environmental Commission are in addition to the recommendations from other sources in Chapter 6. The Township was acting upon some of these suggestions when this document went to press.

The recommendations by Mr. Snyder and the Commission are directed at preserving the Township's natural resources, with special emphasis on its lakes and streams and its drinking water supplies. By preventing contamination and over-use of these water resources, the residents of Byram will avoid paying for expensive cleanups or for the costly process of finding new drinking water supplies should the township's own aquifers become depleted.

The recommendations also are directed at preventing the disturbance of sensitive natural features. These features include steep slopes, forests, streams, aquifer recharge areas, wetlands, areas where water tables are high or where bedrock is close to the surface, and also scenic views.

Haphazard or spotty preservation of these natural areas is insufficient. Sizable, continuous parcels should be permanently preserved so that these natural systems can continue their irreplaceable work--cleaning the air and blocking noise, filtering ground and surface water, resupplying aquifers with adequate drinking water, controlling erosion, providing habitats for wildlife and pleasurable landscapes for people.

FROM THE TOWNSHIP PLANNER

In his September 1991 Natural Resources Inventory Update, Township Planner Eric Snyder recommends specific ordinance amendments. Mr.

Snyder's document was used in the preparation of this 1994 update and is on file at the Municipal Building. His recommendations for new ordinances include:

1. limiting disturbance on all lots to areas of less than 35% grade; banning all construction on slopes in excess of 25%. It is extremely difficult to revegetate such slopes, particularly because soils in these areas are generally thin, highly erodible, and require very expensive methods of restoration.

2. restricting areas of soil disturbance on construction sites; areas that are not disturbed resist erosion better and permit more effective aquifer recharge.

3. requiring at least a100-foot buffer around all water bodies; this buffer should remain undisturbed to act as a filter for all surface runoff.

4. prohibiting development within the 100-year floodplain of all streams, whether delineated or not.

5. paying particular attention to developments located on or abutting the glacial drift aquifers in the Township.

6. requiring the provision of adequate stormwater detention or retention facilities for all subdivisions, with specific emphasis on natural structures, sheet flow of drainage, silt chambers and the like.

7. requiring water quality control basins for all development to control pollution at the source; these would include silt traps and oil-and-water separators where necessary. Other strategies would include frequent street sweeping and catch basin cleaning, the use of grassed waterways for runoff, a reduction in the use of salts for road de-icing.

8. requiring soil erosion and sediment control plans for any site disturbance of 1,500 square feet or greater (not to duplicate existing Soil Conservation District requirements).

9. preparing a comprehensive municipal stormwater management plan

addressing runoff, erosion, and other water quality and control issues.

10. minimizing tree removal and prohibiting the removal of specimen trees (those in excess of 18 inches diameter at breast height) except where absolutely necessary. Where specimen trees are removed, they should be replaced with a greater number of new trees.

Other recommendations from Mr. Snyder include:

1. strictly enforcing lot coverage requirements in order to minimize the amount of off-site runoff caused by development. Other strategies for minimizing runoff would include the use of dry wells, detention ponds, vegetative strips.

2. conducting a survey of the Township to identify potential habitats for endangered species to help protect those habitats from on- or off-site activities.

FROM THE ENVIRONMENTAL COMMISSION

The Environmental Commission supports Mr. Snyder's recommendations, as well as those in Chapter 6. The Commission also recommends:

1. protecting the township's aauifer recharge areas bv avoiding interference with their natural function as much as Dossible.

2. takine special care with development over or around Byram's glacial drift aquifers, which are especially susceptible to contamination.

3. instituting, a carry capacity approach to the township's development, especially with regard to drinking water supplies. Byram depends almost entirely on Pre-Cambrian rock formations for water supply. As Township Planner Eric Snyder notes on page 3 of his September 1991 Natural Resources Inventory Update, "Relative to other geologic formations in New Jersey, these serve as poor sources of water, although there is adequate water available to sustain moderate levels of development." On page 42 of

that document, Mr. Snyder advises, **"It is clear that the township of Byram needs to be extremely sensitive to the impact of development on its water supply."**

Although he concludes that there is adequate water to serve the current zoning plan, Mr. Snyder advises that "any *changes to the zoning which would permit developments of greater intensity should be carefully reviewed and their impact on the overall Township water supply thoroughly studied. "*

A carrying capacity approach to planning assumes that the natural and/or man-made resources of an area can support only a limited number of people. When these resources become overburdened or when costly infrastructure must be built to handle new development, costs to residents often increase dramatically and the natural setting deteriorates.

Byram's limited water supplies, as well as its many other critical environmental constraints, should be the basis for setting reasonable limits on the Township's growth. The Commission has asked for a total population projection based on the Township's zoning, to see whether current planning could overburden the Township's accessible water supplies.

Unless development is carefully controlled, Byram could find that it must built a costly central water system and import drinking water from other areas. This is especially true in the proposed sewer district along Route 206 and Lackawanna Drive, where large volumes of water (which would normally recharge into aquifers after being cleansed in a septic system) could be piped away.

4. applying the 100-foot buffer to streams and to all other water bodies. delineated or not. as a **minimum** buffer. Where appropriate, the buffer would extend 'to the 100-year floodplain or to other terrain lines that would provide reasonable protection for stream flow and water quality.

5. enacting a Well-Head Protection Ordinance to help prevent contamination of public wells, including wells supplying housing developments, public buildings and commercial projects.

In 199 1, the New Jersey Department of Environmental Protection adopted a well-head protection program, as required for each state under the 1986 federal Safe Drinking Water Act Amendments. A well-head protection area (WHPA) includes most of or sometimes more than the land that contributes groundwater recharge to a well. The delineation of the WHPA is based on the hydrogeologic characteristics of the well and of the surrounding aquifer and also on a risk of contamination based on the flow of the recharging water. N.J.D.E.P. delineation regulations were still in draft form when this Natural Resources Inventory was published; and the N.J.D.E.P. was planning several years of work delineating WHPAs for public community wells.

6. establishing more cautious zoning and planning procedures for Byram's lake communities. including more cautious procedures for grant-inn variances and building permits for enlarging houses that sit on small lots or that have sub-standard septics.

The Environmental Commission would like the Township to consider basing septic requirements not only on the numbers of bedrooms but also on the total square footage of the home or on the percentage of impervious coverage of the lot. The Commission also recommends that the Township adopt a 'Rehabitation Ordinance,' requiring a new Certificate of Occupancy each time a house is sold or reoccupied after being vacant and that this C.O. be contingent upon wellwater testing and septic dye-testing *performed by the Township's health department.*

The recent study of Cranberry Lake (completed in April 1992 by Coastal Environmental Resources Inc.) recommends a long-term management plan for the lake to prevent further deterioration of water quality and thus of property values. Among the recommendations are septic management and a 'sensitive land use' plan.

The Township Board of Health had already been passed an August 1990 ordinance establishing the Cranberry Lake Septic Management District. In 1994, Coastal Environmental Resources Inc. is expected to recommend a sensitive land use plan, which should also be usable by all the Township's lake communities. This plan would (quoting from the Cranberry Lake report) "relate specifically to development limitations placed on building on

slopes over 20%, soils of limited stability and septic suitability, and wetlands. These areas are sensitive and must be protected by limiting their disturbance. This includes not only large scale subdivisions, but other forms of development, such as minor subdivisions, single lot development and even certain types of additions to existing dwellings, particularly those with sub-standard septic systems (page 53)."

The report also calls for stricter enforcement of existing ordinances, especially "in reviewing additions to existing dwellings, particularly those that are located in marginally functional soils or those suspected of having sub-standard septic systems" (page 5 1).

7. creating a town-wide open space plan that emphasizes sizable, continuous greenways and that clearly establishes the legal inviolability of areas set aside as open space. Land-use specialists at the Association of New Jersey Environmental Commissions in Mendham warn that many municipalities have discovered that their open space ordinances do not provide adequate legal protection against the future sale or development of those areas. In 1993, the Commission submitted to the Council specific recommendations for language to be added to the Township's ordinances to secure permanent open space.

Open space provides natural beauty, recreation and wildlife habitat. It also helps control air and noise pollution, helps prevent erosion, flooding, and the contamination of surface and sub-surface water, and protects aquifer recharge areas.

Because open space provides cost-free natural engineering and requires no services from the municipality, it is a good ratable. This is especially true, as many studies have shown, when the free benefits of open space are compared to the apparent and hidden costs of development. When natural systems become overwhelmed by excessive development, expensive man-made solutions are often needed.

As part of an open space plan, the Commission would like the Township to consider:

a. a Transfer of Development Rights policy to direct development to areas most suited for it and to permanently protect sensitive areas;

b. a policy of municipal 'right of first refusal' to purchase, exchange or lease open space of special environmental, recreational or scenic value;

c. actively working with developers to save open-space in large, continous tracts. Such greenways would provide more effective recreational pathways, wildlife habitats, and scenic stretches. These greenways and trails might connect with similar areas in neighboring municipalities. For instance, the Morris County Park Commission is trying to develop a trail from Schooley's Mountain Park in Washington Township to Stephens State Park in Hackettstown. This trail could connect to Allamuchy State Park and the West Brookwood section of Byram, to the Morris County Patriot Path system, and perhaps to the International Trade Center. It could also connect to the state's Sussex Branch Trail (the former Erie Lackawanna Railroad bed passing Jefferson Lake and Cranberry Lake), which continues to Newton and Branchville.

d. encouraging Township cooperation with the county, the state and the private sector to promote funding for open space and farmland preservation.

8. limiting: or prohibiting develonment on the Township's rideelines. Most of these ridges are steep, making them unsuitable for development. Limiting or prohibiting development on these ridgelines would also preserve large continuous forested areas to buffer noise and pollution, to diminish wind and erosion, and to provide natural and recreational habitats. Building on these ridge lines also damages Byram's natural attractiveness, as evidenced by the recent home construction at East Brookwood. Throughout the Township, the Commission and Mr. Snyder would like to ban all construction on slopes greater than 25%; Mr. Snyder notes that it is very difficult to revegetate such slopes, especially since soils in these areas tend to be thin and highly erodible.

9. enacting a Tree Removal Ordinance to set workable standards for the size, type and number of trees property owners can remove without municipal approval and to police forest management plans on the many acres in Byram that are farmland assessed.

In addition to their aesthetic value, trees filter air pollution, prevent erosion, help control flooding and runoff, mask noise, save energy by

shielding buildings from wind and sun, and provide pleasant recreational areas and natural habitats.

Byram's lakes are especially susceptible to some of these problems, because clearing trees to make lawns and open areas not only increases erosion but also leads to increased use of lawn fertilizers and pesticides, all of which promote lake degradation.

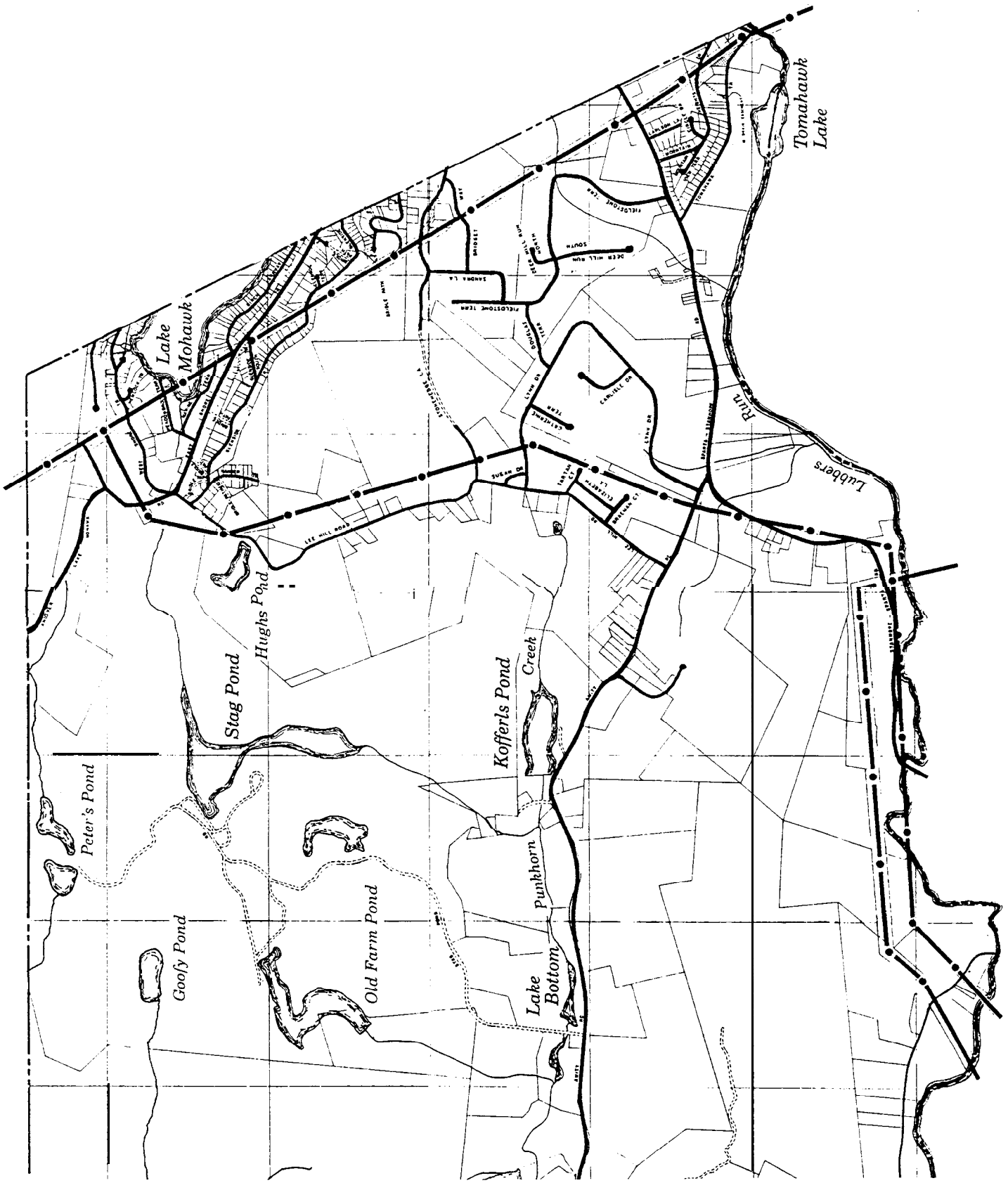
Property owners with farmland assessment are required to file a management plan for cutting and replanting. The Township should see that these plans are followed, since the improper disturbance of large forested tracts could cause serious problems.

The Commission would like to see a Shade Tree Commission appointed to survey and make recommendations on existing and proposed vegetation.

10. setting a precautionary policy for reviewing proposals to construct homes, schools or workplaces close to major power transmission lines and for reviewing proposals to construct new facilities, such as transmission lines or transmission towers, that may produce strong electro-magnetic fields. The map on page 171 shows the locations of such lines in Byram. Many studies point to a link between exposures to electromagnatic fields and several kinds of cancer, including leukemia and other cancers in children, and brain, breast (in men and women), lymph and many other cancers in adults. *A New Yorker magazine article about these studies is in the Environmental Commission files at the municipal building under "Electromagnetic Fields and Cancer" (see the bibliography for this chapter).* California, New York and Florida set exposure or distance limits; Sweden and Oregon are expected to do so. The New Jersey Board of Regulatory Commissioners has recently ordered utilities to survey all schools near transmission lines.

11. creating an Historic Preservation Commission with powers to survey of historic sites, recommend historic preservation districts, and advise land use regulatory bodies on applications for development.

12. promoting a desirable visual environment through preservation



POWER TRANSMISSION CORRIDORS IN ***BYRAM*** ● *&-'O*
In Chapter 7, see the Commission's recommendation #10

of unique and scenic views and through reasonable aesthetic regulation, (for instance, signage, landscaping, and height restrictions).

13. using natural stormwater convevance and detention systems wherever possible and discouraging man-made detention facilities, to minimize construction disturbance, costs, and maintenance.

14. altering Township road reauirements to minimize road and right-of-way widths and to allow proposed streets to lie more naturally on the existing terrain. These changes would not only improve the appearance of new developments but would also reduce soil and vegetation disturbance and help minimize the construction of impervious surfaces.

15. requiring all new roads to set aside a bicycle lane and to include sufficient striping and marking to distinguish that lane. The lanes should be provided not by widening the roadways but by narrowing the traffic lanes, which helps limit traffic speed.

16. clustering develonment awav from criticallv constrained areas.

17. monitoring regional trends. esneciallv to be aware of how activities in neighboring municipalities might affect Bvram's water aualitv.

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Amendment to the
Upper Delaware Water Quality Management Plan
Northeast Water Quality Management Plan
Upper Raritan Water Quality Management Plan
Sussex County Water Quality Management Plan

Total Maximum Daily Loads for Phosphorus To Address 4 Eutrophic Lakes in the Northwest Water Region

CRANBERRY LAKE, SUSSEX COUNTY
GHOST LAKE, WARREN COUNTY
LAKE HOPATCONG, SUSSEX COUNTY
LAKE MUSCONETCONG, SUSSEX COUNTY

Watershed Management Area 1
(Upper Delaware River Watershed)

Proposed:	January 21, 2003
Established:	March 28, 2003
Approved (by EPA Region 2):	September 17, 2003
Adopted:	

New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418

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1.0 Executive Summary

The State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Northwest Water Region as being eutrophic. This report establishes total maximum daily loads (TMDLs) for total phosphorus (TP) that address eutrophication of the lakes listed in Table 1.

Table 1 Eutrophic Lakes for which Phosphorus TMDLs are being established

TMDL Number	Lake Name	Municipality	WMA	Acres
1	Cranberry Lake	Byram Township, Sussex County	01	190
2	Ghost Lake	Independence Township, Warren County	01	18.3
3	Lake Hopatcong	Hopatcong Borough, Sussex County; Mt. Arlington Borough, Jefferson & Roxbury Townships; Morris County	01	2,410
4	Lake Musconetcong	Stanhope, Byram, Netcong and Roxbury Townships; Sussex County	01	314

These TMDLs serve as the foundation on which restoration plans will be developed to restore eutrophic lakes and thereby attain applicable surface water quality standards. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet Surface Water Quality Standards (SWQS). The pollutant of concern for these TMDLs is phosphorus, since phosphorus is generally the nutrient responsible for overfertilization of inland lakes leading to cultural eutrophication. The Department's Geographic Information System (GIS) was used extensively to describe the lakes and lakesheds (drainage basins of the lakes).

In order to prevent excessive primary productivity[1] and consequent impairment of recreational, water supply and aquatic life designated uses, the SWQS define both numerical and narrative criteria that address eutrophication in lakes due to overfertilization. Phosphorus sources were characterized on an annual scale (kg TP/yr) for both point and nonpoint sources. Runoff from land surfaces comprises a substantial source of phosphorus into lakes. An empirical model was used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. To achieve the TMDLs, overall load reductions were calculated for at least eight source categories. In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will augment its ambient monitoring program to include lakes on a rotating schedule. The implementation plan also calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake for which TMDLs are being established. These plans will consider what specific measures are necessary to achieve the nutrient reductions required by the TMDL, as well as what in-lake measures need to be taken to supplement the nutrient reductions required by the TMDL.

[1] Primary productivity refers to the growth rate of primary producers, namely algae and aquatic plants, which form the base of the food web.

Each TMDL shall be proposed and adopted by the Department as an amendment to the appropriate areawide water quality management plan(s) in accordance with N.J.A.C. 7:15-3.4(g).

This TMDL Report is consistent with EPA's May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Suftin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs.

2.0 Introduction

Sublist 5 (also known as List 5 or, traditionally, the 303(d) List) of the State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Northwest Water Region (WMAs 1, 2, and 11) as being eutrophic, as evidenced by elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density that impairs recreational use (a qualitative assessment). Total phosphorus was used as the pollutant of concern, since this "independent" causal pollutant causes "dependent " responses in chlorophyll-*a* concentrations and/or macrophyte density. This report establishes four total maximum daily loads (TMDLs) that address total phosphorus loads to the identified lakes. These TMDLs serve as the foundation on which management approaches or restoration plans will be developed to restore eutrophic lakes and thereby attain applicable surface water quality standards. Several of the lakes are listed on Sublist 5 for impairments caused by other pollutants. These TMDLs address only the impairment of lakes due to eutrophication. Separate TMDL evaluations will be developed to address the other pollutants of concern. The waterbodies will remain on Sublist 5 until such time as TMDL evaluations for all pollutants have been completed and approved by the United States Environmental Protection Agency (USEPA).

A TMDL is considered "proposed" when NJDEP publishes the TMDL Report as a proposed Water Quality Management Plan Amendment in the New Jersey Register (NJR) for public review and comment. A TMDL is considered to be "established" when NJDEP finalizes the TMDL Report after considering comments received during the public comment period for the proposed plan amendment and formally submits it to EPA Region 2 for thirty (30)-day review and approval. The TMDL is considered "approved" when the NJDEP-established TMDL is approved by EPA Region 2. The TMDL is considered to be "adopted" when the EPA-approved TMDL is adopted by NJDEP as a water quality management plan amendment and the adoption notice is published in the NJR.

3.0 Background

3.1 305(b) Report and 303(d) List

In accordance with Section 305(b) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required to biennially prepare and submit to the United States

Environmental Protection Agency (USEPA) a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report.

In accordance with Section 303(d) of the CWA, the State is also required to biennially prepare and submit to USEPA a report that identifies waters that do not meet or are not expected to meet surface water quality standards (SWQS) after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. The listed waterbodies are considered water quality-limited and require total maximum daily load (TMDLs) evaluations. For waterbodies identified on the 303(d) List, there are three possible scenarios that may result in a waterbody being removed from the 303(d) List:

> **Scenario 1:** A TMDL is established for the pollutant of concern;
> **Scenario 2:** A determination is made that the waterbody is meeting water quality standards (no TMDL is required); or
> **Scenario 3:** A determination is made that a TMDL is not the appropriate mechanism for achieving water quality standards and that other control actions will result in meeting standards.

Where a TMDL is required (Scenario 1), it will: 1) specify the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards**;** and 2) allocate pollutant loadings among point and nonpoint pollutant sources.

Recent EPA guidance (Suftin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for USEPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that this TMDL report, which includes four TMDLs, addresses the following items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.
12. Submittal letter.

3.2 Total Maximum Daily Loads (TMDLs)

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint source of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point sources in the form of wasteload allocations (WLAs), nonpoint sources in the form of load allocations (LAs), and a margin of safety. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet SWQS.

Once one of the three possible delisting scenarios, noted above, is completed, states have the option to remove the waterbody and specific pollutant of concern from the 303(d) List or maintain the waterbody on the 303(d) list until SWQS are achieved. The State of New Jersey will be removing lakes from the 303(d) List for eutrophication once their TMDLS are approved by USEPA.

3.3 Integrated List of Waterbodies

In November 2001, USEPA issued guidance that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. This integrated report assigns waterbodies to one of five categories. In general, Categories 1 through 4 include a range of designated use impairments with a discussion of enforceable management strategies, whereas Sublist 5 constitutes the traditional 303(d) List for waters impaired or threatened by a pollutant for which one or more TMDL evaluations are needed. Where more than one pollutant is associated with the impairment for a given waterbody, that waterbody will remain on Sublist 5 until one of the three possible delisting scenarios is completed. In the case of an Integrated List, however, the waterbody is not delisted but moved to one of the other categories.

Following USEPA's guidance, the Department chose to develop an Integrated Report for New Jersey. New Jersey's *2002 Integrated List of Waterbodies* is based upon these five categories and identifies water quality limited surface waters in accordance with N.J.A.C. 7:15-6 and Section 303(d) of the CWA. These TMDLs address eutrophic lakes, as listed on Sublist 5 of the State of New Jersey's *2002 Integrated List of Waterbodies.*

4.0 Pollutant of Concern and Area of Interest

Lakes were designated as eutrophic on Sublist 5 of the *2002 Integrated List of Waterbodies* as a result of evaluations performed through the State's Clean Lakes Program. Indicators used to determine trophic status included elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density. The pollutant of concern for these TMDLs is total phosphorus. The mechanism by which phosphorus can cause use impairment is via excessive primary productivity. Phosphorus is an essential nutrient for plants and algae, but is considered a pollutant because it can stimulate excessive growth (primary production). Phosphorus is

most often the major nutrient in shortest supply relative to the nutritional requirements of primary producers in freshwater lakes; consequently, phosphorus is frequently a prime determinant of the total biomass in a lake. Furthermore, of the major nutrients, phosphorus is the most effectively controlled through engineering technology and land use management (Holdren *et al*, 2001). Eutrophication has been described as the acceleration of the natural aging process of surface waters. It is characterized by excessive loading of silt, organic matter, and nutrients, causing high biological production and decreased basin volume (Cooke et al, 1993). Symptoms of eutrophication (primary impacts) include oxygen super-saturation during the day, oxygen depletion during night, and high sedimentation (filling in) rate. Algae and aquatic plants are the catalysts for these processes. Secondary biological impacts can include loss of biodiversity and structural changes to communities. Phosphorus is generally the nutrient responsible for overfertilization of inland lakes leading to eutrophication.

As reported in the *2002 Integrated List of Waterbodies*, the Department identified the following lakes in Northwest Water Region as being eutrophic for a total of 3,480 acres. These four TMDLs will address 2,930 acres or 84.2%of the total impaired acres in this region (Table 2). Lake Hopatcong is listed for both trophic status and aquatic life, which is based on a fishery assessment performed by the Department's Bureau of Freshwater Fisheries; secondary impacts of eutrophication include poorer fish quality and diversity, often due to oxygen depressions and fluctuations. Therefore, it is likely that management actions directed at addressing eutrophication impairments would also address aquatic life impairments based on fishery assessment. However, the exact causes of the aquatic life impairment have not been determined, therefore it is not certain that a TMDL for eutrophication will address the aquatic life impairment completely. Both eutrophic lakes and aquatic life impairments are ranked as Low Priority in the *2002 Integrated List of Waterbodies* because they are not directly related to human health issues; however, both issues are environmentally important.

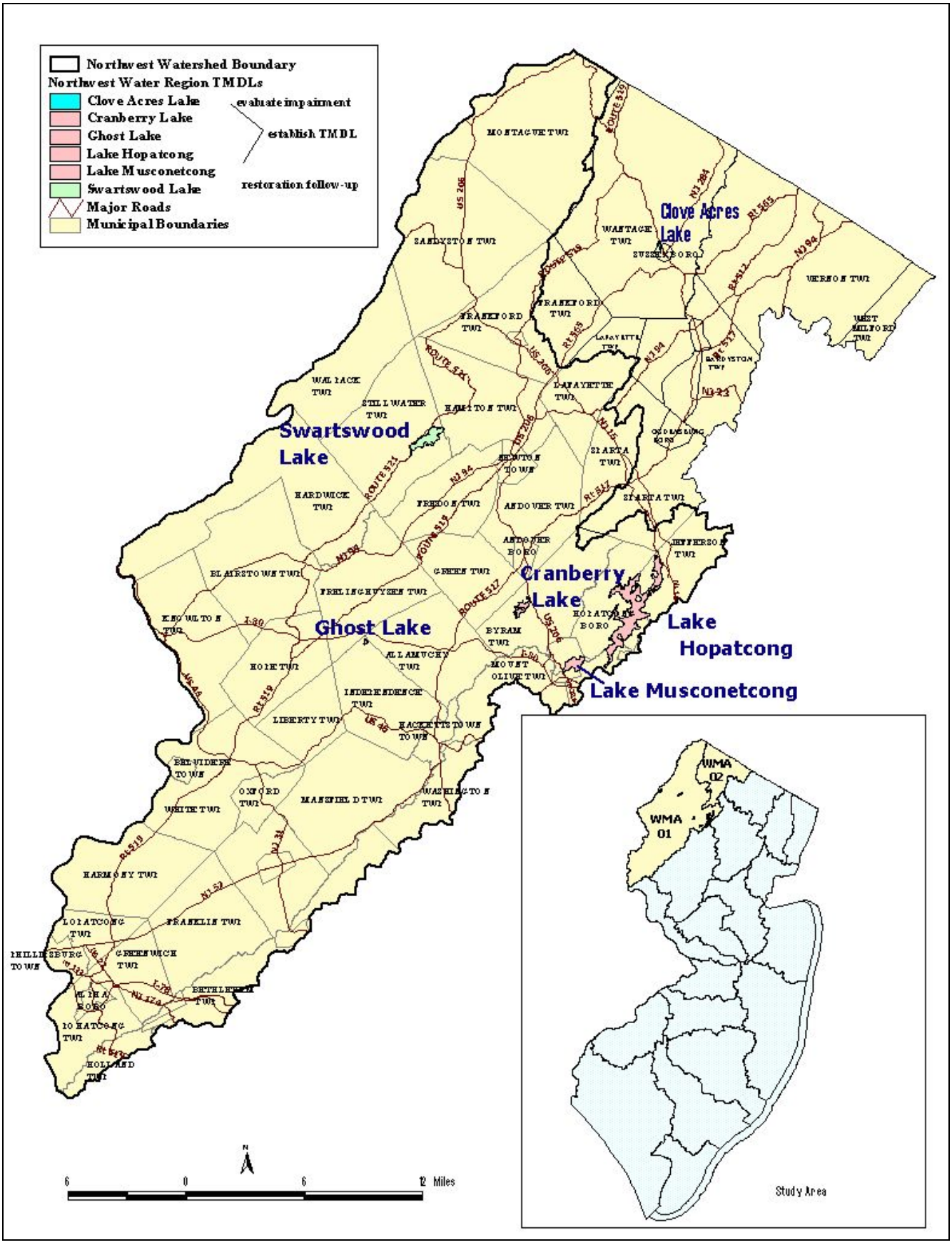
Table 2 Abridged Sublist 5 of the 2002 Integrated List of Waterbodies, eutrophic lakes

No.	WMA	Lake [a]	Lake Acres	Lakeshed Acres	Management Response
1	01	Cranberry Lake	1890	1,740	establish TMDL
2	01	Ghost Lake	18.3	212	establish TMDL
3	01	Lake Hopatcong	2,410	16,200	establish TMDL
4	01	Lake Musconetcong	314	2,980[b]	establish TMDL
5	01	Swartswood Lake	521	6,410	restoration follow-up
6	02	Clove Acres Lake	28.6	12,500	evaluate impairment

a All of the waterbodies covered under these TMDLs have a FW2 classification.

b To avoid "double-counting," watershed area of Lake Musconetcong does not include Lake Hopatcong and its watershed.

Figure 1 Eutrophic lakes in the Northwest Water Region on Sublist 5 of 2002 Integrated List



These TMDLs will address a total of 2,930 acres of lakes with a corresponding total of 21,110 acres of land. Traditionally, land use has been dictated by the topography and transportation system of the area. The Upper Delaware Watershed (WMA-01) exhibits an accelerated pattern of growth, especially around its lakes. In spite of the area's relatively low population density and numerous protected lands, these development trends are likely to negatively impact surrounding water quality and quantity.

The Department's Geographic Information System (GIS) was used extensively to describe the lakes and lakesheds (watersheds of the lakes), specifically the following data coverages:

- 1995/97 Land use/Land cover Update, published 12/01/2000 by NJDEP Bureau of Geographic Information and Analysis , delineated by watershed management area.
- NJDEP Statewide Lakes (Shapefile) with Name Attributes (from 95/97 Land Use/Land Cover) in New Jersey, published 7/13/2001 by NJDEP - Bureau of Freshwater and Biological Monitoring, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njlakes.zip.
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  - NJDEP 10-meter Digital Elevation Grids, published 06/01/2002 by Bureau of Geographic Information and Analysis (BGIA), delineated by watershed management area.
- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1).

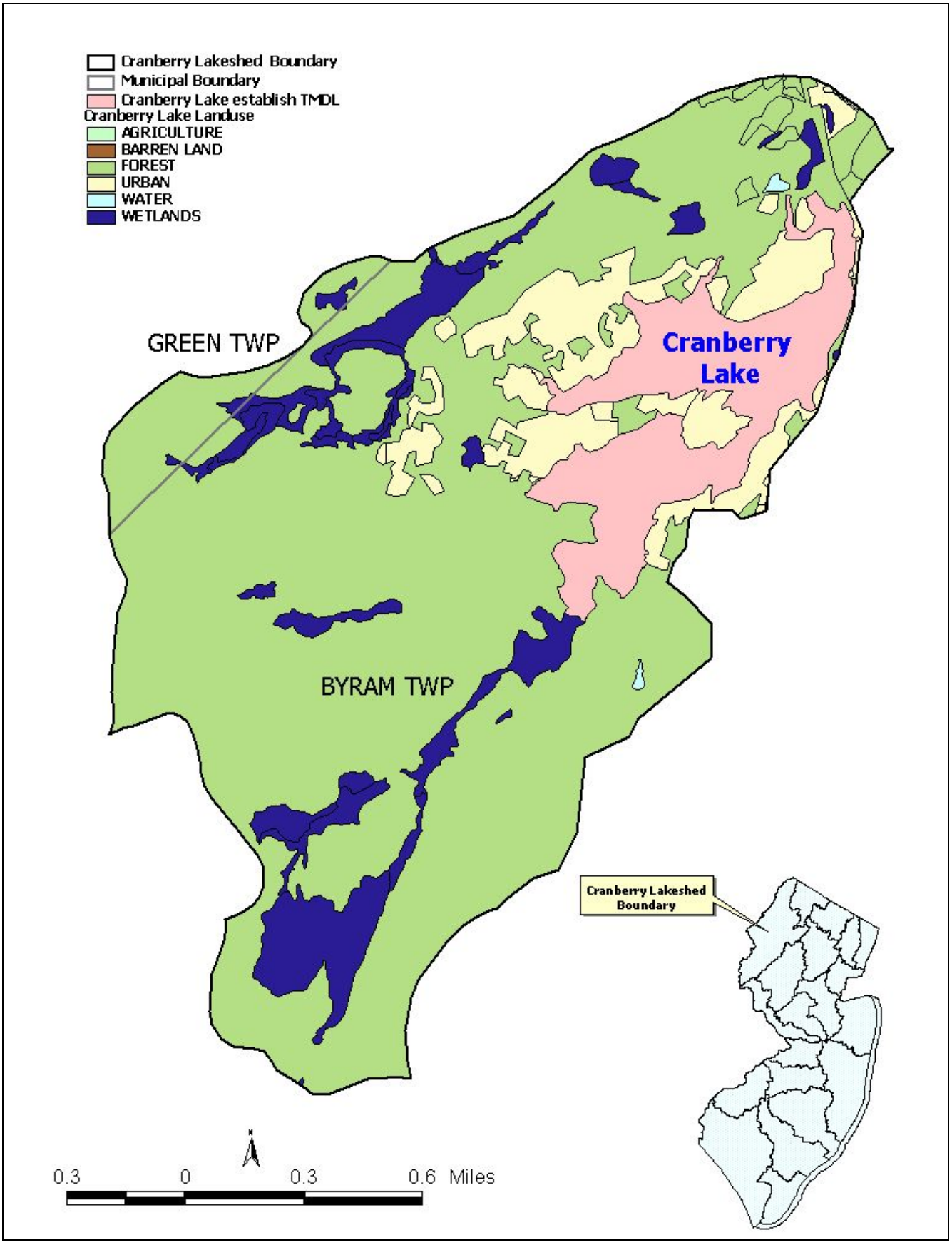
4.1 Cranberry Lake

Cranberry Lake is a 190-acre public lake located in Byram Township, Sussex County, and drains a lakeshed of 1744 acres almost completely within Byram Township. The lakeshed is 9.2 times the area of the lake, making it moderately sized[2]. The lake consists of two basins, each with numerous coves, separated by a large peninsula (Strawberry Point). Tributaries of Lubber's Run feed both basins. Mean depth (2.13m) and total inflow (3,783,000 m^3/yr) were obtained from the Diagnostic Feasibility Study for Cranberry Lake (Coastal Environmental Services, 1992).

[2] A lakeshed seven times the area of its lake is considered small, whereas a lakeshed ten times the area of its lake is considered large (Holdren *et al*, 2001).

Cranberry Lake is a shallow lake within the Musconetcong Watershed, having a mean depth of seven feet and a maximum depth of 15 feet. The lakeshed of Cranberry Lake primarily consists of 1,219 acres of forest, or 70 percent of the entire lakeshed. Approximately half of the land adjacent to the lakeshore is used for medium density residential development, while the remainder is undeveloped (forest cover). Cranberry Lake offers fishing and boating services at the northern end of the lake, where there are boat launch areas (including one trailer launch ramp) and a floating dock. Swimming is available at Cranberry Lake Rose Beach and the Cranberry Lake Club House. The lake is known to have a major septic problem, as indicated in the Phase I Inventory of Current EPA Efforts to Protect Ecosystems report. New Jersey received a Clean Lakes Program Phase II Restoration/Implementation grant in 1992 for Cranberry Lake. The ongoing project entails implementation of in-lake restoration work as well as critical nonpoint source pollution control activities. In 2000 the Weaver House Cove dredging project, which required the lake to be lowered five feet, was nearing completion. In 2001 the Cranberry Lake community was battling watermilfoil vegetation with the herbicide SONAR.

Figure 2 Lakeshed of Cranberry Lake

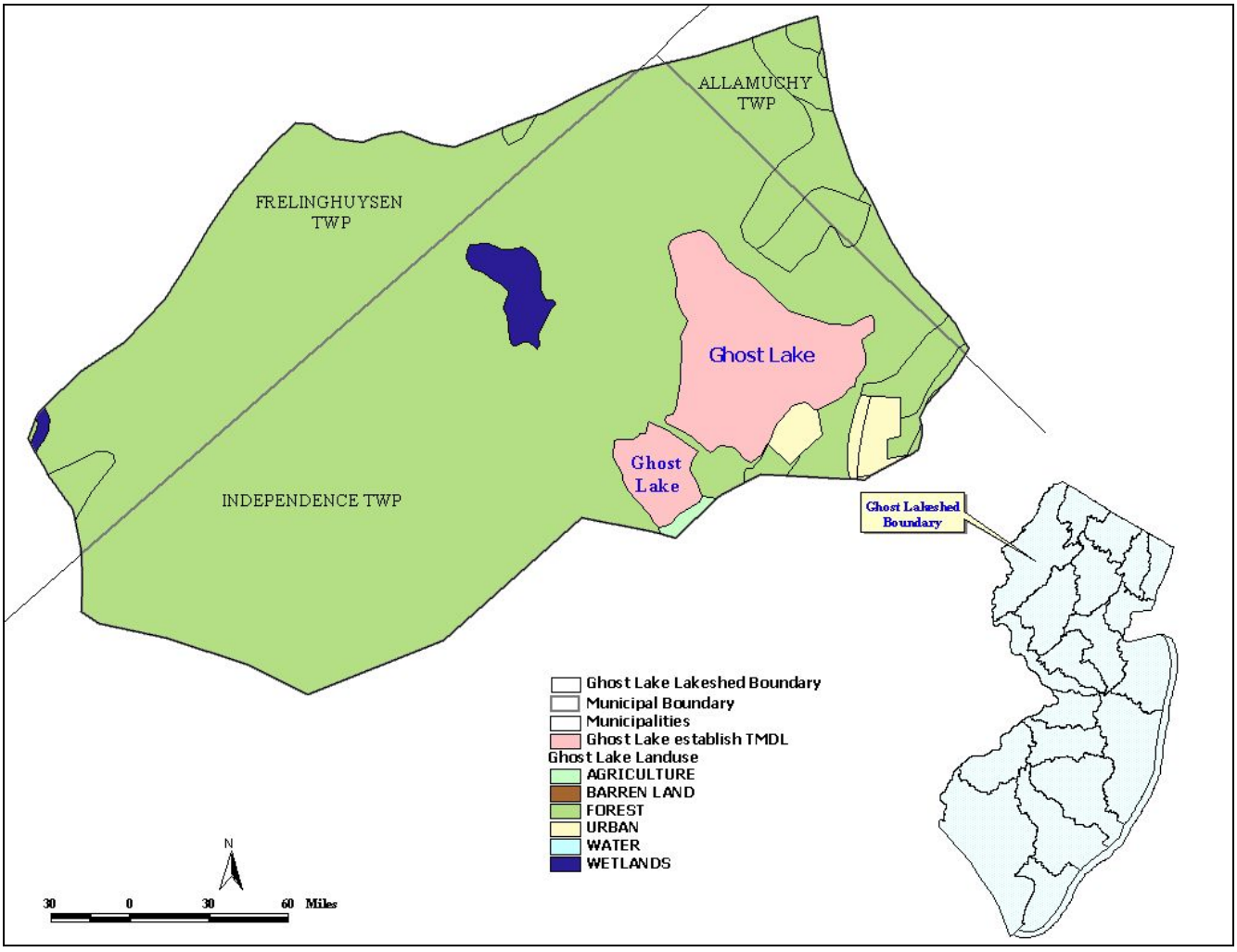


4.2 Ghost Lake

Ghost Lake is located within Jenny Jump State Forest in Independence Township, Warren County, and drains a lakeshed of 212 acres that extends into parts of Frelinghuysen and Allamuchy Townships. The lakeshed is 11.5 times the area of the lakes, making it somewhat large. Ghost Lake has no tributaries; most of the lake's inflow is comprised of groundwater and surface runoff. Mean depth (1.34m) and total inflow (449,000 m^3/yr) were obtained from the Phase 1 Diagnostic / Feasibility Study of Ghost Lake (Princeton Hydro, 2002).

This man-made, shallow lake is 18 acres in size and part of the Pequest River Watershed. A narrow band of land separates the larger upper portion of the lake from the much smaller lower portion. The lakeshed is heavily forested and consists of 187 acres of forest (88 percent). However, in the southeast quadrant of the lakeshed, there are two small clusters of low density/rural development, comprising three acres. Ghost Lake offers fishing and boating (car-top launch only) services at the north end of the lake. Although phosphorus loading to Ghost Lake is currently not excessive, a TMDL is being established to ensure that phosphorus levels do not increase in the future and to establish in-lake measures necessary to restore the lake. To that end, the Department plans to implement as appropriate the recommendations in USEPA Clean Lakes Project Phase I Diagnostic/Feasibility Study, dated February 2002.

Figure 3 Lakeshed of Ghost Lake



4.3 Lake Hopatcong

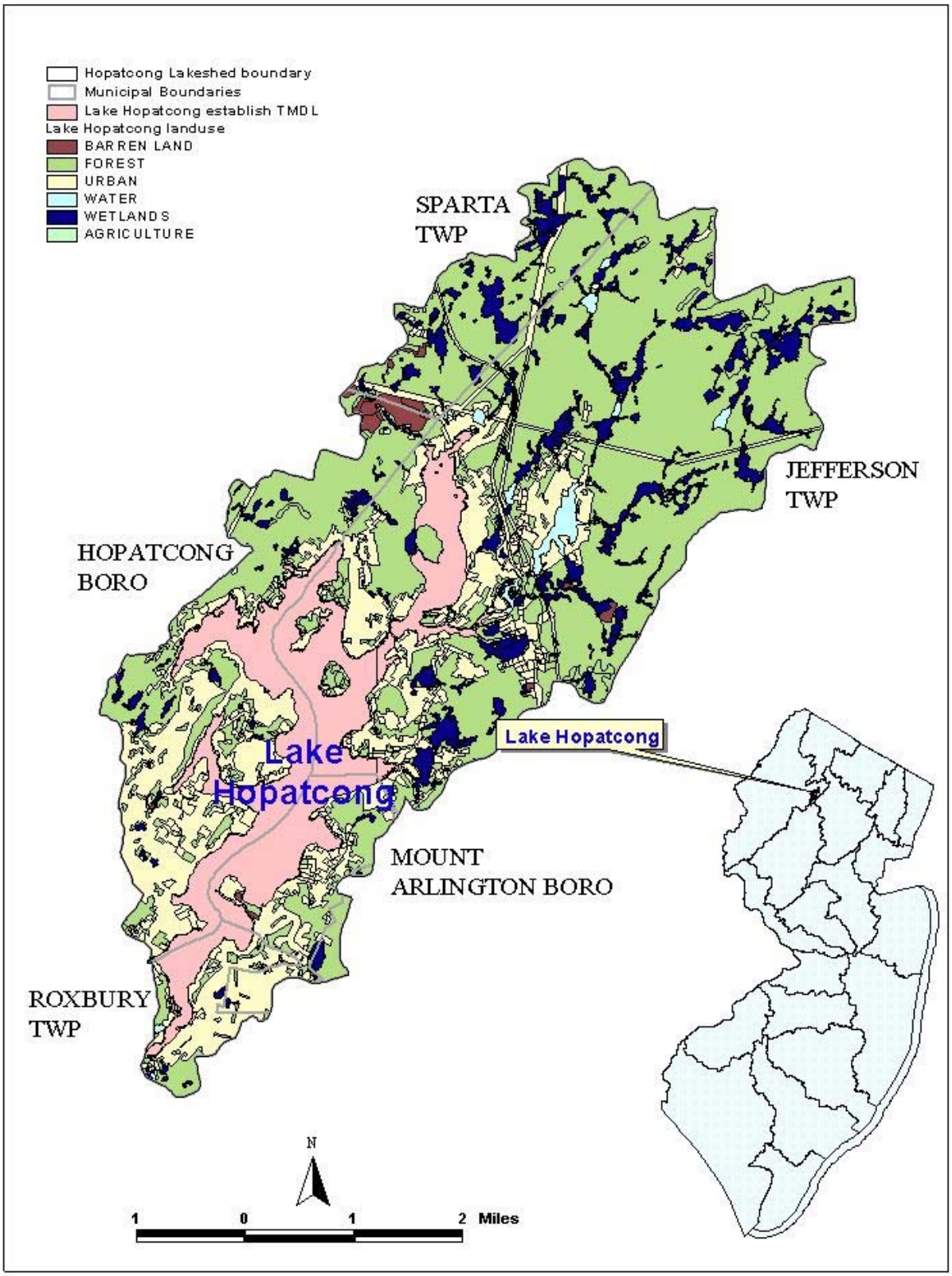
Lake Hopatcong is a 2,406-acre public lake located on the border of Morris and Sussex counties in the municipalities of Mount Arlington Borough, Hopatcong Borough, Jefferson Township, and Roxbury Township. The lake drains a lakeshed of 16,216 acres within the headwaters of the Musconetcong River Watershed. The lakeshed is 6.7 times the area of the lakes, making it fairly small relative to the size of the lake. Lake Hopatcong is a large, irregularly shaped lake composed of many shallow coves around the perimeter. About 50% of the flow into the lake is provided through headwater tributaries of the Musconetcong River, while groudwater inflow comprises about 25% of the flow. Mean depth (5.5m) and total inflow (39,700,000 m^3/yr) were obtained from the Clean Lakes Report for Lake Hopatcong (Princeton Aqua Science, 1983).

Lake Hopatcong is the largest freshwater lake in New Jersey and measures 9.5 miles long with a maximum depth of 58 feet. Originally, Hopatcong consisted of two separate lakes, but a dam built in what is now Lake Hopatcong State Park for the Morris Canal Company linked them together in 1837 to form one large lake. Lake Hopatcong was the major source of water

for the 90-mile waterway that stretched from Newark to Phillipsburg. (The lake is also currently a designated emergency source of drinking water.) The predominant land uses in this lakeshed consist of 9,671 acres of forest and wetlands (including bodies of water other than Lake Hopatcong) and 3,974 acres urban, or 60% and 25%, respectively. About 90% of the land adjacent to the 40-mile lake shore is developed, with the majority in seasonal and year-round low, medium, and high density residential land uses. An estimated 500,000 visitors use Lake Hopatcong's recreational facilities each year for fishing, boating, swimming, sailing, jet skiing, and passive recreation. The lake is known to have some good size fish, with largemouth bass averaging two to five pounds. However, several of its beaches are impaired for fecal coliform, and nonpoint source pollution into the lake has become a critical problem.

The Lake Hopatcong Commission is the entity that has taken control of the lake's improvement and was created in January 2001 under a $3 million startup grant from the State of New Jersey. The Commission's mandate is to safeguard the lake as a natural, scenic, and recreational resource. Some of the tools available to the Commission to accomplish this mandate are monitoring the lake's water quality and quantity; evaluating land use impacts; developing plans, strategies, policies, ordinances, and funding mechanisms; conducting lake management projects; and educating the public on how to protect the lake. A major component of the Lake Hopatcong Commission's protection effort is mechanical harvesting of the overgrowth of aquatic vegetation caused by the influx of phosphorus in the lake. The activity of aquatic plant harvesting began in Lake Hopatcong by the Lake Hopatcong Regional Planning Board and was transferred to the Lake Hopatcong Commission upon its creation. In 2002, the Commission removed over 4.8 million pounds of vegetation from the lake. The Commission has been engaged in a cooperative research effort with the U.S. Geological Survey to conduct a water budget study of Lake Hopatcong. The Commission has initiated plans to address stormwater discharges into Lake Hopatcong, because discharges from such nonpoint sources and catch basins are believed to be a major source of phosphorus in the lake. The Commission also has prepared a geomorphological report describing the Lake Hopatcong area.

Figure 4 Lakeshed of Lake Hopatcong

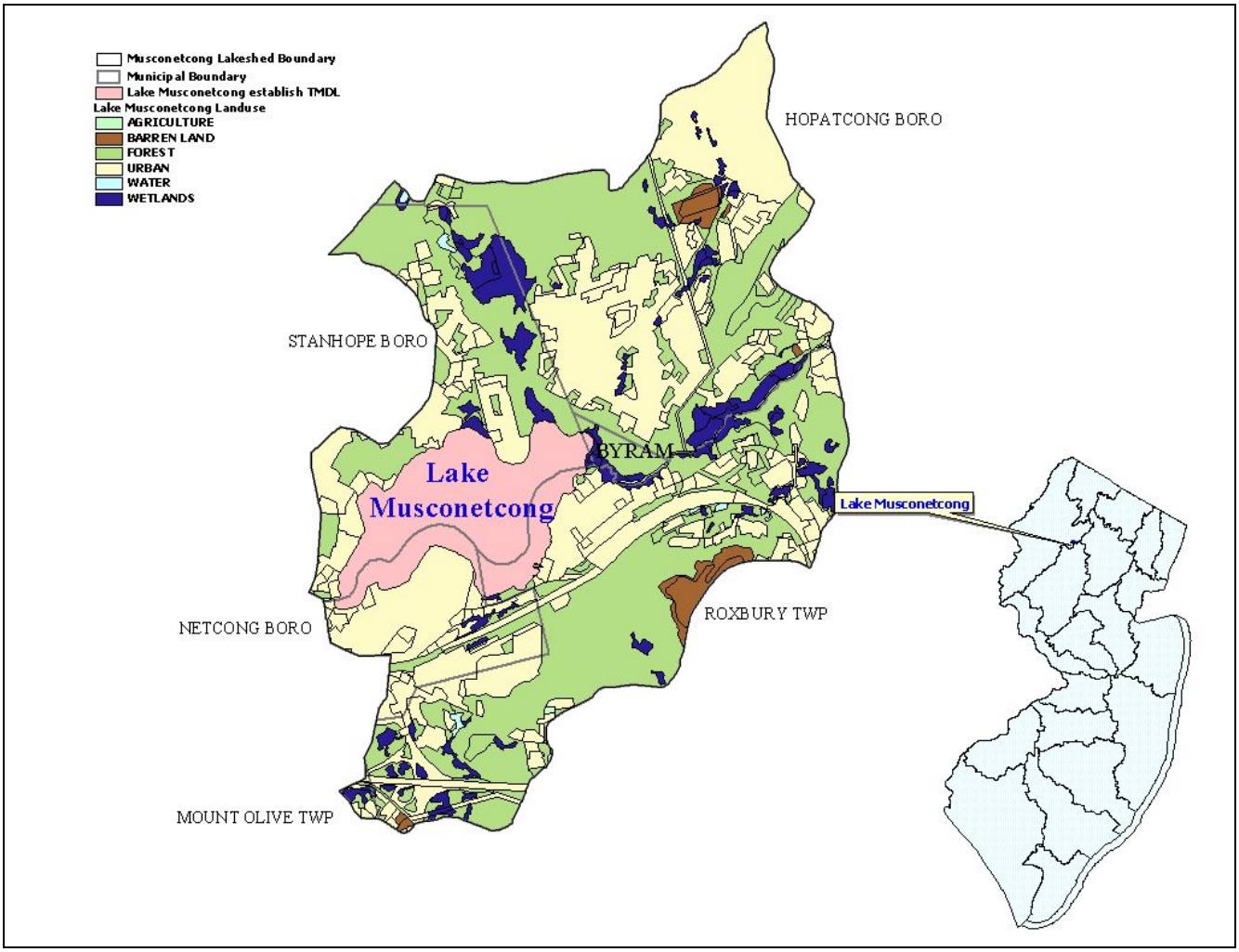


4.4 Lake Musconetcong

Lake Musconetcong is a 314-acre public lake located on the border of Morris and Sussex counties in the municipalities of Netcong, Stanhope, Byram and Roxbury. The lake drains an immediate lakeshed of 2,977 acres within the headwaters of the Musconetcong River Watershed. In addition, Lake Hopatcong drains into the immediate Lake Musconetcong lakeshed, adding 12,091 acres to the total lakeshed. Including the Lake Hopatcong lakeshed, the total lakeshed of Lake Musconetcong is 48 times the area of the lakes, making it very large relative to the size of the lake. Over 80% of the total flow into the lake consists of inflow from Lake Hopatcong through the Musconetcong River. Mean depth (1.5m) and total inflow (48,400,000 m^3/yr) were obtained from the Diagnostic / Feasibility Study for Lake Musconetcong (Coastal Environmental Services, 1993).

By far, the predominant land uses in the Lake Musconetcong lakeshed are forest, with 1,199 acres (40%), and urban, with 1,222 acres (41%). Low and medium density residential land uses surround most of the lakeshore itself. Fishing and boating accommodations are offered at the southern end of Lake Musconetcong. There are several municipal and State park areas on the lake available for fishing, one having a boat launch area. Several dozen private docks, but no public ones, can be found on the lake. Stanhope Beach was dredged several years ago, but it is used for fishing only, due to water conditions. The lake is being aided by two entities, the Musconetcong Regional Planning Board, which advises on land use matters affecting the lake, and the Musconetcong Watershed Association. As a result of the Phase I Clean Lakes project, the area immediately around the lake has been sewered and they have implemented weed harvesting, dredging, and various nonpoint source pollution controls. Lake Musconetcong has received Clean Water Act Section 319(h) funding for best management practices.

Figure 5 immediate Lakeshed of Lake Musconetcong



4.5 Swartswood Lake

This glacier lake, with a mean depth of 22 feet (deep lake) and a maximum depth of 42 feet, is 505 acres in size and located at Swartswood State Park in the Paulins Kill Watershed. Fishing and boating services are available on the east and south sides of the lake, and a swimming area is located on the border of the eastern shore and the State Park. The Swartwood Lakes and Watershed Association has been involved in stormwater projects funded by the Clean Water Act Section 319(h) grants to improve water quality, such as the recently completed five-unit hypolimnetic aeration system to halt deterioration and save the trout fishery. The lake had been suffering from large growths of aquatic weeds, algae, and low dissolved oxygen in deeper waters. Now that this public lake is being restored as a result of remediation projects involving weed harvesting, aeration, and nonpoint source controls, the Department agrees to follow up on its restoration to determine whether uses are still impaired. Malcolm Pirnie is currently performing a diagnostic/feasibility study of Swartswood Lake.

4.6 Clove Acres Lake

Clove Acres Lake is located in Wantage Township and Sussex Borough, Sussex County within the Wallkill River Watershed. The initial water quality evaluation for this shallow lake was completed approximately 20 years ago. Subsequently, the dam broke and the 28-acre lake drained. The lake has not been filled for most of the last fifteen years, during which time a limited amount of dredging took place. The dam was rebuilt and, during the summer of 2002, the lake started to refill. The Department will collect information and determine if the new lake is impaired. It should be noted that, based on the previous morphological and hydrological conditions and land use characteristics as of 1995, the Department estimates that the overall nonpoint source load of total phosphorus would have to be reduced by at least 64%. Currently, a consultant Fred Yoerg/Associates has been engaged to begin working on a lake management plan.

5.0 Applicable Surface Water Quality Standards

In order to prevent excessive primary productivity and consequent impairment of recreational, water supply and aquatic life designated uses, the Surface Water Quality Standards (SWQS, N.J.A.C. 7:9B) define both numerical and narrative criteria that address eutrophication in lakes due to overfertilization. The total phosphorous (TP) criterion for freshwater lakes at N.J.A.C. 7:9B – 1.14(c)5 reads as follows:

> For freshwater 2 classified lakes, Phosphorus as total phosphorus shall not exceed 0.05 mg/l in any lake, pond or reservoir or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed to satisfy N.J.A.C. 7:9B-1.5(g)3.

N.J.A.C. 7:9B-1.5(g)3 states:

> The Department may establish site-specific water quality criteria for nutrients in lakes, ponds, reservoirs or stream, in addition to or in place of the criteria in N.J.A.C. 7:9B-1.14, when necessary to protect existing or designated uses. Such criteria shall become part of the SWQS.

Presently, no site-specific criteria apply to any of these lakes.

Also at N.J.A.C. 7:9B-1.5(g)2, the following is discussed:

> Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, or otherwise render the waters unsuitable for the designated uses.

These TMDLs are designed to meet both numeric and narrative criteria of the SWQS.

All of the waterbodies covered under these TMDLs have a FW2 classification. The designated uses, both existing and potential, that have been established by the Department for waters of the State classified as such are as stated below:

In all FW2 waters, the designated uses are (N.J.A.C. 7:9B-1.12):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

6.0 Source Assessment

Phosphorus sources were characterized on an annual scale (kg TP/yr). Long-term pollutant loads are typically more critical to overall lake water quality than the load at any particular short-term time period (e.g. day). Storage and recycling mechanisms in the lake, such as luxury uptake and sediments dynamics, allow phosphorus to be used as needed regardless of the rate of delivery to the system. Also, empirical lake models use annual loads rather than daily or monthly loads to estimate in-lake concentrations.

6.1 Assessment of Point Sources other than Stormwater

Point sources of phosphorus other than stormwater were identified using the Department's GIS as all Major Municipal (MMJ), Minor Municipal (MMI), and Combined Sewer Overflow (CSO) discharges within each lakeshed. Other types of discharges, such as Industrial, were not included because their contribution, if any, is negligible compared to municipal discharges and runoff from land surfaces. No municipal point sources exist anywhere within the lakesheds of Cranberry Lake or Ghost Lake. One MMI, Arthur Stanlick School, discharges within the Lake Hopatcong lakeshed. The current annual TP load was estimated by multiplying the monthly average TP concentration of 0.314 mg TP/l by the average flow of 0.0014 million gallons per day (MGD), and converting to units of kg/yr. Average flow and concentration were calculated from data submitted to the Department as required in the form of Discharge Monitoring Reports. Similarly, the currently permitted annual TP load was estimated by multiplying the current TP concentration limit of 1.0 mg TP/l by the permitted flow of 0.013 MGD, and converting to units of kg/yr. Since Lake Hopatcong discharges into the Lake Musconetcong lakeshed, the point source was included only indirectly as part of the tributary load into Lake Musconetcong.

Table 3 Point Source Phosphorus Loads

Lake	NJPDES #	Facility Name	receiving water	current P load (kg TP/yr)	permitted P load (kg TP/yr)
Lake Hopatcong	NJ0021105	Arthur Stanlick School	Lake Shawnee	0.6	18.0

6.2 Assessment of Nonpoint Sources and Stormwater

Runoff from land surfaces comprises most of the nonpoint and stormwater sources of phosphorus into lakes. Watershed loads for total phosphorus were therefore estimated using the Unit Areal Load (UAL) methodology, which applies pollutant export coefficients obtained from literature sources to the land use patterns within the watershed, as described in USEPA's Clean Lakes Program guidance manual (Reckhow,1979b). Land use was determined using the Department's GIS system using the 1995/1997 land use coverage. The Department reviewed phosphorus export coefficients from an extensive database (Appendix B) and selected the land use categories and values shown in Table 4.

Table 4 Phosphorus export coefficients (Unit Areal Loads)

land use / land cover	LU/LC codes[3]	UAL (kg TP/ha/yr)
medium / high density residential	1110, 1120, 1150	1.6
low density / rural residential	1130, 1140	0.7
Commercial	1200	2.0
Industrial	1300, 1500	1.7
mixed urban / other urban	other urban codes	1.0
Agricultural	2000	1.5
forest, wetland, water	4000, 6000, 5000	0.1
barren land	7000	0.5

Units: 1 hectare (ha) = 2.47 acres
1 kilogram (kg) = 2.2 pounds (lbs)
1 kg/ha/yr = 0.89 lbs/acre/yr

For all lakes in this TMDL document, a UAL of 0.07 kg TP/ha/yr was used to estimate air deposition of phosphorus directly onto the lake surface. This value was developed from statewide mean concentrations of total phosphorus from the New Jersey Air Deposition Network (Eisenreich and Reinfelder, 2001). For Lake Musconetcong, land use runoff loads were only calculated for the immediate watershed downstream of Lake Hopatcong. An additional annual tributary load from Lake Hopatcong into Lake Musconetcong was estimated by multiplying the annual discharge from the lake by the mean phosphorus concentration as calculated under Current Condition in section 7.1 below. Land uses and calculated runoff loading rates for each of the lakes are shown in Table 5. Also included in Table 5 are estimates of loading rates from septic systems and from internal sources (sediment regeneration, macrophyte decomposition, and/or groundwater) developed

[3] LU/LC code is an attribute of the land use coverage that provides the Anderson classification code for the land use. The Anderson classification system is a hierarchical system based on four digits. The four digits represent one to four levels of classification, the first digit being the most general and the fourth digit being the most specific description.

previously (Coastal Environmental Services, 1992; Princeton Aqua Science, 1983; Coastal Environmental Services, 1993; Princeton Hydro, 2002) for each of the lakes.

Table 5 Nonpoint and Stormwater Sources of Phosphorus Loads*

	Cranberry Lake		Lake Hopatcong		Lake Musconetcong		Ghost Lake	
Nonpoint Source	**acres**	**Kg TP/yr**	**acres**	**Kg TP/yr**	**acres**	**Kg TP/yr**	**acres**	**Kg TP/yr**
medium / high density residential	156	101	2,790	1,800	759	492	0.0	0.0
low density / rural residential	9.0	2.5	423	120	116	32.9	3.2	0.9
commercial	1.5	1.2	237	192	107	86.9	0.0	0.0
industrial	0.0	0.0	7.7	5.3	37.1	25.6	0.0	0.0
mixed urban / other urban	0.0	0.0	521	211	207	83.7	0.0	0.0
agricultural	0.4	0.2	0	0	0.9	0.5	0.4	0.3
forest, wetland, water	1,380	55.9	9,670	391	1,360	55.2	190	7.7
barren land	6.8	1.4	165	33.3	72.6	14.7	0.0	0.0
Direct air deposition on lake surface	190	5.4	2,410	68.2	314	8.9	18.3	0.5
septic systems	n/a	731	n/a	1,600	n/a		n/a	
internal load	n/a	104	n/a	595	n/a	151	n/a	12.4
tributary load	n/a		n/a		n/a	1,240	n/a	
TOTAL	1,740	1,000	16,200	5,020	2,980	2,190	211	21.8

* all figures rounded to not more than three significant digits

7.0 Water Quality Analysis

Empirical models were used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. These empirical models consist of equations derived from simplified mass balances that have been fitted to large datasets of actual lake measurements. The resulting regressions can be applied to lakes that fit within the range of hydrology, morphology and loading of the lakes in the model database. The Department surveyed the commonly used models in Table 6.

Table 6 Empirical models considered by the Department

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Rast, Jones and Lee, 1983	$1.81 \times NPL^{0.81}$	$NPL = \left(\frac{P_a \times DT / D_m}{1 + \sqrt{DT}} \right)$	expanded database of mostly large lakes
Vollenweider and Kerekes, 1982	$1.22 \times NPL^{0.87}$	$NPL = \left(\frac{P_a \times DT / D_m}{1 + \sqrt{DT}} \right)$	mostly large natural lakes
Reckhow, 1980	$\frac{P_a}{13.2}$	none	Upper bound for closed lake
Reckhow, 1979a	$\frac{P_a}{(11.6 + 1.2 \times Q_a)}$	$Q_a = \frac{Q_i}{A_l}$	General north temperate lakes, wide range of loading concentration, areal loading, and water load

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Walker, 1977	$\frac{P_a \times DT/D_m}{\left(1+0.824\times DT^{0.454}\right)}$	none	oxic lakes with $D_m/DT < 50$ m/yr
Jones and Bachmann, 1976	$\frac{0.84\times P_a}{\left(D_m\times\left(0.65+DT^{-1}\right)\right)}$	none	may overestimate P in shallow lakes with high D_m/DT
Vollenweider, 1975	$\frac{P_a}{\left(D_m\times\left(DT^{-1}+S\right)\right)}$	$S = 10/D_m$	Overestimate P lakes with high D_m/DT
Dillon-Kirchner, 1975	$\frac{P_a}{\left(13.2+D_m/DT\right)}$	none	low loading concentration range
Dillon-Rigler, 1974	$P_a \times DT/D_m \times\left(1-R\right)$	R = phosphorus retention coefficient	general form
Ostrofksy, 1978	Dillon-Rigler, 1974	$R = 0.201\times e^{\left(-0.0425\times Q_a\right)} + 0.5743\times e^{-0.00949*Q_a}$	lakes that flush infrequently
Kirchner-Dillon, 1975	Dillon-Rigler, 1974	$R = 0.426\times e^{\left(-0.271\times D_m/DT\right)} + 0.5743\times e^{-0.00949*D_m/DT}$	general application
Larsen-Mercier, 1975	Dillon-Rigler, 1974	$R = \frac{1}{1+\sqrt{1/DT}}$	Unparameterized form

where:
NPL = normalized phosphorus loading
P_a = areal phosphorus loading ($g/m^2/yr$)
DT = detention time (yr)
D_m = mean depth (m)
Qa = areal water load (m/yr) [4]
Q_i = total inflow (m^3/yr)
A_l = area of lake (m^2)
S = settling rate (per year)

Reckhow (1979a) model was selected because it has the broadest range of hydrologic, morphological and loading characteristics in its database. Also, the model includes an uncertainty estimate that was used to calculate a Margin of Safety. The Reckhow (1979a) model is described in USEPA Clean Lakes guidance documents: Quantitative Techniques for the Assessment of Lake Quality (Reckhow, 1979b) and Modeling Phosphorus Loading and Lake Response Under Uncertainty (Reckhow *et al*, 1980). The derivation of the model is

[4] Areal water load is defined as the annual water load entering a lake divided by the area of the lake. Since, under steady-state conditions, the water coming in to the lake is equal to the water leaving the lake, either total inflow or total outflow can be used to calculate areal water load. If different values were reported for total inflow and total outflow, the Department used the higher of the two to calculate areal water load.

summarized in Appendix C. The model relates TP load to steady state TP concentration, and is generally applicable to north temperate lakes, which exhibit the following ranges of characteristics (see Symbol definitions after Table 5):

phosphorus concentration:	$0.004 < P < 0.135$ mg/l
average influent phosphorus concentration:	$P_a*DT/D_m < 0.298$ mg/l
areal water load:	$0.75 < Q_a < 187$ m/yr
areal phosphorus load:	$0.07 < P_a < 31.4$ g/m²/yr

For comparison, Table 7 below summarizes the characteristics for each lake based on their current and target conditions as described below. While the target concentration for each lake (section 7) is well within the range, the areal phosphorus load provides a better representation of a lake's intrinsic loading characteristics. Also, it is the model's prediction of target condition that is being used to calculate the TMDL; if current loads are higher than the range that can produce reliable model results, this has no affect on the model's reliability to predict target condition under reduced loads. It should also be noted that no attempt was made to recalibrate the Reckhow (1979a) model for lakes in New Jersey or in this Water Region, since sufficient lake data were not available to make comparisons with model predictions of steady-state in-lake concentration of total phosphorus. The model was already calibrated to the dataset on which it is based, and is generally applicable to north temperate lakes that exhibit the range of characteristics listed previously.

Table 7 Hydrologic and loading characteristics of lakes

Lake	Current Avg Influent [TP] (mg/l)	Target Avg Influent [TP] (mg/l)	Current Areal TP load (g/m²/yr)	Target Areal TP load (g/m²/yr)	Areal Water Load (m/year)
Cranberry Lake	0.265	0.071	1.31	0.35	4.9
Ghost Lake	0.049	0.049	0.19	0.19	6.0
Lake Hopatcong	0.126	0.080	0.52	0.33	4.1
Lake Musconetcong	0.045	0.030	1.73	1.14	38.1

7.1 Current Condition

Using these estimated physical parameters and current loads, the predicted steady-state phosphorus concentration of each lake was calculated using the Reckhow (1979a) formulation and listed in Table 8. The current phosphorus load distribution for each lake is shown in Figures 6 to 9 below.

Figure 6 **Current distribution of phosphorus load for Cranberry Lake**

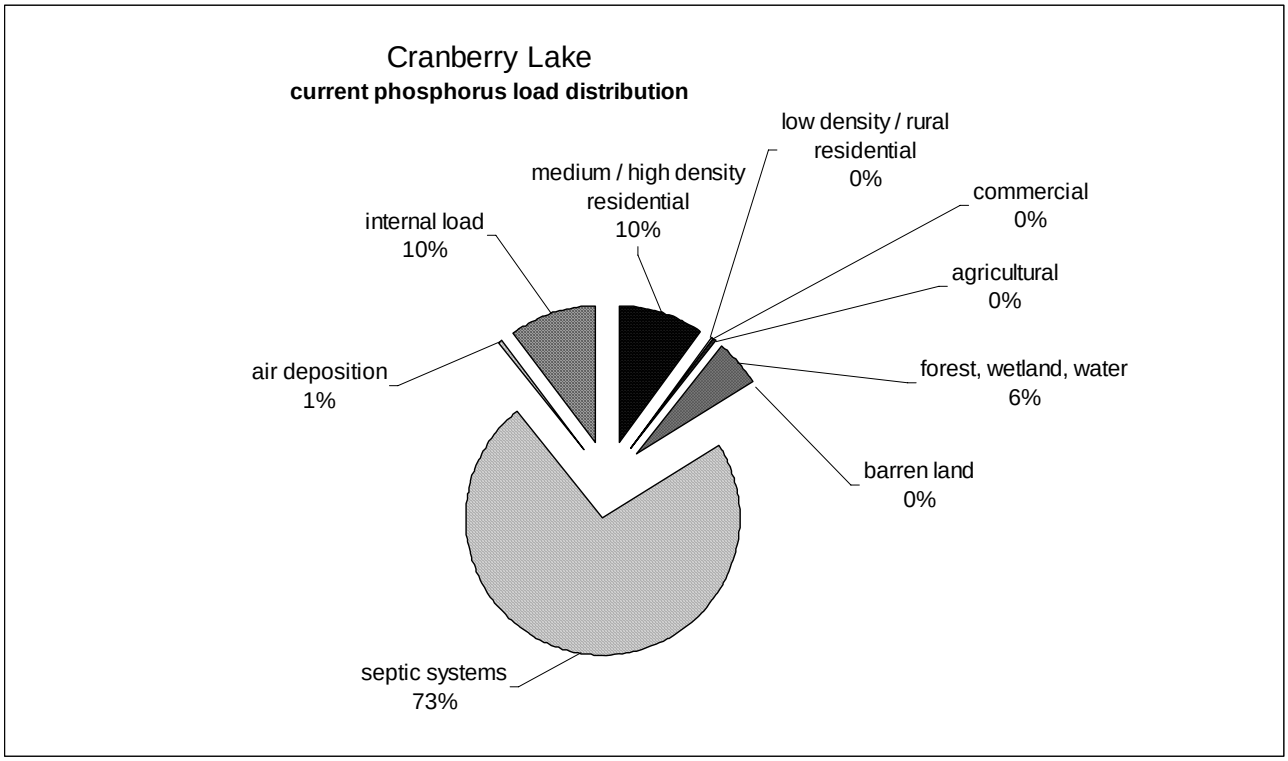


Figure 7 **Current distribution of phosphorus load for Ghost Lake**

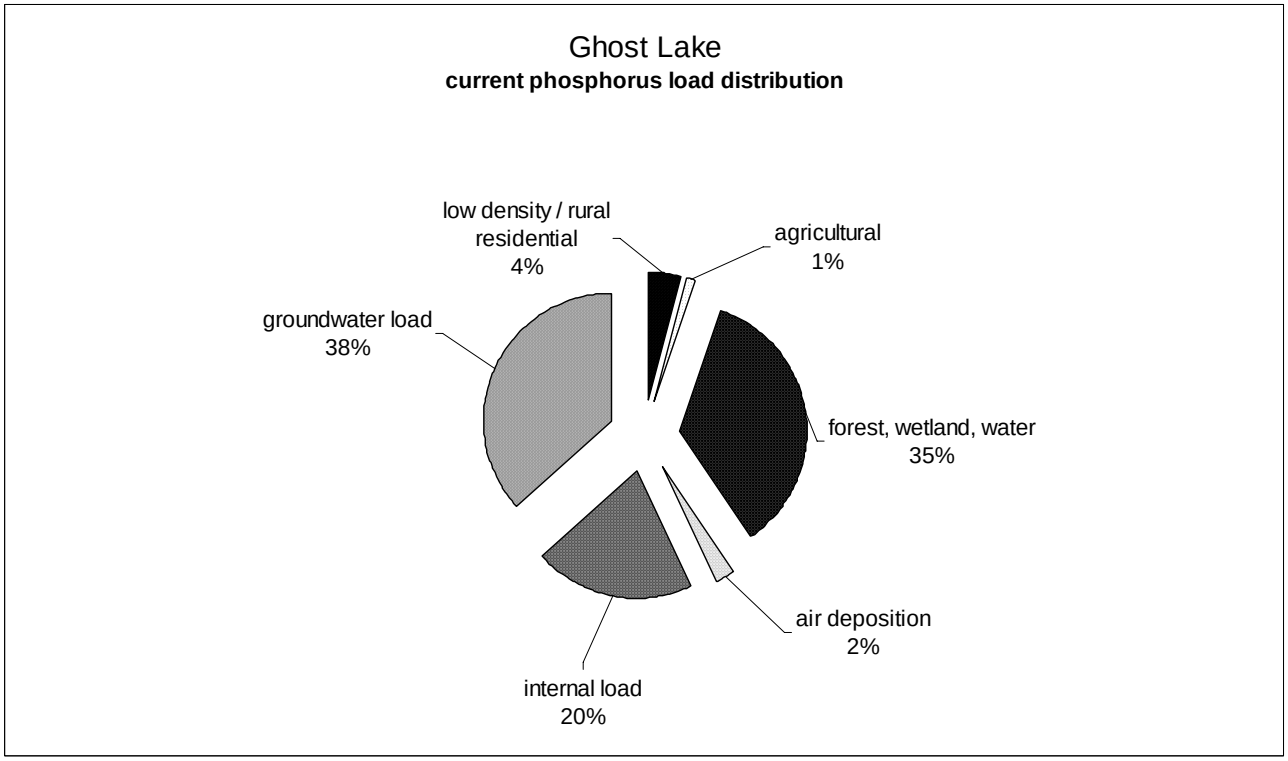


Figure 8 **Current distribution of phosphorus load for Lake Hopatcong**

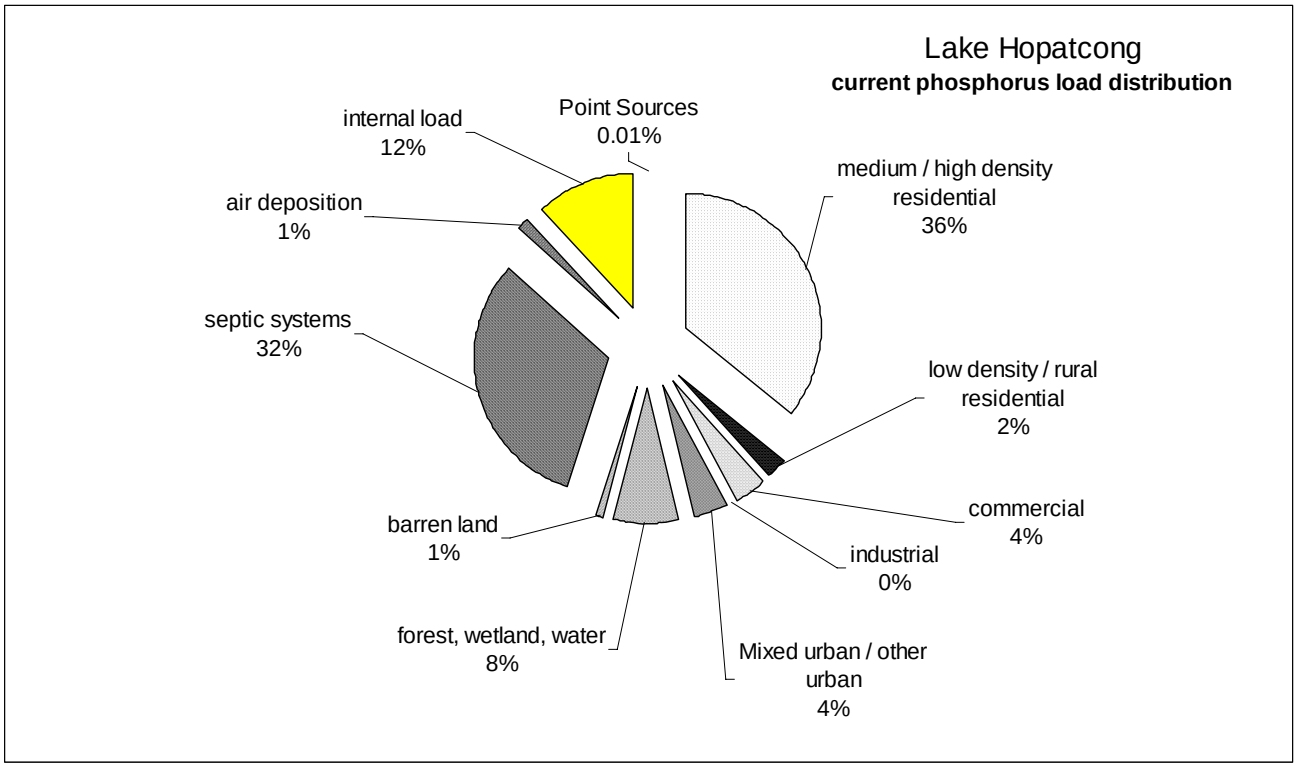
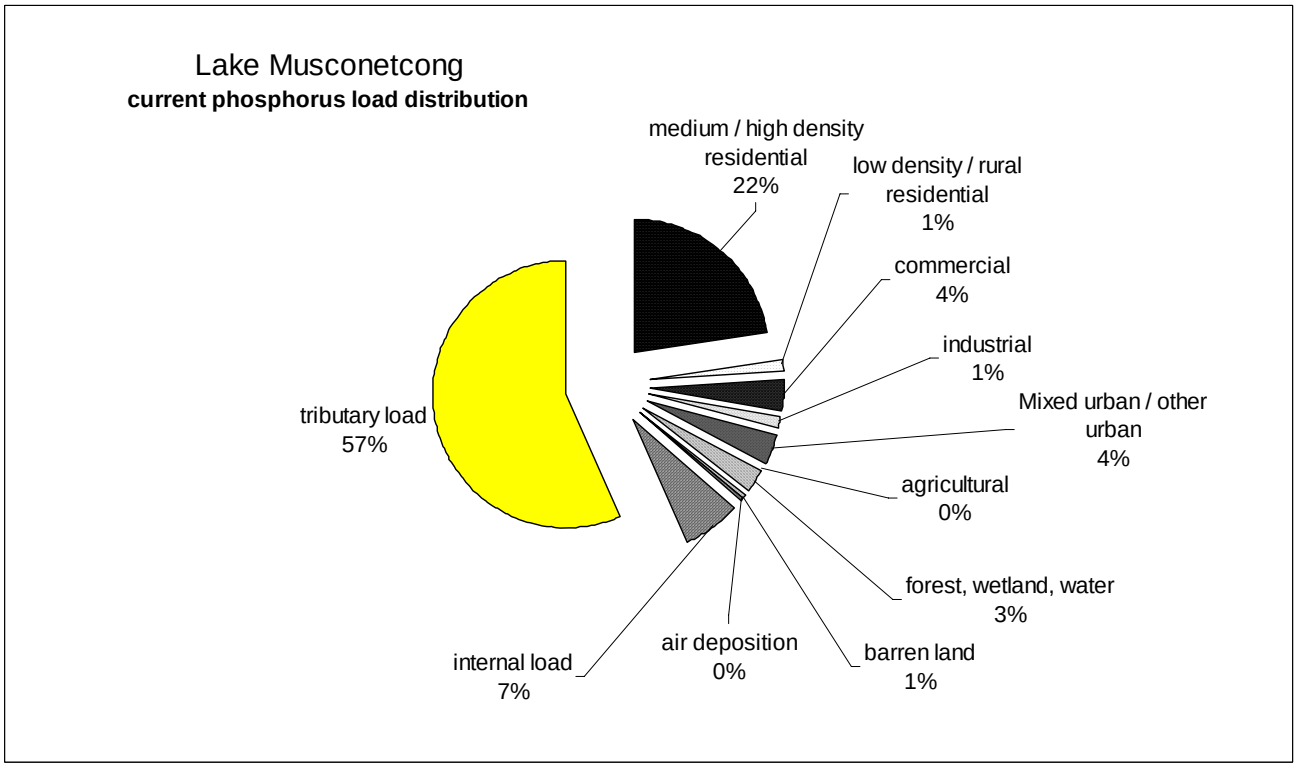


Figure 9 **Current distribution of phosphorus load for Lake Musconetcong**



7.2 Reference Condition

A reference condition for each lake was estimated by calculating external loads as if the land use throughout the lakeshed were completely forest and wetlands. Using the same physical parameters and external loads from forest and wetlands, a reference steady-state phosphorus concentration was calculated for each lake using the Reckhow (1979a) formulation and listed in Table 8.

7.3 Seasonal Variation/Critical Conditions

These TMDLs will attain applicable surface water quality standards year round. The Reckhow model predicts steady-state phosphorus concentration. To account for data variability, the Department generally interprets threshold criteria as greater than 10% exceedance for the purpose of defining impaired waterbodies. Data from two lakes in New Jersey for which the Department had ready access to data (Strawbridge Lake, NJDEP 2000a; Sylvan Lake, NJDEP 2000b) exhibit peak (based on the 90th percentile) to mean ratios of 1.56 and 1.48, resulting in target phosphorus concentrations of 0.032 and 0.034 mg TP/l, respectively. Since the peak to mean ratios were close and the target concentration not very sensitive to differences in peak to mean ratios, the Department determined that a target phosphorus concentration of 0.03 mg TP/l is reasonably conservative. The seasonal variation was therefore assumed to be 67%, resulting in a target phosphorus concentration of 0.03 mg TP/l. Since it is the annual pollutant load rather than the load at any particular time that determines overall lake water quality (section 6), the target phosphorus concentration of 0.03 mg TP/l accounts for critical conditions.

7.4 Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality." (40 CFR 130.7(c)). A MOS is required in order to account for uncertainty in the loading estimates, physical parameters and the model itself. The margin of safety, as described in USEPA guidance (Sutfin, 2002), can be either explicit or implicit (i.e., addressed through conservative assumptions used in establishing the TMDL). For these TMDL calculations, an implicit as well as explicit Margin of Safety (MOS) is provided.

These TMDLs contain an implicit margin of safety by using conservative critical conditions, over-estimated loads, and total phosphorus. Each conservative assumption is further explained below.

Critical conditions are accounted by comparing peak concentrations to mean concentrations and adjusting the target concentration accordingly (0.03 mg TP/l instead of 0.05 mg TP/l). In addition to the conservative approach used for critical conditions, the land use export methodology does not account for the distance between the land use and the lake, which will result in phosphorus reduction due to adsorption onto land surfaces and in-stream kinetic processes**.** Furthermore, the lakesheds are based on topography without accounting for the

diversion of stormwater from lakes, which is common in urban areas. Neither are any reductions assumed due to the addition of lakeside vegetative buffer construction or other management practices aimed at minimizing phosphorus loads. Finally, the use of total phosphorus, as both the endpoint for the standard and in the loading estimates, is a conservative assumption. Use of total phosphorous does not distinguish readily between dissolved orthophosphorus, which is available for algal growth, and unavailable forms of phosphorus (e.g. particulate). While many forms of phosphorus are converted into orthophosphorus in the lake, many are captured in the sediment, for instance, and never made available for algal uptake.

In addition to the multiple conservative assumptions built in to the calculation, an additional explicit margin of safety was included to account for the uncertainty in the model itself. As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. Transforming the terms in the model error analysis from Reckhow *et al* (1980) yields the following (Appendix D):

$$MoS_p = \sqrt{1/((1-\rho)*4.5)} \times \left(10^{0.128} - 1\right),$$

where: MoS_p = margin of safety as a percentage over the predicted phosphorus concentration;

ρ = the probability that the real phosphorus concentration is less than or equal to the predicted phosphorus concentration plus the margin of safety as a concentration.

Setting the probability to 90% yields a margin of safety of 51% when expressed as a percentage over predicted phosphorus concentration or estimated external load. The external load for each lake was therefore multiplied by 1.51 to calculate an "upper bound" estimate of steady-state phosphorus concentration. An additional explicit margin of safety was included in the analyses by setting the upper bound calculations equal to the target phosphorus concentration of 0.3 mg TP/l, as described in the next section and shown in Table 8. Note that the explicit Margin of Safety is equal to 51% when expressed as a percentage over the predicted phosphorus concentration; when expressed as a percentage of total loading capacity, the Margin of Safety is equal to 34%:

$$\left(MoS_{lc} = \frac{MoS_p \times P}{P + (MoS_p \times P)} = \frac{MoS_p}{1 + MoS_p} = \frac{0.51}{1.51} = 0.34\right),$$

where: MoS_p = margin of safety expressed as a percentage over the predicted phosphorus concentration or external load;

MoS_{lc} = margin of safety as a percentage of total loading capacity;

P = predicted phosphorus concentration (or external load).

7.5 Target Condition

As discussed above, the current steady state concentration of phosphorus in each lake must be reduced to a steady state concentration of 0.03 mg/l to avoid exceeding the 0.05 mg/l phosphorus criterion. Using the Reckhow (1979a) formulation, the target conditions were calculated by reducing the loads as necessary to make the upper bound predictions (which incorporate the Margin of Safety) equal to the target phosphorus concentration of 0.03 mg TP/l. The target condition for Ghost Lake was set equal to the current condition, since the upper bound prediction assuming current loads is already less than the target phosphorus concentration of 0.03 mg TP/l. The target condition for Lake Hopatcong was used to calculate the tributary load for the target condition of Lake Musconetcong. Overall reductions necessary to attain the target steady state concentration of total phosphorus in each lake were calculated by comparing the current condition to the target condition (Table 8).

Table 8 Current condition, reference condition, target condition and overall percent reduction for each lake

Lake	current condition [TP] (mg/l)	reference condition [TP] (mg/l)	upper bound target condition [TP] (mg/l)	target condition [TP] (mg/l)	% overall TP load reduction
Cranberry Lake	0.075	0.005	0.030	0.020	73%
Ghost Lake	0.016	0.006	0.024	0.016	0%
Lake Hopatcong	0.031	0.004	0.030	0.020	36%
Lake Musconetcong	0.030	0.011	0.030	0.020	34%

8.0 TMDL Calculations

8.1 Loading Capacity

The Reckhow (1979a) model was used to solve for loading rate given the upper bound target concentration of 0.03 mg/l (which incorporates the Margin of Safety). Reducing the current loading rates by the percentages in Table 8 yields the same results. The acceptable loading capacity for each lake is provided in Table 10.

8.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included at this time. Therefore, the loading capacities and accompanying WLAs and LAs must be attained in consideration of any new sources that may accompany future development. The primary means by which future growth could increase phosphorus load is through the development of forest land within the lakesheds. The implementation plan includes the development of Lake Restoration Plans that require the collection of more detailed information about each lakeshed. If the development of forest with the watershed of a particular lake is planned, the issue of reserve capacity to account for the additional runoff load of phosphorus may be revisited.

8.3 Allocations

USEPA regulations at 40 CFR § 130.2(i), state that "pollutant loadings may be expressed in terms of either mass per time, toxicity, or other appropriate measure." For lake nutrient TMDLs, it is appropriate to express the TMDL on a yearly basis. Long-term average pollutant loadings are typically more critical to overall lake water quality due to the storage and recycling mechanisms in the lake. Also, most available empirical lake models, such as the Reckhow model used in this analysis, use annual loads rather than daily loads to estimate in-lake concentrations.

The TMDLs for total phosphorus are therefore calculated as follows (Table 10):

TMDL = loading capacity
= Sum of the wasteload allocations (WLAs) + load allocations (LAs) + margin of safety + reserve capacity.

WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system." (Wayland, November 2002, p.1) While the Department does not have the data to actually delineate lakesheds according to stormwater drainage areas subject to NJPDES regulation, the land use runoff categories previously defined can be used to estimate between them. Therefore allocations are established according to source categories as shown in Table 9. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs, including Table 9, shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES. WLAs are hereby established for all NJPDES-regulated point sources, including stormwater, according to their source category. Quantifying WLAs and LAs according to source categories provides the best estimation defined as narrowly as data allow. However it is clearly noted that WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. The WLAs and LAs in Table 9 are not themselves "Additional Measures" under proposed N.J.A.C. 7:14A-25.6 or 25.8.

Table 9 Distribution of WLAs and LAs among source categories

Source category	TMDL allocation
Point Sources other than Stormwater	WLA
Nonpoint and Stormwater Sources	
medium / high density residential	WLA
low density / rural residential	WLA
commercial	WLA
industrial	WLA
Mixed urban / other urban	WLA
agricultural	LA
forest, wetland, water	LA
barren land	LA
air deposition onto lake surface	LA
septic systems	LA
internal load	LA
tributary load	LA

In order to attain the TMDLs, the overall load reductions shown in Table 8, or those determined through additional monitoring, must be achieved. Since loading rates have been defined for at least eight source categories, countless combinations of source reductions could be used to achieve the overall reduction target. The selected scenarios focus on land use and septic sources that can be affected by BMP implementation or NJPDES regulation, requiring equal percent reductions from each in order to achieve the necessary overall load reduction (Table 10). The Lake Restoration Plans developed for each lake as part of the TMDL implementation (section 10) may revisit the distribution of reductions among the various sources in order to better reflect actual implementation projects. The resulting TMDLs, rounded to two significant digits, are shown in Table 10 and illustrated in Figures 10 to 13.

The WLA of 5.5 kg TP/yr for Arthur Stanlick School was calculated by multiplying the current TP concentration limit of 1.0 mg TP/l by the 20-year planned flow of 0.004 MGD, and converting to units of kg/yr. This WLA represents about a 70% decrease from currently permitted annual TP load of 18 kg/yr; however, the actual current annual TP load is only 0.6 kg/yr (section 6.1). Since the WLA represents only 0.1% of the loading capacity for Lake Hopatcong, reduction of the currently permitted concentration limit is not justified. However a WLA was established for this facility in order to prevent the source from becoming significant by incorporating the 20-year planned flow into the next permit. The resulting TMDLs, rounded to two significant digits, are shown in Table 10 and illustrated in Figures 10 to 13.

Table 10 TMDL calculations for each lake (annual loads and percent reductions[a])

lake	Cranberry Lake		% reduction	Ghost Lake		% reduction
	kg TP/yr	% of LC		kg TP/yr	% of LC	
loading capacity (LC)	400	100%	n/a	33	100%	n/a
Point Sources other than Stormwater	n/a			n/a		
Nonpoint and Stormwater Sources						
medium / high density residential	12	3.0%	88%	0.00	0.0%	n/a
low density / rural residential	0.30	0.08%	88%	0.91	2.8%	0%
commercial	0.15	0.04%	88%	0.00	0.0%	n/a
industrial	0.00	0.00%	n/a	0.00	0.0%	n/a
Mixed urban / other urban	0.00	0.00%	n/a	0.00	0.0%	n/a
agricultural	0.23	0.06%	0%	0.27	0.81%	0%
forest, wetland, water	56	14%	0%	7.7	23%	0%
barren land	1.4	0.34%	0%	0.00	0.0%	n/a
air deposition onto lake surface	5.4	1.3%	0%	0.52	1.6%	0%
septic systems	87	22%	88%			
internal load	100	26%	0%	12	38%	0%
Other Allocations						
explicit Margin of Safety	140	34%	n/a	11	34%	n/a
Reserve Capacity	n/a			n/a		

lake	Lake Hopatcong		% reduction	Lake Musconetcong		% reduction
	kg TP/yr	% of LC		kg TP/yr	% of LC	
loading capacity (LC)	4800	100%	n/a	2200	100%	n/a
Point Sources other than Stormwater	5.5	0.11%	69%[b]	n/a		
Nonpoint and Stormwater Sources						
medium / high density residential	960	20%	47%	290	13%	41%
low density / rural residential	64	1.3%	47%	20	0.89%	41%
commercial	100	2.1%	47%	52	2.4%	41%
industrial	2.8	0.06%	47%	15	0.69%	41%
Mixed urban / other urban	110	2.3%	47%	50	2.3%	41%
agricultural	0.0	0.0%	n/a	0.52	0.02%	0%
forest, wetland, water	390	8.1%	0%	55	2.5%	0%
barren land	33	0.69%	0%	15	0.67%	0%
air deposition onto lake surface	68	1.4%	0%	8.9	0.41%	0%
septic systems	850	18%	47%	n/a		
internal load	600	12%	0%	150	6.9%	0%
tributary load	n/a			790	36%	36%
Other Allocations						
explicit Margin of Safety	1600	34%	n/a	740	34%	n/a
Reserve Capacity	n/a			n/a		

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 7.

b Percent reduction for point source is compared to currently permitted annual load, not actual current load.

Figure 10 **Phosphorus allocations for Cranberry Lake TMDL**

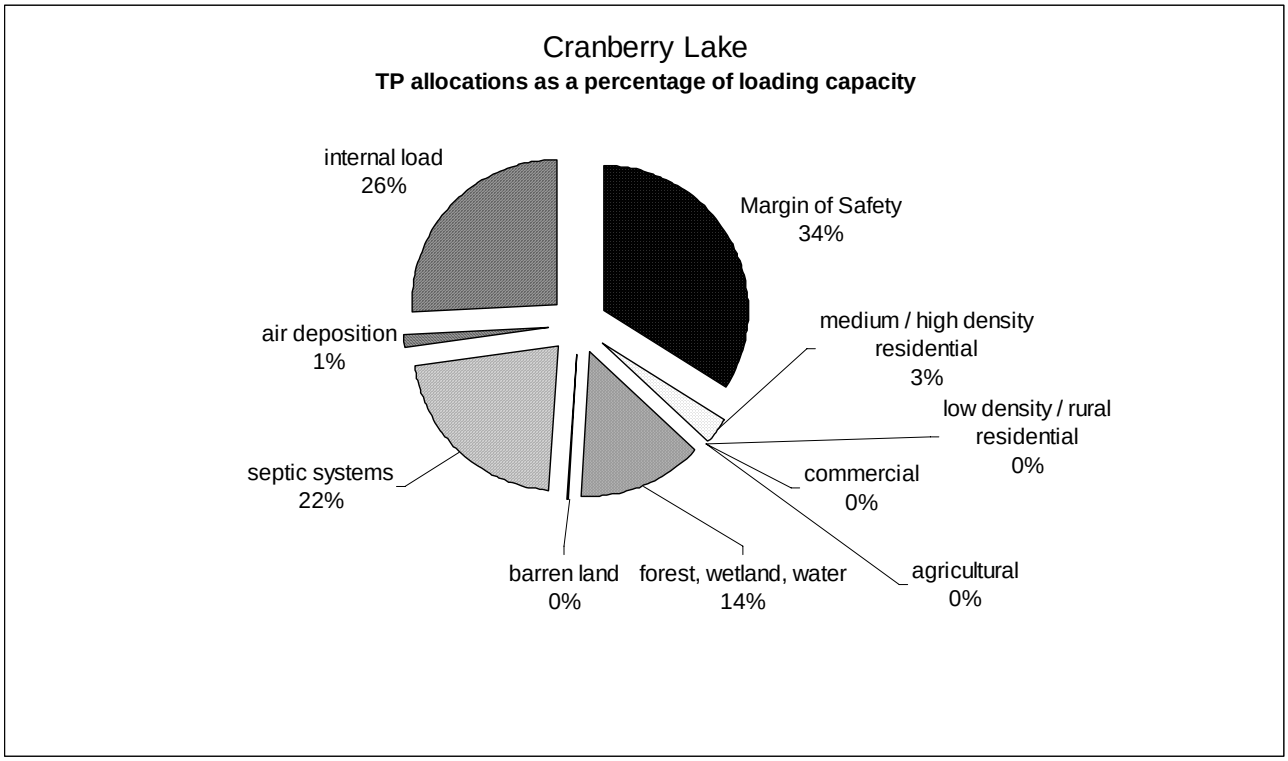


Figure 11 **Phosphorus allocations for Ghost Lake**

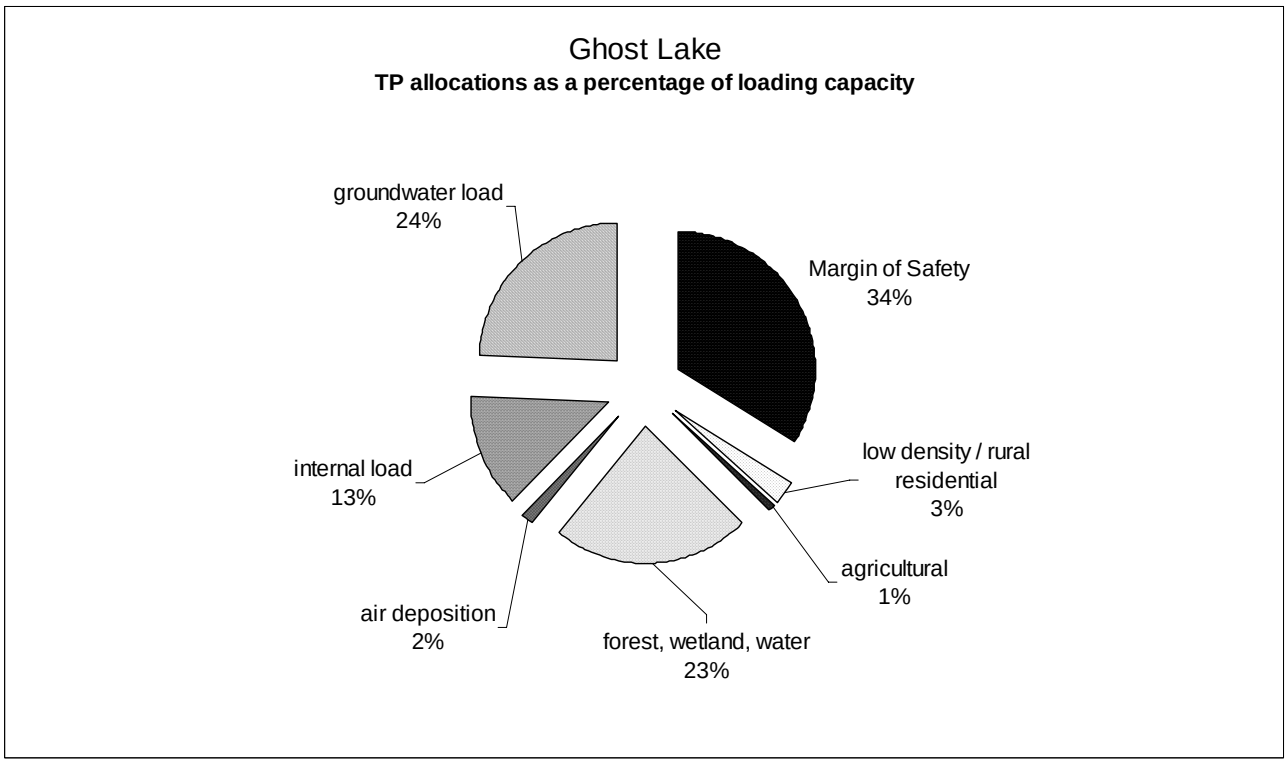


Figure 12 **Phosphorus allocations for Lake Hopatcong TMDL**

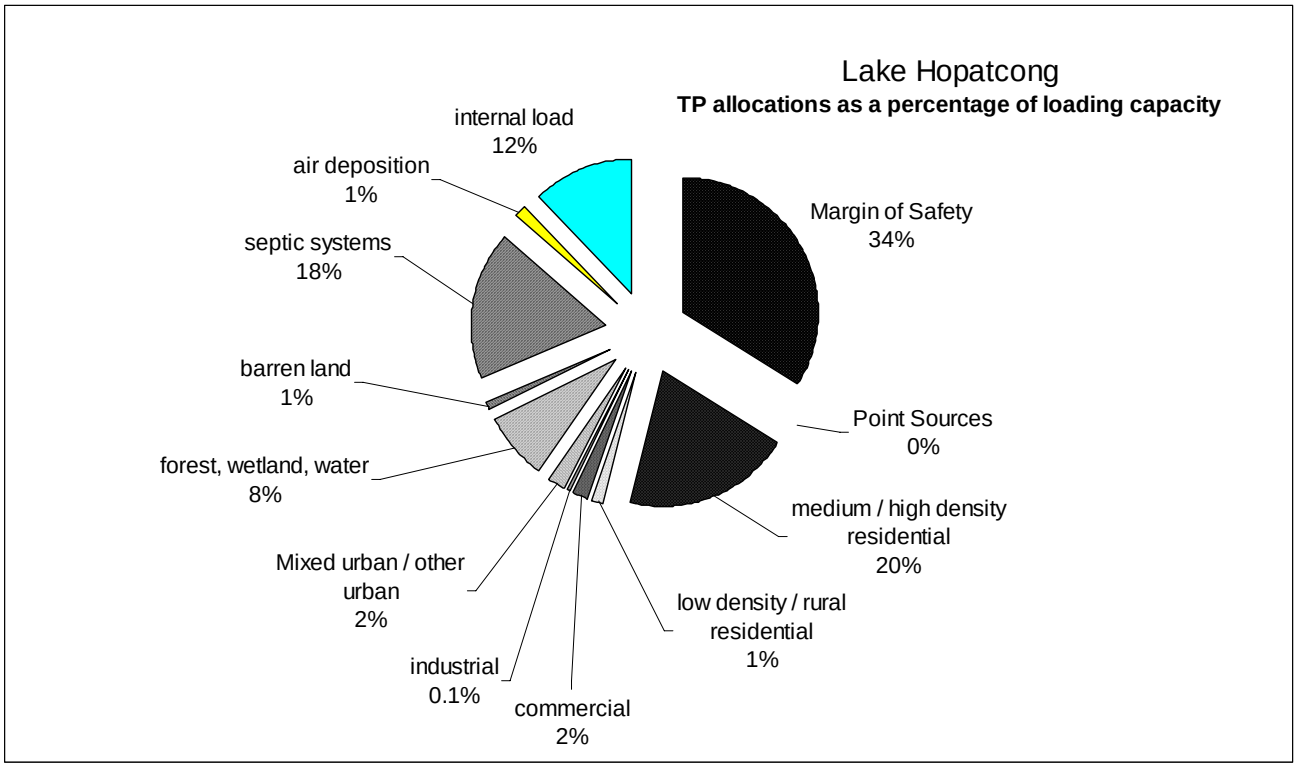
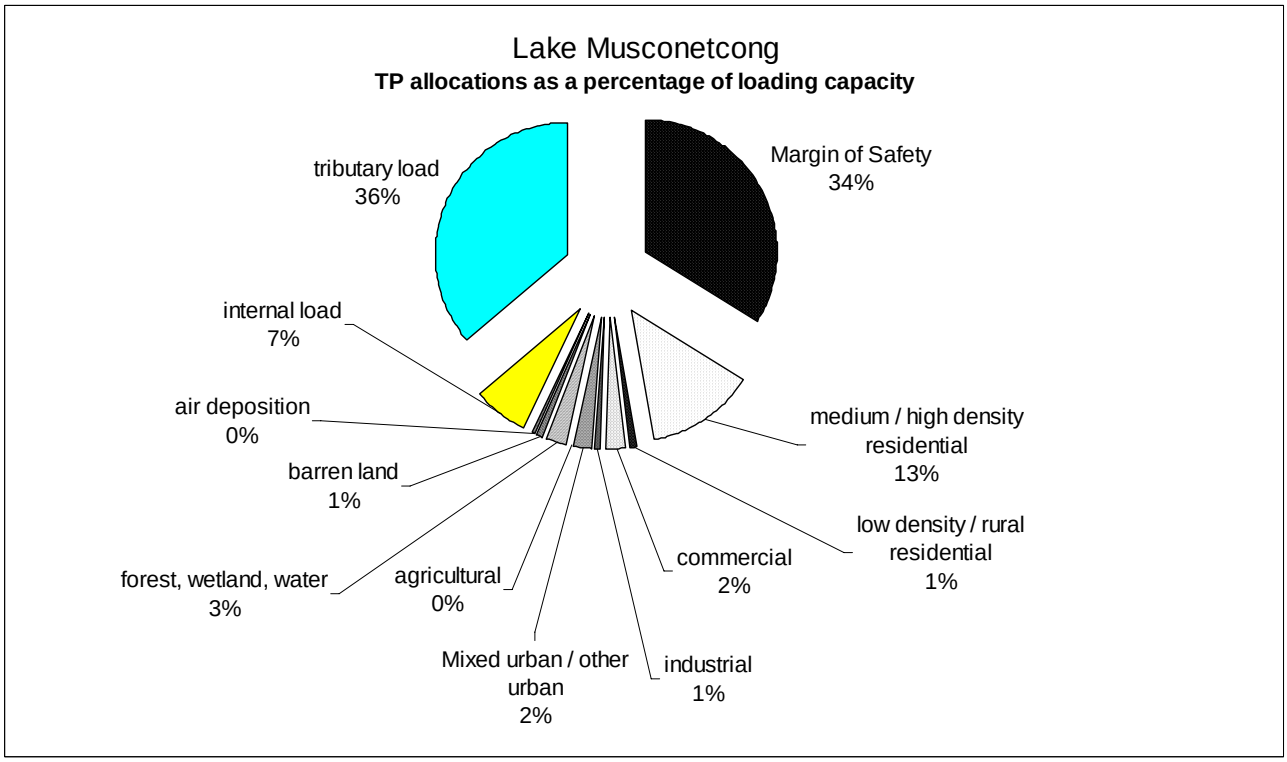


Figure 13 **Phosphorus allocations for Lake Musconetcong TMDL**



9.0 Follow-up Monitoring

In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will augment its ambient monitoring program to include lakes on a rotating schedule. The details of a new Lakes Monitoring Network will be published by December 31, 2003. Lakes for which remediation measures have been performed will be given top priority on whatever rotating schedule is developed.

Follow-up monitoring will include evaluations (qualitative using a field index or quantitative) of algal blooms (presence, severity, extent) and aquatic vegetation (density, extent, diversity). Measurements such as secchi depths, nutrient concentrations, and chlorophyll-*a* will be included, in addition to dissolved oxygen, temperature and pH profiles. Basic hydrologic and morphometric information will be measured as necessary to obtain current data, including discharge and bathymetry. The details as to what data will be collected by the Lakes Monitoring Network will be included in the network description.

10.0 Implementation

The next steps toward implementation are preparation of lake characterizations and lake restoration plans, where they have not already been developed. In the development of these plans, the loads by source will be revised, as necessary, to reflect refinements in source contributions. It will be on the basis of refined source estimates that specific strategies for reduction will be developed. These will consider issues such as cost and feasibility when specifying the reduction target for any source or source type. As appropriate, WLAs or other measures to be applied to traditional or stormwater point sources through NJPDES permits will be adopted by the Department as amendments to the applicable areawide Water Quality Management Plan.

The Department recognizes that TMDLs alone are not sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides the regulatory framework to effect those reductions. However, the nutrient load only affects the eutrophication potential of a lake. The implementation plan therefore calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake. The plans will consider in-lake measures that need to be taken to supplement the nutrient reduction measures required by the TMDL. In addition, the plans will consider the ecology of the lake and adjust the eutrophication indicator target as necessary to protect the designated uses.

For instance, with the exception of Lake Hopatcong, all of these lakes are shallow lakes, as defined by having a mean depth less than 3 meters. Even Lake Hopatcong includes many basins that behave like shallow lakes, such as Woodport Bay. For a lake to be shallow means that most of the lake volume is within the photic zone and therefore more able to support aquatic plant growth (Holdren *et al*, 2001). Shallow lakes are generally characterized by either

abundant submerged macrophytes and clear water or by abundant phytoplankton and turbid water. From an aquatic life and biodiversity perspective, it is desirable for shallow lakes to be dominated by aquatic plants rather than algae, especially phytoplankton. While lower nutrient concentrations favor the clear/plant state, either state can persist over a wide range of nutrient concentrations. Shallow lakes have ecological stabilizing mechanisms that tend to resist switches from clear/plant state to turbid/algae state, and vice-versa. The clear/plant state is more stable at lower nutrient concentrations and irreversible at very low nutrient concentrations; the turbid/algae state is more stable at higher nutrient concentrations. The Lake Restoration Plans for each lake will need to consider the ecological nuances of shallow and deep lakes.

The State of New Jersey has adopted a watershed approach to water quality management. That plan divides the state into five watershed management regions, one of which is the Northwest Region. The Department recognizes that lake restoration requires a watershed approach. Lake Restoration Plans will be used as a basis to address overfertilization and sedimentation issues in watersheds that drain to these sensitive lakes. In addition, the Department will direct research funds to understand and demonstrate biomanipulation and other techniques that can be applied in New Jersey lakes to promote the establishment of healthy and diverse aquatic plant communities in shallow lakes. Finally, public education efforts will focus on the benefits of aquatic plants in shallow lakes and the balance of aquatic life uses with recreational uses of these lakes. With the combination of New Jersey's strong commitment to the collection and use of high quality data to support environmental decisions and regulatory programs, including TMDLs, the Department is reasonably assured compliance with the total phosphorus criteria applicable to these eutrophic lakes.

10.1 Lake Characterization

Additional monitoring may be performed in order to develop the Lake Restoration Plans to implement these TMDLs. The level of characterization necessary to plan restoration will be specific to individual lakes depending on the remedial options being considered. During at least one or two summer trips, the following information may be collected as necessary.

- for shallow lakes, vegetation mapping using shore to center transects, measuring density and composition (emergents, rooted floaters, submergents, free-floating plants, submerged macro-algae)
- 1-5 mid-lake sampling stations as needed to characterize the lake
    - at least 2 samples per station per day; min 4 samples per trip
    - secchi depths
- chemistry (nutrients, chlorophyll-*a*, etc.)
    - surface, metalimnion, hypolimnion, and bottom if stratified
    - otherwise surface and bottom
- biology (integrated sample from mixed surface layer)
    - algal abundance and composition (greens, diatoms, blue-greens)
    - zooplankton abundance, composition and size ranges
- DO, temperature and pH profiles (hourly throughout day)

Where necessary, flow and water quality measurements of influent and effluent streams will be taken periodically from Spring to Fall, and fish abundance and composition will be assessed in early autumn.

The schedules for lake characterization and development of Lake Restoration Plans to implement these TMDLs are provided in Table 11.

Table 11 Implementation Schedule

Lake	Lake Characterization	Lake Restoration Plan
Cranberry Lake[a]	Summer 2004	Spring 2005
Ghost Lake[b]	Completed 2000 and 2001	Completed February 2002
Lake Hopatcong	Summer 2003	Spring 2004
Lake Musconetcong	Summer 2003	Spring 2004

a While Phase 2 remediation of Cranberry Lake is already underway, the TMDL implementation will focus on how successful the nutrient reduction efforts have been, and what additional measures are necessary to restore the lake.

b The Diagnostic / Feasibility study for Ghost Lake (Princeton Hydro, 2002) fulfills the TMDL requirements for lake characterization and lake restoration planning. While nutrient reductions are not required, the report specifies a management plan to restore the lake, including biomanipulation through fishery management.

10.2 Reasonable Assurance

Reasonable assurance for the implementation of these TMDLs has been considered for point and nonpoint sources for which phosphorus load reductions are necessary. These TMDLs obligate the Department to routinely monitor lake water quality as well as characterize and develop specific restoration plan for these particular lakes according to the schedule in Table 11. Moreover, stormwater sources for which WLAs have been established will be regulated as NJPDES point sources.

With the implementation of follow-up monitoring and development of Lake Restoration Plans through watershed management process, the Department is reasonably assured that New Jersey's Surface Water Quality Standards will be attained for these lakes. Activities directed in the watersheds to reduce nutrient loadings shall include a whole host of options, included but not limited to education projects that teach best management practices, approval of projects funded by CWA Section 319 Nonpoint Source (NPS) Grants, recommendations for municipal ordinances regarding feeding of wildlife, and pooper-scooper laws, and stormwater control measures.

11.0 Public Participation

Presently, the Upper Delaware Watershed public participation process is being managed by the Department under a contract with the North Jersey Resource Conservation and Development Council. It is comprised of the Project Work Group, an Action Now Committee, an Education and Outreach Committee, an Open Space and Farmland Preservation Committee, and a Characterization and Assessment Committee. It holds regular meetings and relies on its diverse partners and the general public to work on

watershed tasks and issues. In June 2002 the Department gave a presentation to the Upper Delaware Watershed Project Work Group on the New Jersey 2002 Integrated List of Waterbodies and the Water Quality Monitoring and Assessment Methodology, and also encouraged submittal of any comments.

In accordance with N.J.A.C. 7:15–7.2(g), these TMDLs are hereby proposed by the Department as an amendment to the Upper Delaware Water Quality Management Plan, Northeast Water Quality Management Plan, Upper Raritan Water Quality Management Plan, and Sussex County Water Quality Management Plan. N.J.A.C. 7:15-3.4(g)5 states that when the Department proposes to amend the areawide plan on its own initiative, the Department shall give public notice by publication in a newspaper of general circulation in the planning area, shall send copies of the public notice to the applicable designated planning agency, if any, and may hold a public hearing or request written statements of consent as if the Department were an applicant. The public notice shall also be published in the New Jersey Register.

Notice of these TMDLs was published January 21, 2003 pursuant to the above noted Administrative Code, in order to provide the public an opportunity to review the TMDLs and submit comments. The Department has determined that due to the level of interest in these TMDLs, a public hearing will be held. Public notice of the hearing, provided at least 30 days before the hearing, was published in the New Jersey Register and in two newspapers of general circulation and will be mailed to the applicable designated planning agency, if any, and to each party, if any, who was requested to issue written statement of consents for the amendment.

All comments received during the public notice period and at any public hearings will become part of the record for these TMDLs. All comments will be considered in the establishment of these TMDLs and the ultimate adoption of these TMDLs. When the Department takes final agency action to establish these TMDLs, the final decision and supporting documentation will be sent to U.S.E.P.A. Region 2 for review and approval pursuant to 303(d) of the Clean Water Act (33 U.S.C. 1313(d)) and 40 CFR 130.7.

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Appendix B: Database of Phosphorus Export Coefficients

In December 2001, the Department concluded a contract with the USEPA, Region 2, and a contracting entity, TetraTech, Inc., the purpose of which was to identify export coefficients applicable to New Jersey. As part of that contract, a database of literature values was assembled that includes approximately four-thousand values accompanied by site-specific characteristics such as location, soil type, mean annual rainfall, and site percent-impervious. In conjunction with the database, the contractor reported on recommendations for selecting values for use in New Jersey. Analysis of mean annual rainfall data revealed noticeable trends, and, of the categories analyzed, was shown to have the most influence on the reported export coefficients. Incorporating this and other contractor recommendations, the Department took steps to identify appropriate export values for these TMDLs by first filtering the database to include only those studies whose reported mean annual rainfall was between 40 and 51 inches per year. From the remaining studies, total phosphorus values were selected based on best professional judgement for eight land uses categories.

The sources incorporated in the database include a variety of governmental and non-governmental documents. All values used to develop the database and the total phosphorus values in this document are included in the below reference list.

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Appendix C: Summary of Reckhow (1979a) model derivation

The following general expression for phosphorus mass balance in lake assumes the removal of phosphorus from a lake occurs through two pathways, the outlet (M_o) and the sediments (ϕ):

$$V \cdot \frac{dP}{dt} = M_i - M_o - \phi \qquad \textbf{Equation 1}$$

where:
- V = lake volume (10^3 m^3)
- P = lake phosphorus concentration (mg/l)
- M_i = annual mass influx of phosphorus (kg/yr)
- M_o = annual mass efflux of phosphorus (kg/yr)
- ϕ = annual net flux of phosphorus to the sediments (kg/yr).

The sediment removal term is a multidimensional variable (dependent on a number of variables) that has been expressed as a phosphorus retention coefficient, a sedimentation coefficient, or an effective settling velocity. All three have been shown to yield similar results; Reckhow's formulation assumes a constant effective settling velocity, which treats sedimentation as an areal sink.

Assuming the lake is completely mixed such that the outflow concentration is the same as the lake concentration, the phosphorus mass balance can be expressed as:

$$V \cdot \frac{dP}{dt} = M_i - v_s \cdot P \cdot A - P \cdot Q \qquad \textbf{Equation 2}$$

where:
- v_s = effective settling velocity (m/yr)
- A = area of lake (10^3 m^2)
- Q = annual outflow (10^3 m^3/yr).

The steady-state solution of Equation 2 can be expressed as:

$$P = \frac{P_a}{v_s + z/T} = \frac{P_a}{v_s + Q_a} \qquad \textbf{Equation 3}$$

where:
- P_a = areal phosphorus loading rate (g/m^2/yr)
- z = mean depth (m)
- T = hydraulic detention time (yr)
- Q_a = Q/A = areal water load (m/yr).

Using least squares regression on a database of 47 north temperate lakes, Reckhow fit the effective settling velocity using a function of areal water load: $P = \frac{P_a}{11.6 + 1.2 \cdot Q_a}$. **Equation 4**

Appendix D: Derivation of Margin of Safety from Reckhow *et al* (1980)

As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. The model error analysis from Reckhow *et al* (1980) defined the following confidence limits:

$$P_L = P - h \cdot \left(10^{(\log P - 0.128)} - P\right)$$
$$P_U = P + h \cdot \left(10^{(\log P + 0.128)} - P\right)$$
$$\rho \geq 1 - \frac{1}{2.25 \cdot h^2}$$

where:
- P_L = lower bound phosphorus concentration (mg/l);
- P_U = upper bound phosphorus concentration (mg/l);
- P = predicted phosphorus concentration (mg/l);
- h = prediction error multiple
- ρ = the probability that the real phosphorus concentration lies within the lower and upper bound phosphorus concentrations, inclusively.

Assuming an even-tailed probability distribution, the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration is:

$$\rho_u = \rho + \frac{1-\rho}{2} = \rho + \frac{1}{2} - \frac{\rho}{2} = \rho \cdot \left(1 - \frac{1}{2}\right) + \frac{1}{2} = \frac{1}{2} \cdot \rho + \frac{1}{2}$$

Substituting for ρ as a function of h:

$$\rho_u = \frac{1}{2} \cdot \left(1 - \frac{1}{2.25 \cdot h^2}\right) + \frac{1}{2} = \frac{1}{2} - \frac{1}{4.5 \cdot h^2} + \frac{1}{2} = 1 - \frac{1}{4.5 \cdot h^2}$$

Solving for h as a function of the probability that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$\frac{1}{4.5 \cdot h^2} = 1 - \rho_u$$
$$h^2 = \frac{1}{4.5(1 - \rho_u)}$$
$$h = \sqrt{\frac{1}{4.5(1 - \rho_u)}}$$

Expressing Margin of Safety (MoS_p) as a percentage over the predicted phosphorus concentration yields:

$$MoS_p = \frac{P_U}{P} - 1 = \frac{P_U - P}{P}$$

Substituting the equation for $P_{U:}$

$$MoS_p = \frac{P + h \cdot \left(10^{(\log P + 0.128)} - P\right) - P}{P} = \frac{h \cdot \left(10^{(\log P + 0.128)} - P\right)}{P}$$

$$P \cdot MoS_p = h \cdot \left(10^{(\log P + 0.128)} - P\right)$$

$$\frac{P \cdot MoS_p}{h} = 10^{(\log P + 0.128)} - P$$

$$\frac{P \cdot MoS_p}{h} + P = 10^{(\log P + 0.128)}$$

Taking the log of both sides and solving for margin of safety:

$$\log\left(\frac{P \cdot MoS_p}{h} + P\right) = \log P + 0.128$$

$$\log\left(\frac{P \cdot MoS_p}{h} + P\right) - \log P = 0.128$$

$$\log\left(P\left(\frac{MoS_p}{h} + 1\right)\right) - \log P = 0.128$$

$$\log P + \log\left(\frac{MoS_p}{h} + 1\right) - \log P = 0.128$$

$$\log\left(\frac{MoS_p}{h} + 1\right) = 0.128$$

$$\frac{MoS_p}{h} + 1 = 10^{0.128}$$

$$\frac{MoS_p}{h} = 10^{0.128} - 1$$

$$MoS_p = h\left(10^{0.128} - 1\right)$$

Finally, substituting for *h* yields Margin of Safety (MoS_p) as a percentage over the predicted phosphorus concentration, expressed as a function of the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$MoS_p = \sqrt{1 \Big/ \left((1 - \rho_u) * 4.5\right)} \times \left(10^{0.128} - 1\right)$$

Amendment to the
Upper Delaware Water Quality Management Plan
Northeast Water Quality Management Plan
Upper Raritan Water Quality Management Plan
Sussex County Water Quality Management Plan

Total Maximum Daily Loads for Phosphorus To Address 4 Eutrophic Lakes in the Northwest Water Region

CRANBERRY LAKE, SUSSEX COUNTY
GHOST LAKE, WARREN COUNTY
LAKE HOPATCONG, SUSSEX COUNTY
LAKE MUSCONETCONG, SUSSEX COUNTY

Watershed Management Area 1
(Upper Delaware River Watershed)

Proposed:	January 21, 2003
Established:	March 28, 2003
Approved (by EPA Region 2):	September 17, 2003
Adopted:	

New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
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1.0 Executive Summary

The State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Northwest Water Region as being eutrophic. This report establishes total maximum daily loads (TMDLs) for total phosphorus (TP) that address eutrophication of the lakes listed in Table 1.

Table 1 Eutrophic Lakes for which Phosphorus TMDLs are being established

TMDL Number	Lake Name	Municipality	WMA	Acres
1	Cranberry Lake	Byram Township, Sussex County	01	190
2	Ghost Lake	Independence Township, Warren County	01	18.3
3	Lake Hopatcong	Hopatcong Borough, Sussex County; Mt. Arlington Borough, Jefferson & Roxbury Townships; Morris County	01	2,410
4	Lake Musconetcong	Stanhope, Byram, Netcong and Roxbury Townships; Sussex County	01	314

These TMDLs serve as the foundation on which restoration plans will be developed to restore eutrophic lakes and thereby attain applicable surface water quality standards. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet Surface Water Quality Standards (SWQS). The pollutant of concern for these TMDLs is phosphorus, since phosphorus is generally the nutrient responsible for overfertilization of inland lakes leading to cultural eutrophication. The Department's Geographic Information System (GIS) was used extensively to describe the lakes and lakesheds (drainage basins of the lakes).

In order to prevent excessive primary productivity[1] and consequent impairment of recreational, water supply and aquatic life designated uses, the SWQS define both numerical and narrative criteria that address eutrophication in lakes due to overfertilization. Phosphorus sources were characterized on an annual scale (kg TP/yr) for both point and nonpoint sources. Runoff from land surfaces comprises a substantial source of phosphorus into lakes. An empirical model was used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. To achieve the TMDLs, overall load reductions were calculated for at least eight source categories. In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will augment its ambient monitoring program to include lakes on a rotating schedule. The implementation plan also calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake for which TMDLs are being established. These plans will consider what specific measures are necessary to achieve the nutrient reductions required by the TMDL, as well as what in-lake measures need to be taken to supplement the nutrient reductions required by the TMDL.

[1] Primary productivity refers to the growth rate of primary producers, namely algae and aquatic plants, which form the base of the food web.

Each TMDL shall be proposed and adopted by the Department as an amendment to the appropriate areawide water quality management plan(s) in accordance with N.J.A.C. 7:15-3.4(g).

This TMDL Report is consistent with EPA's May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Suftin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs.

2.0 Introduction

Sublist 5 (also known as List 5 or, traditionally, the 303(d) List) of the State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Northwest Water Region (WMAs 1, 2, and 11) as being eutrophic, as evidenced by elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density that impairs recreational use (a qualitative assessment). Total phosphorus was used as the pollutant of concern, since this "independent" causal pollutant causes "dependent " responses in chlorophyll-*a* concentrations and/or macrophyte density. This report establishes four total maximum daily loads (TMDLs) that address total phosphorus loads to the identified lakes. These TMDLs serve as the foundation on which management approaches or restoration plans will be developed to restore eutrophic lakes and thereby attain applicable surface water quality standards. Several of the lakes are listed on Sublist 5 for impairments caused by other pollutants. These TMDLs address only the impairment of lakes due to eutrophication. Separate TMDL evaluations will be developed to address the other pollutants of concern. The waterbodies will remain on Sublist 5 until such time as TMDL evaluations for all pollutants have been completed and approved by the United States Environmental Protection Agency (USEPA).

A TMDL is considered "proposed" when NJDEP publishes the TMDL Report as a proposed Water Quality Management Plan Amendment in the New Jersey Register (NJR) for public review and comment. A TMDL is considered to be "established" when NJDEP finalizes the TMDL Report after considering comments received during the public comment period for the proposed plan amendment and formally submits it to EPA Region 2 for thirty (30)-day review and approval. The TMDL is considered "approved" when the NJDEP-established TMDL is approved by EPA Region 2. The TMDL is considered to be "adopted" when the EPA-approved TMDL is adopted by NJDEP as a water quality management plan amendment and the adoption notice is published in the NJR.

3.0 Background

3.1 305(b) Report and 303(d) List

In accordance with Section 305(b) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required to biennially prepare and submit to the United States

Environmental Protection Agency (USEPA) a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report.

In accordance with Section 303(d) of the CWA, the State is also required to biennially prepare and submit to USEPA a report that identifies waters that do not meet or are not expected to meet surface water quality standards (SWQS) after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. The listed waterbodies are considered water quality-limited and require total maximum daily load (TMDLs) evaluations. For waterbodies identified on the 303(d) List, there are three possible scenarios that may result in a waterbody being removed from the 303(d) List:

> **Scenario 1:** A TMDL is established for the pollutant of concern;
> **Scenario 2:** A determination is made that the waterbody is meeting water quality standards (no TMDL is required); or
> **Scenario 3:** A determination is made that a TMDL is not the appropriate mechanism for achieving water quality standards and that other control actions will result in meeting standards.

Where a TMDL is required (Scenario 1), it will: 1) specify the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards**;** and 2) allocate pollutant loadings among point and nonpoint pollutant sources.

Recent EPA guidance (Suftin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for USEPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that this TMDL report, which includes four TMDLs, addresses the following items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.
12. Submittal letter.

3.2 Total Maximum Daily Loads (TMDLs)

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint source of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point sources in the form of wasteload allocations (WLAs), nonpoint sources in the form of load allocations (LAs), and a margin of safety. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet SWQS.

Once one of the three possible delisting scenarios, noted above, is completed, states have the option to remove the waterbody and specific pollutant of concern from the 303(d) List or maintain the waterbody on the 303(d) list until SWQS are achieved. The State of New Jersey will be removing lakes from the 303(d) List for eutrophication once their TMDLS are approved by USEPA.

3.3 Integrated List of Waterbodies

In November 2001, USEPA issued guidance that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. This integrated report assigns waterbodies to one of five categories. In general, Categories 1 through 4 include a range of designated use impairments with a discussion of enforceable management strategies, whereas Sublist 5 constitutes the traditional 303(d) List for waters impaired or threatened by a pollutant for which one or more TMDL evaluations are needed. Where more than one pollutant is associated with the impairment for a given waterbody, that waterbody will remain on Sublist 5 until one of the three possible delisting scenarios is completed. In the case of an Integrated List, however, the waterbody is not delisted but moved to one of the other categories.

Following USEPA's guidance, the Department chose to develop an Integrated Report for New Jersey. New Jersey's *2002 Integrated List of Waterbodies* is based upon these five categories and identifies water quality limited surface waters in accordance with N.J.A.C. 7:15-6 and Section 303(d) of the CWA. These TMDLs address eutrophic lakes, as listed on Sublist 5 of the State of New Jersey's *2002 Integrated List of Waterbodies.*

4.0 Pollutant of Concern and Area of Interest

Lakes were designated as eutrophic on Sublist 5 of the *2002 Integrated List of Waterbodies* as a result of evaluations performed through the State's Clean Lakes Program. Indicators used to determine trophic status included elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density. The pollutant of concern for these TMDLs is total phosphorus. The mechanism by which phosphorus can cause use impairment is via excessive primary productivity. Phosphorus is an essential nutrient for plants and algae, but is considered a pollutant because it can stimulate excessive growth (primary production). Phosphorus is

most often the major nutrient in shortest supply relative to the nutritional requirements of primary producers in freshwater lakes; consequently, phosphorus is frequently a prime determinant of the total biomass in a lake. Furthermore, of the major nutrients, phosphorus is the most effectively controlled through engineering technology and land use management (Holdren *et al*, 2001). Eutrophication has been described as the acceleration of the natural aging process of surface waters. It is characterized by excessive loading of silt, organic matter, and nutrients, causing high biological production and decreased basin volume (Cooke et al, 1993). Symptoms of eutrophication (primary impacts) include oxygen super-saturation during the day, oxygen depletion during night, and high sedimentation (filling in) rate. Algae and aquatic plants are the catalysts for these processes. Secondary biological impacts can include loss of biodiversity and structural changes to communities. Phosphorus is generally the nutrient responsible for overfertilization of inland lakes leading to eutrophication.

As reported in the *2002 Integrated List of Waterbodies*, the Department identified the following lakes in Northwest Water Region as being eutrophic for a total of 3,480 acres. These four TMDLs will address 2,930 acres or 84.2%of the total impaired acres in this region (Table 2). Lake Hopatcong is listed for both trophic status and aquatic life, which is based on a fishery assessment performed by the Department's Bureau of Freshwater Fisheries; secondary impacts of eutrophication include poorer fish quality and diversity, often due to oxygen depressions and fluctuations. Therefore, it is likely that management actions directed at addressing eutrophication impairments would also address aquatic life impairments based on fishery assessment. However, the exact causes of the aquatic life impairment have not been determined, therefore it is not certain that a TMDL for eutrophication will address the aquatic life impairment completely. Both eutrophic lakes and aquatic life impairments are ranked as Low Priority in the *2002 Integrated List of Waterbodies* because they are not directly related to human health issues; however, both issues are environmentally important.

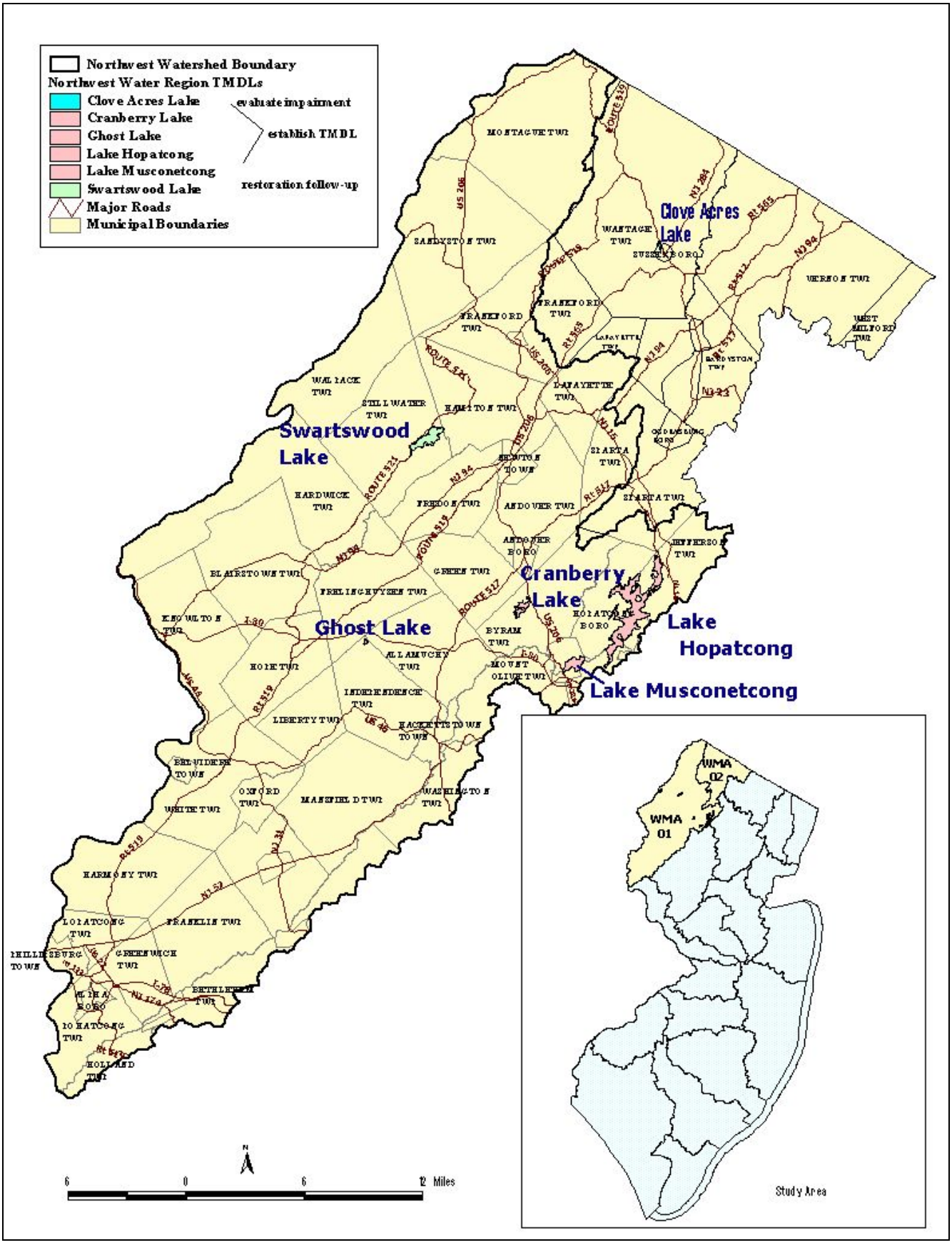
Table 2 Abridged Sublist 5 of the 2002 Integrated List of Waterbodies, eutrophic lakes

No.	WMA	Lake [a]	Lake Acres	Lakeshed Acres	Management Response
1	01	Cranberry Lake	1890	1,740	establish TMDL
2	01	Ghost Lake	18.3	212	establish TMDL
3	01	Lake Hopatcong	2,410	16,200	establish TMDL
4	01	Lake Musconetcong	314	2,980[b]	establish TMDL
5	01	Swartswood Lake	521	6,410	restoration follow-up
6	02	Clove Acres Lake	28.6	12,500	evaluate impairment

a All of the waterbodies covered under these TMDLs have a FW2 classification.

b To avoid "double-counting," watershed area of Lake Musconetcong does not include Lake Hopatcong and its watershed.

Figure 1 Eutrophic lakes in the Northwest Water Region on Sublist 5 of 2002 Integrated List



These TMDLs will address a total of 2,930 acres of lakes with a corresponding total of 21,110 acres of land. Traditionally, land use has been dictated by the topography and transportation system of the area. The Upper Delaware Watershed (WMA-01) exhibits an accelerated pattern of growth, especially around its lakes. In spite of the area's relatively low population density and numerous protected lands, these development trends are likely to negatively impact surrounding water quality and quantity.

The Department's Geographic Information System (GIS) was used extensively to describe the lakes and lakesheds (watersheds of the lakes), specifically the following data coverages:

- 1995/97 Land use/Land cover Update, published 12/01/2000 by NJDEP Bureau of Geographic Information and Analysis , delineated by watershed management area.
- NJDEP Statewide Lakes (Shapefile) with Name Attributes (from 95/97 Land Use/Land Cover) in New Jersey, published 7/13/2001 by NJDEP - Bureau of Freshwater and Biological Monitoring, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njlakes.zip.
- Lakesheds were delineated based on 14-digit hydrologic unit code coverage (HUC-14) elevation contours, and 10 meter digital elevation model grids.
  - NJDEP 14 Digit Hydrologic Unit Code delineations (DEPHUC14), published 4/5/2000 by New Jersey Geological Survey, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip.
  - Statewide Elevation Contours (10 Foot Intervals), unpublished, auto-generated from: 7.5 minute Digital Elevation Models, published 7/1/1979 by U.S. Geological Survey.
  - NJDEP Statewide Elevation Contours (20 Foot Intervals), published 1987 by Bureau of Geographic Information and Analysis (BGIA), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stcon.zip.
  - NJDEP 10-meter Digital Elevation Grids, published 06/01/2002 by Bureau of Geographic Information and Analysis (BGIA), delineated by watershed management area.
- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1).

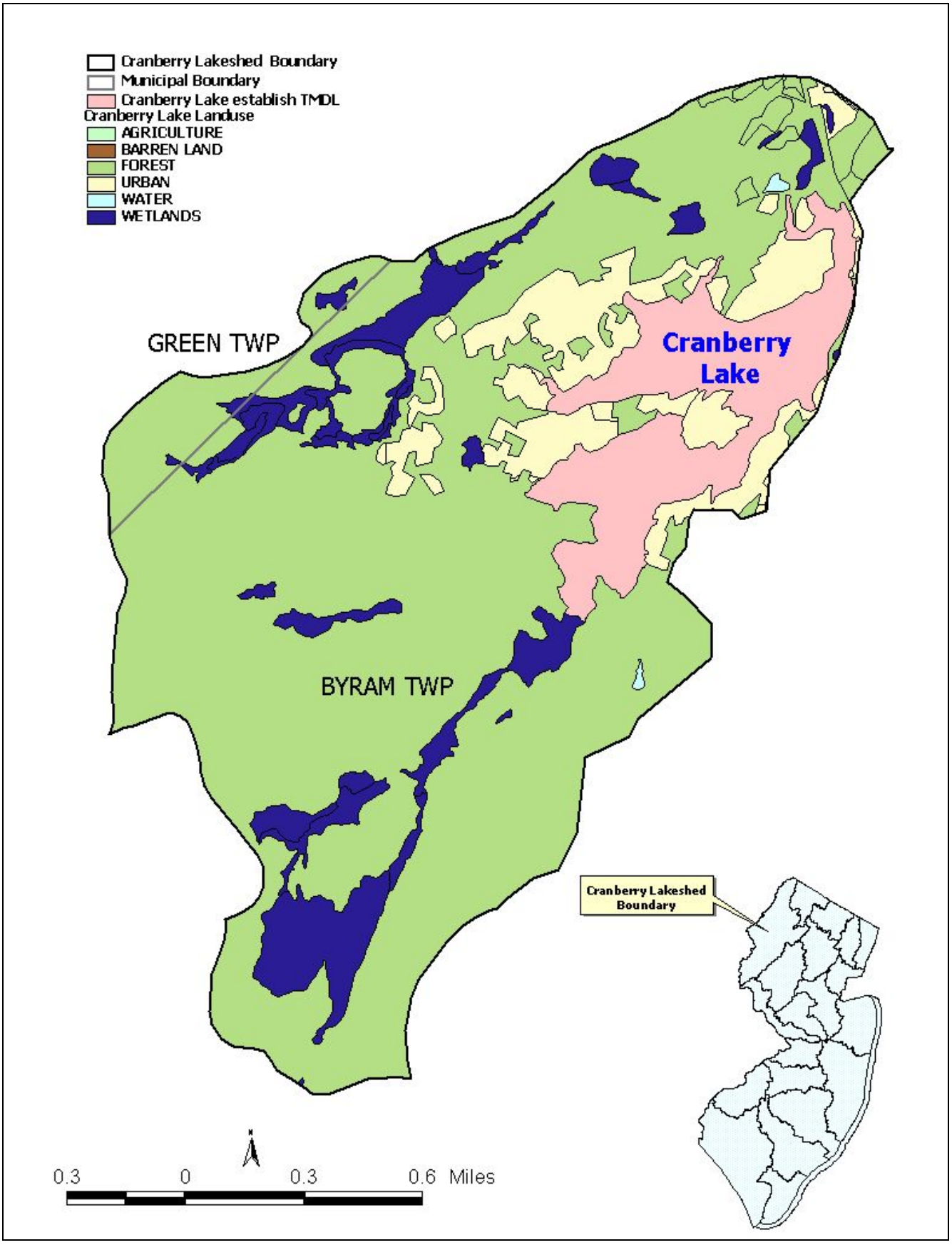
4.1 Cranberry Lake

Cranberry Lake is a 190-acre public lake located in Byram Township, Sussex County, and drains a lakeshed of 1744 acres almost completely within Byram Township. The lakeshed is 9.2 times the area of the lake, making it moderately sized[2]. The lake consists of two basins, each with numerous coves, separated by a large peninsula (Strawberry Point). Tributaries of Lubber's Run feed both basins. Mean depth (2.13m) and total inflow (3,783,000 m^3/yr) were obtained from the Diagnostic Feasibility Study for Cranberry Lake (Coastal Environmental Services, 1992).

[2] A lakeshed seven times the area of its lake is considered small, whereas a lakeshed ten times the area of its lake is considered large (Holdren *et al*, 2001).

Cranberry Lake is a shallow lake within the Musconetcong Watershed, having a mean depth of seven feet and a maximum depth of 15 feet. The lakeshed of Cranberry Lake primarily consists of 1,219 acres of forest, or 70 percent of the entire lakeshed. Approximately half of the land adjacent to the lakeshore is used for medium density residential development, while the remainder is undeveloped (forest cover). Cranberry Lake offers fishing and boating services at the northern end of the lake, where there are boat launch areas (including one trailer launch ramp) and a floating dock. Swimming is available at Cranberry Lake Rose Beach and the Cranberry Lake Club House. The lake is known to have a major septic problem, as indicated in the Phase I Inventory of Current EPA Efforts to Protect Ecosystems report. New Jersey received a Clean Lakes Program Phase II Restoration/Implementation grant in 1992 for Cranberry Lake. The ongoing project entails implementation of in-lake restoration work as well as critical nonpoint source pollution control activities. In 2000 the Weaver House Cove dredging project, which required the lake to be lowered five feet, was nearing completion. In 2001 the Cranberry Lake community was battling watermilfoil vegetation with the herbicide SONAR.

Figure 2 Lakeshed of Cranberry Lake

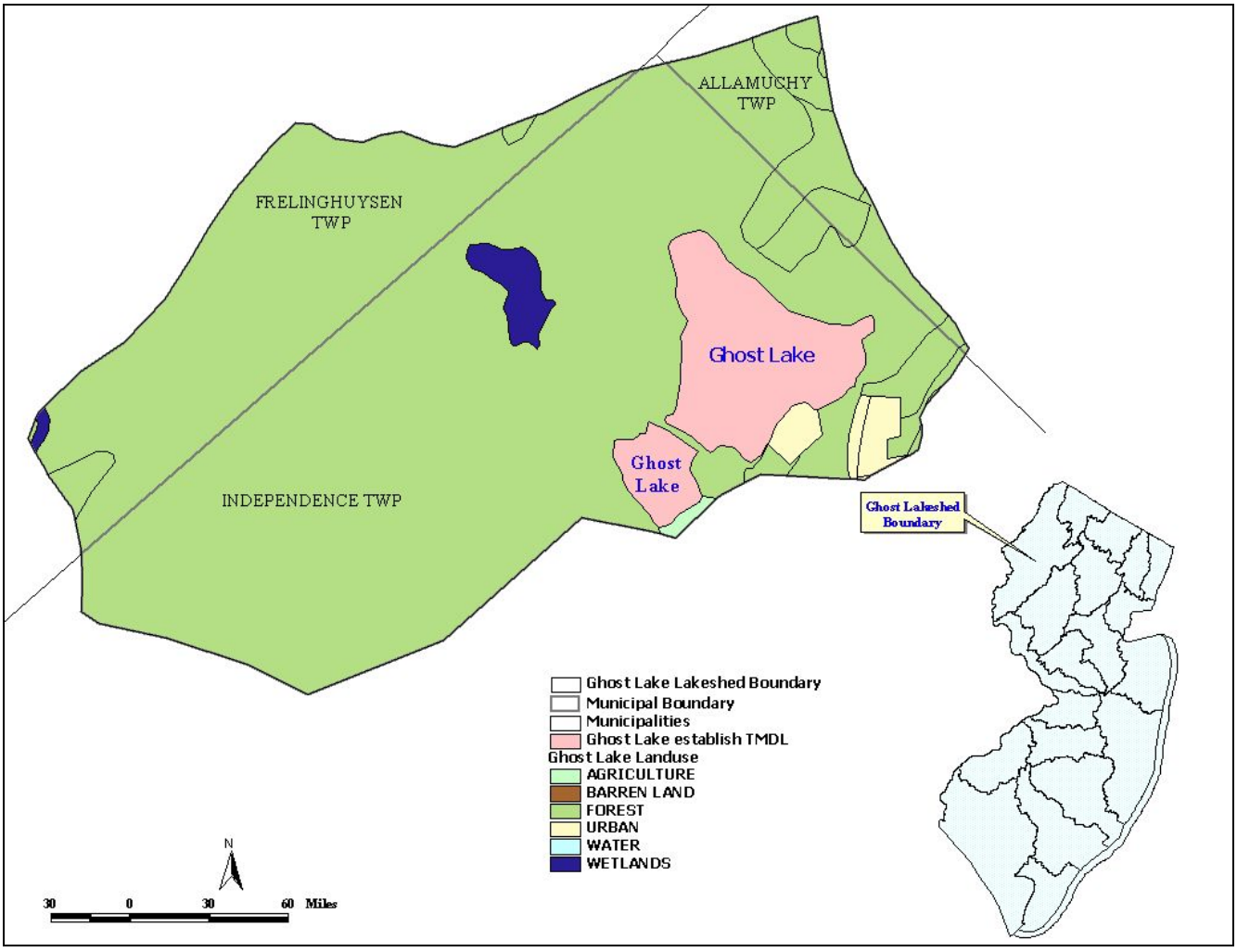


4.2 Ghost Lake

Ghost Lake is located within Jenny Jump State Forest in Independence Township, Warren County, and drains a lakeshed of 212 acres that extends into parts of Frelinghuysen and Allamuchy Townships. The lakeshed is 11.5 times the area of the lakes, making it somewhat large. Ghost Lake has no tributaries; most of the lake's inflow is comprised of groundwater and surface runoff. Mean depth (1.34m) and total inflow (449,000 m^3/yr) were obtained from the Phase 1 Diagnostic / Feasibility Study of Ghost Lake (Princeton Hydro, 2002).

This man-made, shallow lake is 18 acres in size and part of the Pequest River Watershed. A narrow band of land separates the larger upper portion of the lake from the much smaller lower portion. The lakeshed is heavily forested and consists of 187 acres of forest (88 percent). However, in the southeast quadrant of the lakeshed, there are two small clusters of low density/rural development, comprising three acres. Ghost Lake offers fishing and boating (car-top launch only) services at the north end of the lake. Although phosphorus loading to Ghost Lake is currently not excessive, a TMDL is being established to ensure that phosphorus levels do not increase in the future and to establish in-lake measures necessary to restore the lake. To that end, the Department plans to implement as appropriate the recommendations in USEPA Clean Lakes Project Phase I Diagnostic/Feasibility Study, dated February 2002.

Figure 3 Lakeshed of Ghost Lake



4.3 Lake Hopatcong

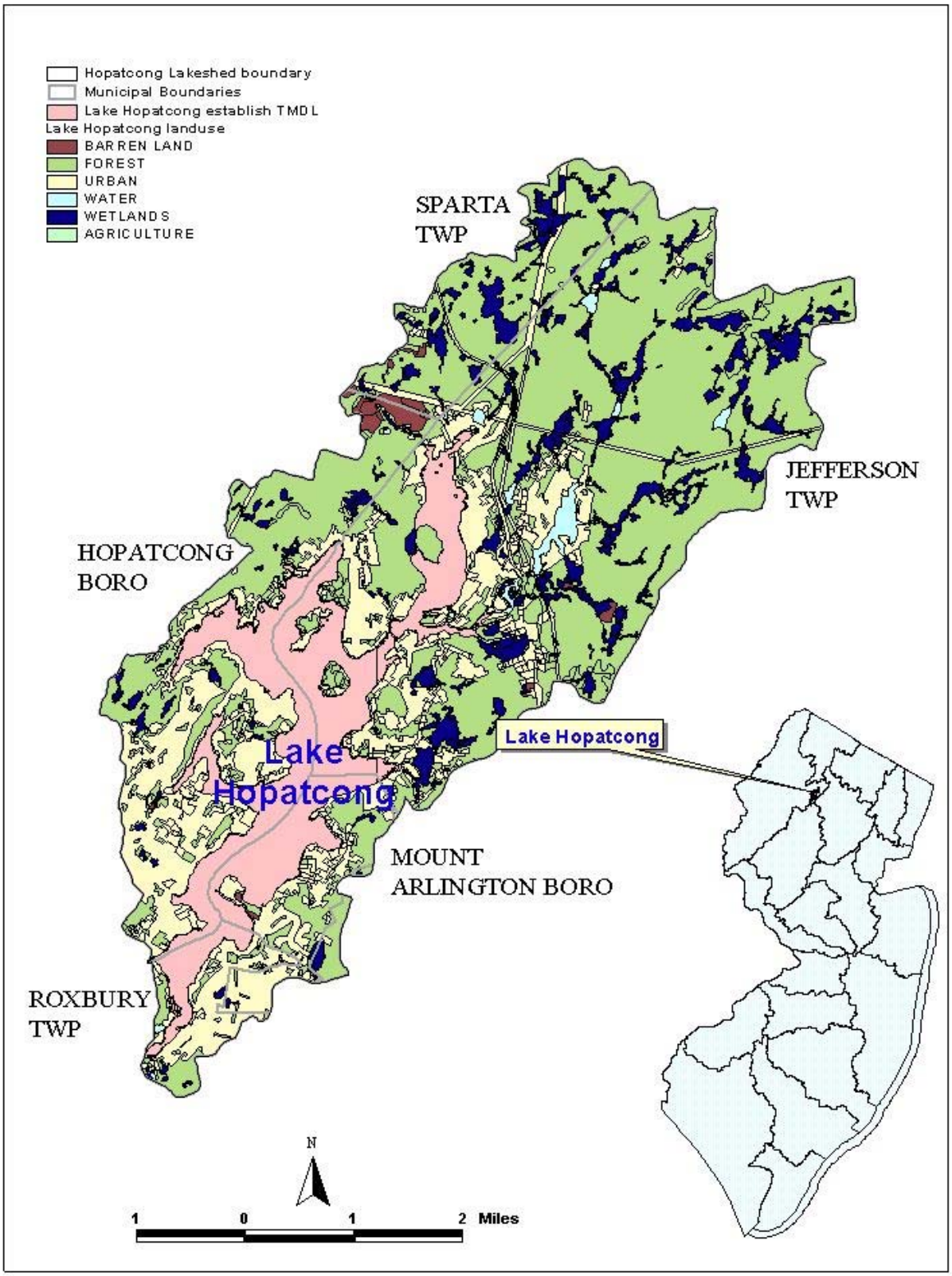
Lake Hopatcong is a 2,406-acre public lake located on the border of Morris and Sussex counties in the municipalities of Mount Arlington Borough, Hopatcong Borough, Jefferson Township, and Roxbury Township. The lake drains a lakeshed of 16,216 acres within the headwaters of the Musconetcong River Watershed. The lakeshed is 6.7 times the area of the lakes, making it fairly small relative to the size of the lake. Lake Hopatcong is a large, irregularly shaped lake composed of many shallow coves around the perimeter. About 50% of the flow into the lake is provided through headwater tributaries of the Musconetcong River, while groudwater inflow comprises about 25% of the flow. Mean depth (5.5m) and total inflow (39,700,000 m^3/yr) were obtained from the Clean Lakes Report for Lake Hopatcong (Princeton Aqua Science, 1983).

Lake Hopatcong is the largest freshwater lake in New Jersey and measures 9.5 miles long with a maximum depth of 58 feet. Originally, Hopatcong consisted of two separate lakes, but a dam built in what is now Lake Hopatcong State Park for the Morris Canal Company linked them together in 1837 to form one large lake. Lake Hopatcong was the major source of water

for the 90-mile waterway that stretched from Newark to Phillipsburg. (The lake is also currently a designated emergency source of drinking water.) The predominant land uses in this lakeshed consist of 9,671 acres of forest and wetlands (including bodies of water other than Lake Hopatcong) and 3,974 acres urban, or 60% and 25%, respectively. About 90% of the land adjacent to the 40-mile lake shore is developed, with the majority in seasonal and year-round low, medium, and high density residential land uses. An estimated 500,000 visitors use Lake Hopatcong's recreational facilities each year for fishing, boating, swimming, sailing, jet skiing, and passive recreation. The lake is known to have some good size fish, with largemouth bass averaging two to five pounds. However, several of its beaches are impaired for fecal coliform, and nonpoint source pollution into the lake has become a critical problem.

The Lake Hopatcong Commission is the entity that has taken control of the lake's improvement and was created in January 2001 under a $3 million startup grant from the State of New Jersey. The Commission's mandate is to safeguard the lake as a natural, scenic, and recreational resource. Some of the tools available to the Commission to accomplish this mandate are monitoring the lake's water quality and quantity; evaluating land use impacts; developing plans, strategies, policies, ordinances, and funding mechanisms; conducting lake management projects; and educating the public on how to protect the lake. A major component of the Lake Hopatcong Commission's protection effort is mechanical harvesting of the overgrowth of aquatic vegetation caused by the influx of phosphorus in the lake. The activity of aquatic plant harvesting began in Lake Hopatcong by the Lake Hopatcong Regional Planning Board and was transferred to the Lake Hopatcong Commission upon its creation. In 2002, the Commission removed over 4.8 million pounds of vegetation from the lake. The Commission has been engaged in a cooperative research effort with the U.S. Geological Survey to conduct a water budget study of Lake Hopatcong. The Commission has initiated plans to address stormwater discharges into Lake Hopatcong, because discharges from such nonpoint sources and catch basins are believed to be a major source of phosphorus in the lake. The Commission also has prepared a geomorphological report describing the Lake Hopatcong area.

Figure 4 Lakeshed of Lake Hopatcong

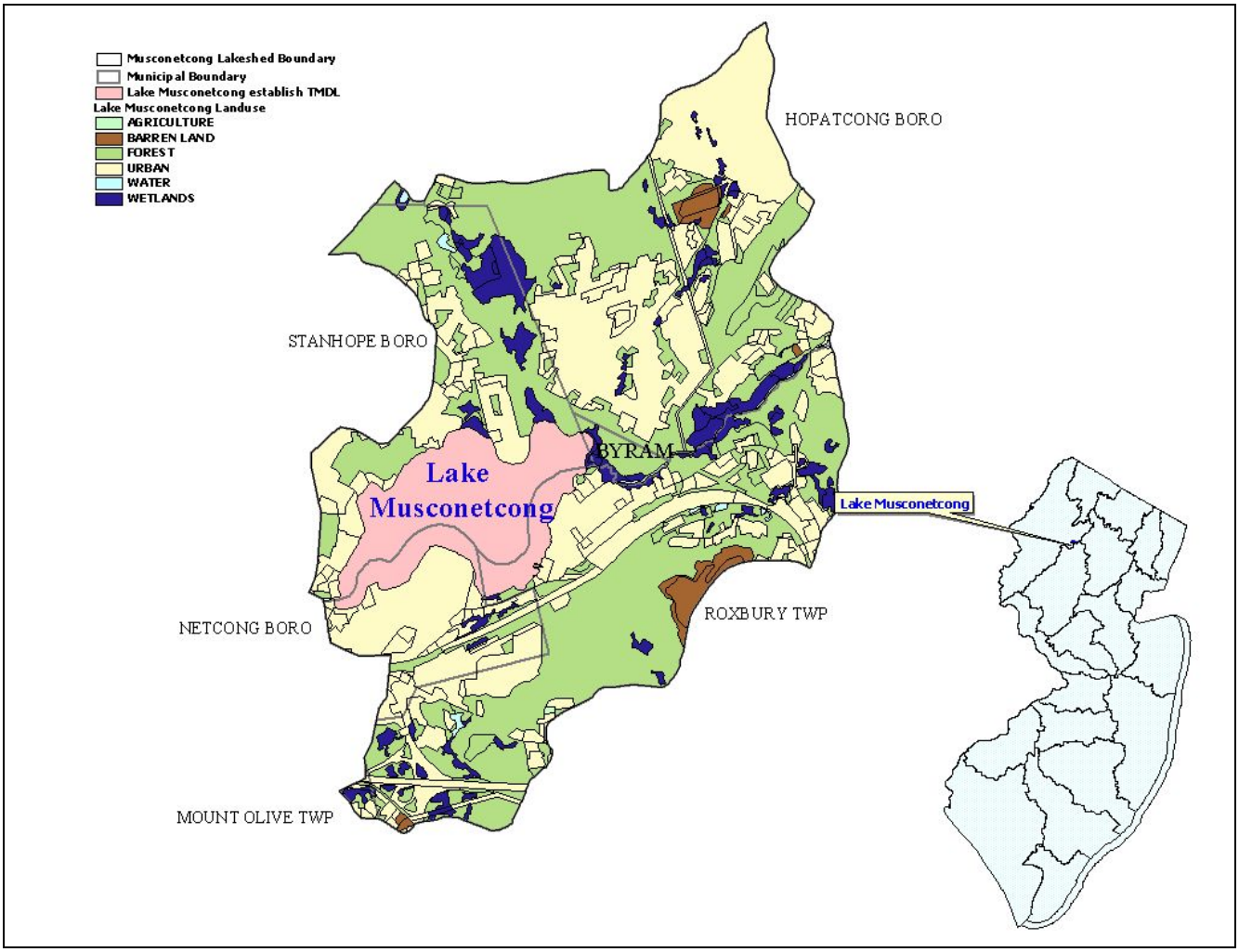


4.4 Lake Musconetcong

Lake Musconetcong is a 314-acre public lake located on the border of Morris and Sussex counties in the municipalities of Netcong, Stanhope, Byram and Roxbury. The lake drains an immediate lakeshed of 2,977 acres within the headwaters of the Musconetcong River Watershed. In addition, Lake Hopatcong drains into the immediate Lake Musconetcong lakeshed, adding 12,091 acres to the total lakeshed. Including the Lake Hopatcong lakeshed, the total lakeshed of Lake Musconetcong is 48 times the area of the lakes, making it very large relative to the size of the lake. Over 80% of the total flow into the lake consists of inflow from Lake Hopatcong through the Musconetcong River. Mean depth (1.5m) and total inflow (48,400,000 m^3/yr) were obtained from the Diagnostic / Feasibility Study for Lake Musconetcong (Coastal Environmental Services, 1993).

By far, the predominant land uses in the Lake Musconetcong lakeshed are forest, with 1,199 acres (40%), and urban, with 1,222 acres (41%). Low and medium density residential land uses surround most of the lakeshore itself. Fishing and boating accommodations are offered at the southern end of Lake Musconetcong. There are several municipal and State park areas on the lake available for fishing, one having a boat launch area. Several dozen private docks, but no public ones, can be found on the lake. Stanhope Beach was dredged several years ago, but it is used for fishing only, due to water conditions. The lake is being aided by two entities, the Musconetcong Regional Planning Board, which advises on land use matters affecting the lake, and the Musconetcong Watershed Association. As a result of the Phase I Clean Lakes project, the area immediately around the lake has been sewered and they have implemented weed harvesting, dredging, and various nonpoint source pollution controls. Lake Musconetcong has received Clean Water Act Section 319(h) funding for best management practices.

Figure 5 immediate Lakeshed of Lake Musconetcong



4.5 Swartswood Lake

This glacier lake, with a mean depth of 22 feet (deep lake) and a maximum depth of 42 feet, is 505 acres in size and located at Swartswood State Park in the Paulins Kill Watershed. Fishing and boating services are available on the east and south sides of the lake, and a swimming area is located on the border of the eastern shore and the State Park. The Swartwood Lakes and Watershed Association has been involved in stormwater projects funded by the Clean Water Act Section 319(h) grants to improve water quality, such as the recently completed five-unit hypolimnetic aeration system to halt deterioration and save the trout fishery. The lake had been suffering from large growths of aquatic weeds, algae, and low dissolved oxygen in deeper waters. Now that this public lake is being restored as a result of remediation projects involving weed harvesting, aeration, and nonpoint source controls, the Department agrees to follow up on its restoration to determine whether uses are still impaired. Malcolm Pirnie is currently performing a diagnostic/feasibility study of Swartswood Lake.

4.6 Clove Acres Lake

Clove Acres Lake is located in Wantage Township and Sussex Borough, Sussex County within the Wallkill River Watershed. The initial water quality evaluation for this shallow lake was completed approximately 20 years ago. Subsequently, the dam broke and the 28-acre lake drained. The lake has not been filled for most of the last fifteen years, during which time a limited amount of dredging took place. The dam was rebuilt and, during the summer of 2002, the lake started to refill. The Department will collect information and determine if the new lake is impaired. It should be noted that, based on the previous morphological and hydrological conditions and land use characteristics as of 1995, the Department estimates that the overall nonpoint source load of total phosphorus would have to be reduced by at least 64%. Currently, a consultant Fred Yoerg/Associates has been engaged to begin working on a lake management plan.

5.0 Applicable Surface Water Quality Standards

In order to prevent excessive primary productivity and consequent impairment of recreational, water supply and aquatic life designated uses, the Surface Water Quality Standards (SWQS, N.J.A.C. 7:9B) define both numerical and narrative criteria that address eutrophication in lakes due to overfertilization. The total phosphorous (TP) criterion for freshwater lakes at N.J.A.C. 7:9B – 1.14(c)5 reads as follows:

> For freshwater 2 classified lakes, Phosphorus as total phosphorus shall not exceed 0.05 mg/l in any lake, pond or reservoir or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed to satisfy N.J.A.C. 7:9B-1.5(g)3.

N.J.A.C. 7:9B-1.5(g)3 states:

> The Department may establish site-specific water quality criteria for nutrients in lakes, ponds, reservoirs or stream, in addition to or in place of the criteria in N.J.A.C. 7:9B-1.14, when necessary to protect existing or designated uses. Such criteria shall become part of the SWQS.

Presently, no site-specific criteria apply to any of these lakes.

Also at N.J.A.C. 7:9B-1.5(g)2, the following is discussed:

> Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, or otherwise render the waters unsuitable for the designated uses.

These TMDLs are designed to meet both numeric and narrative criteria of the SWQS.

All of the waterbodies covered under these TMDLs have a FW2 classification. The designated uses, both existing and potential, that have been established by the Department for waters of the State classified as such are as stated below:

In all FW2 waters, the designated uses are (N.J.A.C. 7:9B-1.12):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

6.0 Source Assessment

Phosphorus sources were characterized on an annual scale (kg TP/yr). Long-term pollutant loads are typically more critical to overall lake water quality than the load at any particular short-term time period (e.g. day). Storage and recycling mechanisms in the lake, such as luxury uptake and sediments dynamics, allow phosphorus to be used as needed regardless of the rate of delivery to the system. Also, empirical lake models use annual loads rather than daily or monthly loads to estimate in-lake concentrations.

6.1 Assessment of Point Sources other than Stormwater

Point sources of phosphorus other than stormwater were identified using the Department's GIS as all Major Municipal (MMJ), Minor Municipal (MMI), and Combined Sewer Overflow (CSO) discharges within each lakeshed. Other types of discharges, such as Industrial, were not included because their contribution, if any, is negligible compared to municipal discharges and runoff from land surfaces. No municipal point sources exist anywhere within the lakesheds of Cranberry Lake or Ghost Lake. One MMI, Arthur Stanlick School, discharges within the Lake Hopatcong lakeshed. The current annual TP load was estimated by multiplying the monthly average TP concentration of 0.314 mg TP/l by the average flow of 0.0014 million gallons per day (MGD), and converting to units of kg/yr. Average flow and concentration were calculated from data submitted to the Department as required in the form of Discharge Monitoring Reports. Similarly, the currently permitted annual TP load was estimated by multiplying the current TP concentration limit of 1.0 mg TP/l by the permitted flow of 0.013 MGD, and converting to units of kg/yr. Since Lake Hopatcong discharges into the Lake Musconetcong lakeshed, the point source was included only indirectly as part of the tributary load into Lake Musconetcong.

Table 3 Point Source Phosphorus Loads

Lake	NJPDES #	Facility Name	receiving water	current P load (kg TP/yr)	permitted P load (kg TP/yr)
Lake Hopatcong	NJ0021105	Arthur Stanlick School	Lake Shawnee	0.6	18.0

6.2 Assessment of Nonpoint Sources and Stormwater

Runoff from land surfaces comprises most of the nonpoint and stormwater sources of phosphorus into lakes. Watershed loads for total phosphorus were therefore estimated using the Unit Areal Load (UAL) methodology, which applies pollutant export coefficients obtained from literature sources to the land use patterns within the watershed, as described in USEPA's Clean Lakes Program guidance manual (Reckhow,1979b). Land use was determined using the Department's GIS system using the 1995/1997 land use coverage. The Department reviewed phosphorus export coefficients from an extensive database (Appendix B) and selected the land use categories and values shown in Table 4.

Table 4 Phosphorus export coefficients (Unit Areal Loads)

land use / land cover	LU/LC codes[3]	UAL (kg TP/ha/yr)
medium / high density residential	1110, 1120, 1150	1.6
low density / rural residential	1130, 1140	0.7
Commercial	1200	2.0
Industrial	1300, 1500	1.7
mixed urban / other urban	other urban codes	1.0
Agricultural	2000	1.5
forest, wetland, water	4000, 6000, 5000	0.1
barren land	7000	0.5

Units: 1 hectare (ha) = 2.47 acres
1 kilogram (kg) = 2.2 pounds (lbs)
1 kg/ha/yr = 0.89 lbs/acre/yr

For all lakes in this TMDL document, a UAL of 0.07 kg TP/ha/yr was used to estimate air deposition of phosphorus directly onto the lake surface. This value was developed from statewide mean concentrations of total phosphorus from the New Jersey Air Deposition Network (Eisenreich and Reinfelder, 2001). For Lake Musconetcong, land use runoff loads were only calculated for the immediate watershed downstream of Lake Hopatcong. An additional annual tributary load from Lake Hopatcong into Lake Musconetcong was estimated by multiplying the annual discharge from the lake by the mean phosphorus concentration as calculated under Current Condition in section 7.1 below. Land uses and calculated runoff loading rates for each of the lakes are shown in Table 5. Also included in Table 5 are estimates of loading rates from septic systems and from internal sources (sediment regeneration, macrophyte decomposition, and/or groundwater) developed

[3] LU/LC code is an attribute of the land use coverage that provides the Anderson classification code for the land use. The Anderson classification system is a hierarchical system based on four digits. The four digits represent one to four levels of classification, the first digit being the most general and the fourth digit being the most specific description.

previously (Coastal Environmental Services, 1992; Princeton Aqua Science, 1983; Coastal Environmental Services, 1993; Princeton Hydro, 2002) for each of the lakes.

Table 5 Nonpoint and Stormwater Sources of Phosphorus Loads*

	Cranberry Lake		Lake Hopatcong		Lake Musconetcong		Ghost Lake	
Nonpoint Source	**acres**	**Kg TP/yr**	**acres**	**Kg TP/yr**	**acres**	**Kg TP/yr**	**acres**	**Kg TP/yr**
medium / high density residential	156	101	2,790	1,800	759	492	0.0	0.0
low density / rural residential	9.0	2.5	423	120	116	32.9	3.2	0.9
commercial	1.5	1.2	237	192	107	86.9	0.0	0.0
industrial	0.0	0.0	7.7	5.3	37.1	25.6	0.0	0.0
mixed urban / other urban	0.0	0.0	521	211	207	83.7	0.0	0.0
agricultural	0.4	0.2	0	0	0.9	0.5	0.4	0.3
forest, wetland, water	1,380	55.9	9,670	391	1,360	55.2	190	7.7
barren land	6.8	1.4	165	33.3	72.6	14.7	0.0	0.0
Direct air deposition on lake surface	190	5.4	2,410	68.2	314	8.9	18.3	0.5
septic systems	n/a	731	n/a	1,600	n/a		n/a	
internal load	n/a	104	n/a	595	n/a	151	n/a	12.4
tributary load	n/a		n/a		n/a	1,240	n/a	
TOTAL	1,740	1,000	16,200	5,020	2,980	2,190	211	21.8

* all figures rounded to not more than three significant digits

7.0 Water Quality Analysis

Empirical models were used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. These empirical models consist of equations derived from simplified mass balances that have been fitted to large datasets of actual lake measurements. The resulting regressions can be applied to lakes that fit within the range of hydrology, morphology and loading of the lakes in the model database. The Department surveyed the commonly used models in Table 6.

Table 6 Empirical models considered by the Department

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Rast, Jones and Lee, 1983	$1.81 \times NPL^{0.81}$	$NPL = \left(\frac{P_a \times DT / D_m}{1 + \sqrt{DT}} \right)$	expanded database of mostly large lakes
Vollenweider and Kerekes, 1982	$1.22 \times NPL^{0.87}$	$NPL = \left(\frac{P_a \times DT / D_m}{1 + \sqrt{DT}} \right)$	mostly large natural lakes
Reckhow, 1980	$\frac{P_a}{13.2}$	none	Upper bound for closed lake
Reckhow, 1979a	$\frac{P_a}{(11.6 + 1.2 \times Q_a)}$	$Q_a = \frac{Q_i}{A_l}$	General north temperate lakes, wide range of loading concentration, areal loading, and water load

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Walker, 1977	$\frac{P_a \times DT/D_m}{\left(1+0.824\times DT^{0.454}\right)}$	none	oxic lakes with $D_m/DT < 50$ m/yr
Jones and Bachmann, 1976	$\frac{0.84\times P_a}{\left(D_m\times\left(0.65+DT^{-1}\right)\right)}$	none	may overestimate P in shallow lakes with high D_m/DT
Vollenweider, 1975	$\frac{P_a}{\left(D_m\times\left(DT^{-1}+S\right)\right)}$	$S = 10/D_m$	Overestimate P lakes with high D_m/DT
Dillon-Kirchner, 1975	$\frac{P_a}{\left(13.2+D_m/DT\right)}$	none	low loading concentration range
Dillon-Rigler, 1974	$P_a \times DT/D_m \times\left(1-R\right)$	R = phosphorus retention coefficient	general form
Ostrofksy, 1978	Dillon-Rigler, 1974	$R = 0.201\times e^{\left(-0.0425\times Q_a\right)} + 0.5743\times e^{-0.00949*Q_a}$	lakes that flush infrequently
Kirchner-Dillon, 1975	Dillon-Rigler, 1974	$R = 0.426\times e^{\left(-0.271\times D_m/DT\right)} + 0.5743\times e^{-0.00949*D_m/DT}$	general application
Larsen-Mercier, 1975	Dillon-Rigler, 1974	$R = \frac{1}{1+\sqrt{1/DT}}$	Unparameterized form

where:
NPL = normalized phosphorus loading
P_a = areal phosphorus loading ($g/m^2/yr$)
DT = detention time (yr)
D_m = mean depth (m)
Qa = areal water load (m/yr) [4]
Q_i = total inflow (m^3/yr)
A_l = area of lake (m^2)
S = settling rate (per year)

Reckhow (1979a) model was selected because it has the broadest range of hydrologic, morphological and loading characteristics in its database. Also, the model includes an uncertainty estimate that was used to calculate a Margin of Safety. The Reckhow (1979a) model is described in USEPA Clean Lakes guidance documents: Quantitative Techniques for the Assessment of Lake Quality (Reckhow, 1979b) and Modeling Phosphorus Loading and Lake Response Under Uncertainty (Reckhow *et al*, 1980). The derivation of the model is

[4] Areal water load is defined as the annual water load entering a lake divided by the area of the lake. Since, under steady-state conditions, the water coming in to the lake is equal to the water leaving the lake, either total inflow or total outflow can be used to calculate areal water load. If different values were reported for total inflow and total outflow, the Department used the higher of the two to calculate areal water load.

summarized in Appendix C. The model relates TP load to steady state TP concentration, and is generally applicable to north temperate lakes, which exhibit the following ranges of characteristics (see Symbol definitions after Table 5):

phosphorus concentration:	$0.004 < P < 0.135$ mg/l
average influent phosphorus concentration:	$P_a*DT/D_m < 0.298$ mg/l
areal water load:	$0.75 < Q_a < 187$ m/yr
areal phosphorus load:	$0.07 < P_a < 31.4$ g/m²/yr

For comparison, Table 7 below summarizes the characteristics for each lake based on their current and target conditions as described below. While the target concentration for each lake (section 7) is well within the range, the areal phosphorus load provides a better representation of a lake's intrinsic loading characteristics. Also, it is the model's prediction of target condition that is being used to calculate the TMDL; if current loads are higher than the range that can produce reliable model results, this has no affect on the model's reliability to predict target condition under reduced loads. It should also be noted that no attempt was made to recalibrate the Reckhow (1979a) model for lakes in New Jersey or in this Water Region, since sufficient lake data were not available to make comparisons with model predictions of steady-state in-lake concentration of total phosphorus. The model was already calibrated to the dataset on which it is based, and is generally applicable to north temperate lakes that exhibit the range of characteristics listed previously.

Table 7 Hydrologic and loading characteristics of lakes

Lake	Current Avg Influent [TP] (mg/l)	Target Avg Influent [TP] (mg/l)	Current Areal TP load (g/m²/yr)	Target Areal TP load (g/m²/yr)	Areal Water Load (m/year)
Cranberry Lake	0.265	0.071	1.31	0.35	4.9
Ghost Lake	0.049	0.049	0.19	0.19	6.0
Lake Hopatcong	0.126	0.080	0.52	0.33	4.1
Lake Musconetcong	0.045	0.030	1.73	1.14	38.1

7.1 Current Condition

Using these estimated physical parameters and current loads, the predicted steady-state phosphorus concentration of each lake was calculated using the Reckhow (1979a) formulation and listed in Table 8. The current phosphorus load distribution for each lake is shown in Figures 6 to 9 below.

Figure 6 **Current distribution of phosphorus load for Cranberry Lake**

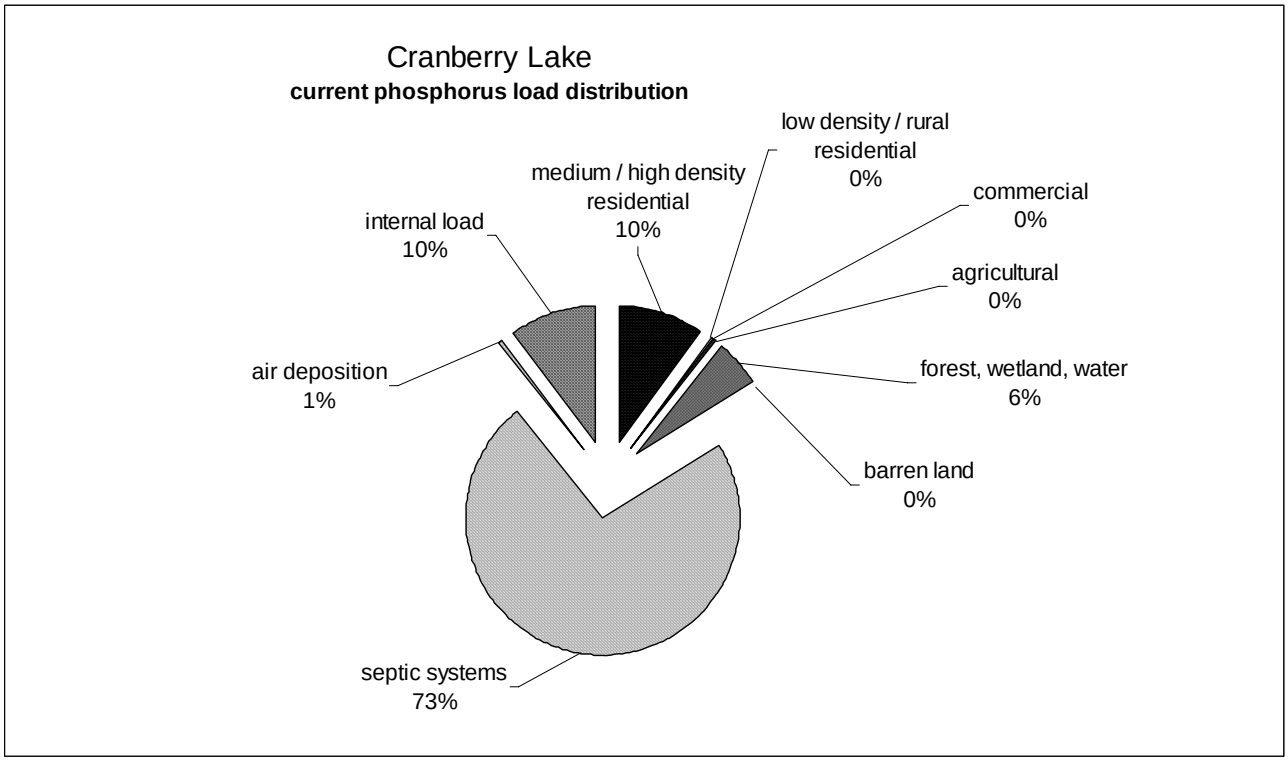


Figure 7 **Current distribution of phosphorus load for Ghost Lake**

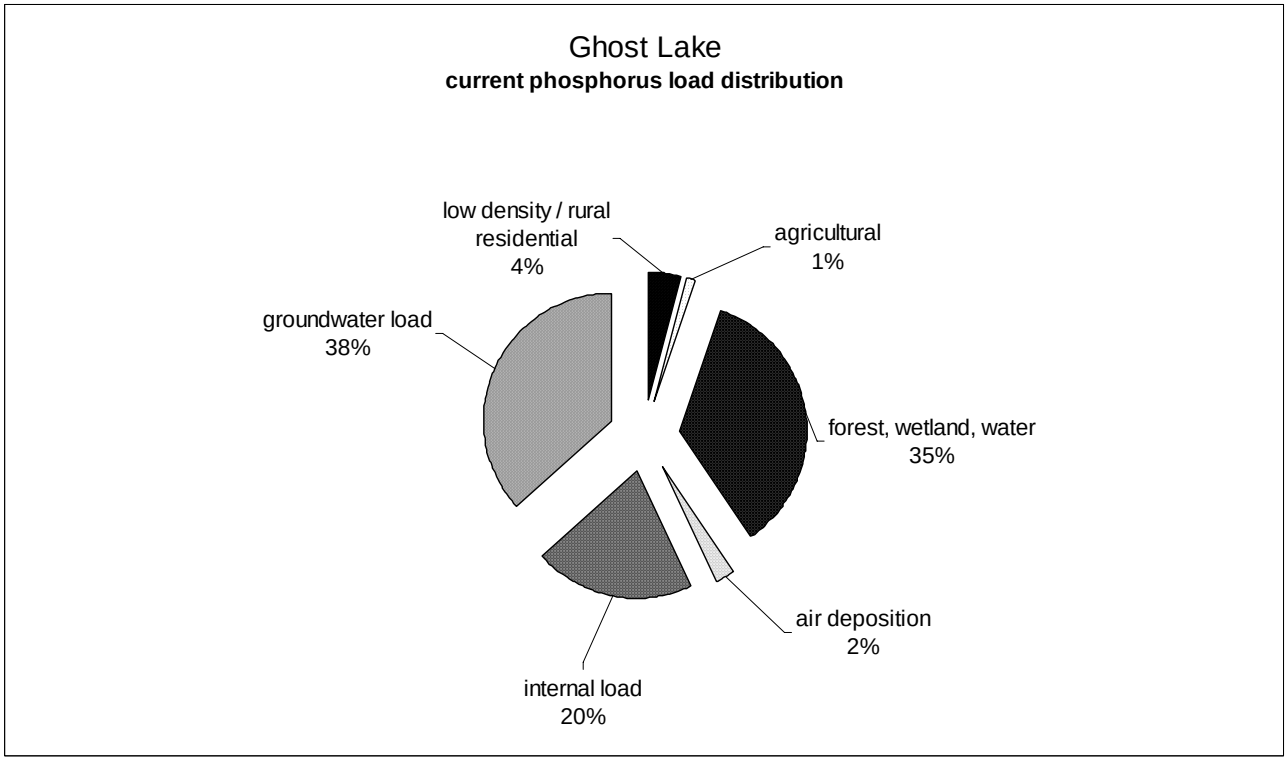


Figure 8 **Current distribution of phosphorus load for Lake Hopatcong**

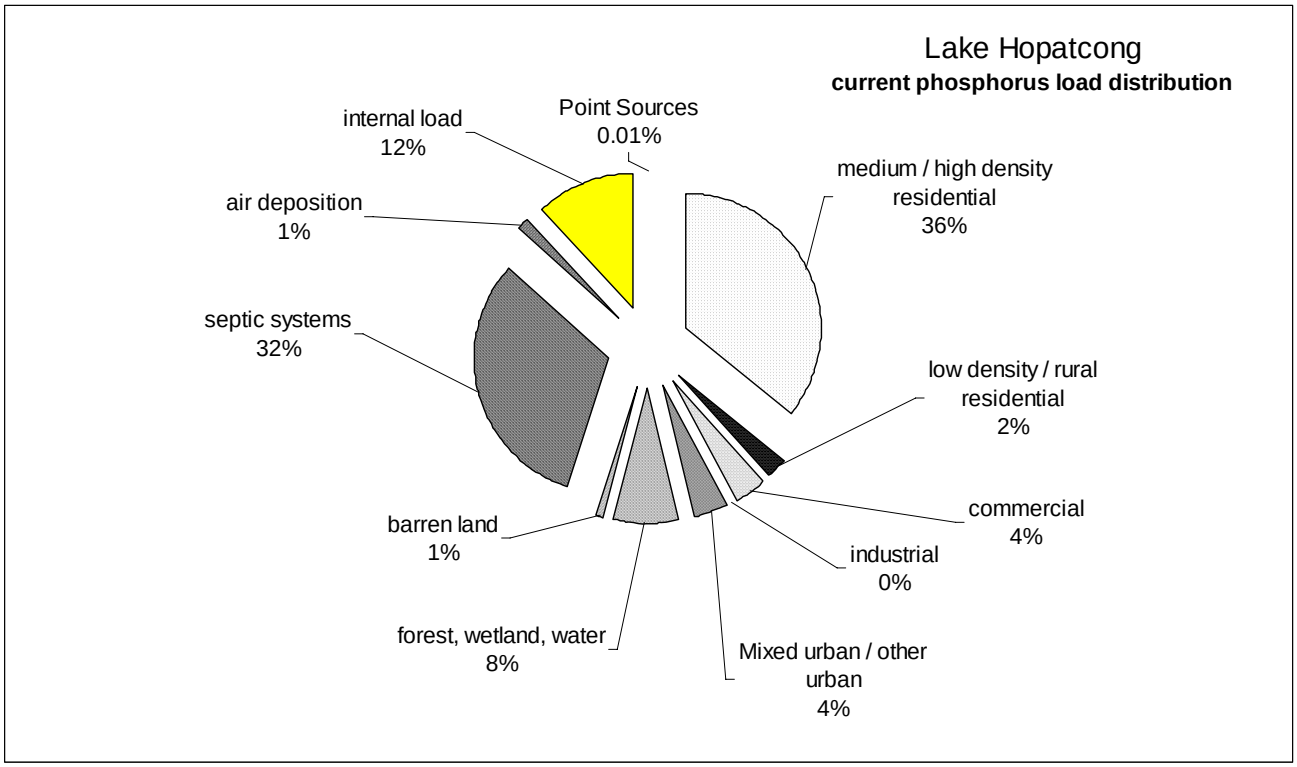
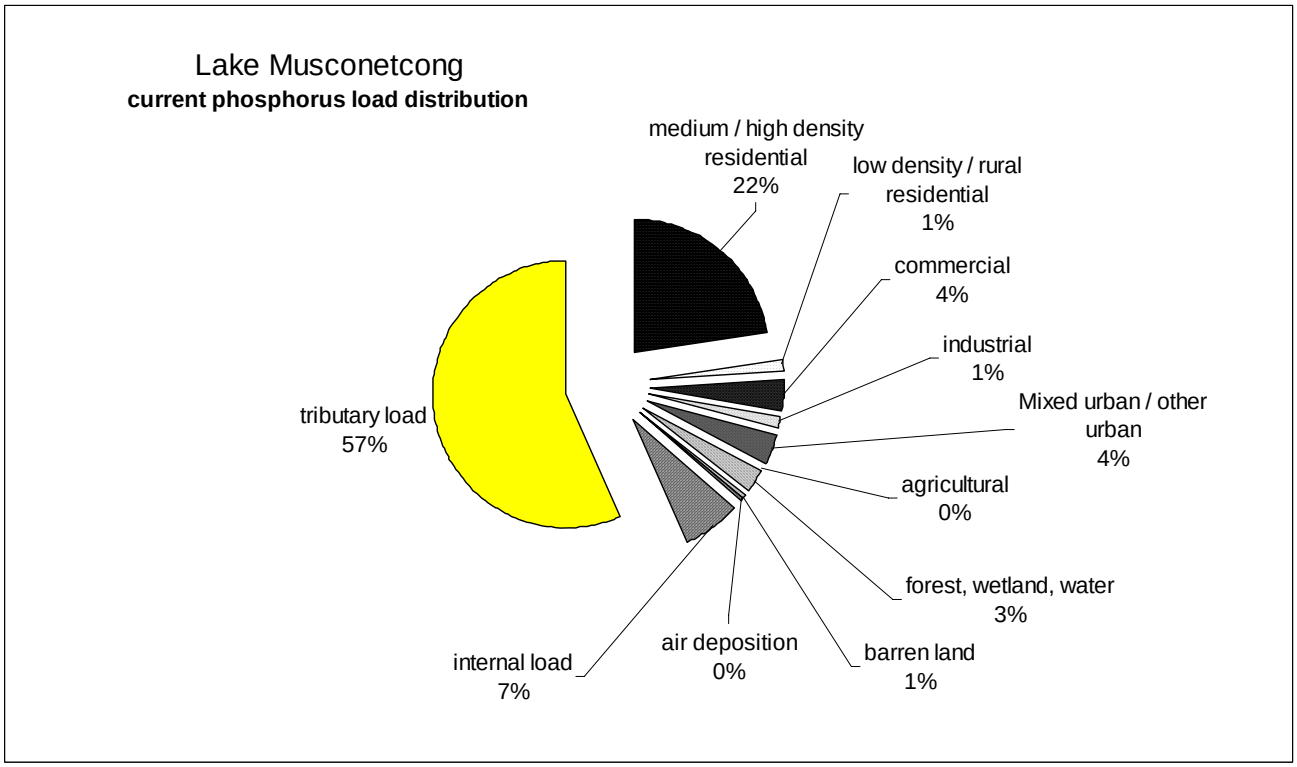


Figure 9 **Current distribution of phosphorus load for Lake Musconetcong**



7.2 Reference Condition

A reference condition for each lake was estimated by calculating external loads as if the land use throughout the lakeshed were completely forest and wetlands. Using the same physical parameters and external loads from forest and wetlands, a reference steady-state phosphorus concentration was calculated for each lake using the Reckhow (1979a) formulation and listed in Table 8.

7.3 Seasonal Variation/Critical Conditions

These TMDLs will attain applicable surface water quality standards year round. The Reckhow model predicts steady-state phosphorus concentration. To account for data variability, the Department generally interprets threshold criteria as greater than 10% exceedance for the purpose of defining impaired waterbodies. Data from two lakes in New Jersey for which the Department had ready access to data (Strawbridge Lake, NJDEP 2000a; Sylvan Lake, NJDEP 2000b) exhibit peak (based on the 90th percentile) to mean ratios of 1.56 and 1.48, resulting in target phosphorus concentrations of 0.032 and 0.034 mg TP/l, respectively. Since the peak to mean ratios were close and the target concentration not very sensitive to differences in peak to mean ratios, the Department determined that a target phosphorus concentration of 0.03 mg TP/l is reasonably conservative. The seasonal variation was therefore assumed to be 67%, resulting in a target phosphorus concentration of 0.03 mg TP/l. Since it is the annual pollutant load rather than the load at any particular time that determines overall lake water quality (section 6), the target phosphorus concentration of 0.03 mg TP/l accounts for critical conditions.

7.4 Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality." (40 CFR 130.7(c)). A MOS is required in order to account for uncertainty in the loading estimates, physical parameters and the model itself. The margin of safety, as described in USEPA guidance (Sutfin, 2002), can be either explicit or implicit (i.e., addressed through conservative assumptions used in establishing the TMDL). For these TMDL calculations, an implicit as well as explicit Margin of Safety (MOS) is provided.

These TMDLs contain an implicit margin of safety by using conservative critical conditions, over-estimated loads, and total phosphorus. Each conservative assumption is further explained below.

Critical conditions are accounted by comparing peak concentrations to mean concentrations and adjusting the target concentration accordingly (0.03 mg TP/l instead of 0.05 mg TP/l). In addition to the conservative approach used for critical conditions, the land use export methodology does not account for the distance between the land use and the lake, which will result in phosphorus reduction due to adsorption onto land surfaces and in-stream kinetic processes**.** Furthermore, the lakesheds are based on topography without accounting for the

diversion of stormwater from lakes, which is common in urban areas. Neither are any reductions assumed due to the addition of lakeside vegetative buffer construction or other management practices aimed at minimizing phosphorus loads. Finally, the use of total phosphorus, as both the endpoint for the standard and in the loading estimates, is a conservative assumption. Use of total phosphorous does not distinguish readily between dissolved orthophosphorus, which is available for algal growth, and unavailable forms of phosphorus (e.g. particulate). While many forms of phosphorus are converted into orthophosphorus in the lake, many are captured in the sediment, for instance, and never made available for algal uptake.

In addition to the multiple conservative assumptions built in to the calculation, an additional explicit margin of safety was included to account for the uncertainty in the model itself. As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. Transforming the terms in the model error analysis from Reckhow *et al* (1980) yields the following (Appendix D):

$$MoS_p = \sqrt{1/((1-\rho)*4.5)} \times \left(10^{0.128} - 1\right),$$

where: MoS_p = margin of safety as a percentage over the predicted phosphorus concentration;

ρ = the probability that the real phosphorus concentration is less than or equal to the predicted phosphorus concentration plus the margin of safety as a concentration.

Setting the probability to 90% yields a margin of safety of 51% when expressed as a percentage over predicted phosphorus concentration or estimated external load. The external load for each lake was therefore multiplied by 1.51 to calculate an "upper bound" estimate of steady-state phosphorus concentration. An additional explicit margin of safety was included in the analyses by setting the upper bound calculations equal to the target phosphorus concentration of 0.3 mg TP/l, as described in the next section and shown in Table 8. Note that the explicit Margin of Safety is equal to 51% when expressed as a percentage over the predicted phosphorus concentration; when expressed as a percentage of total loading capacity, the Margin of Safety is equal to 34%:

$$\left(MoS_{lc} = \frac{MoS_p \times P}{P + (MoS_p \times P)} = \frac{MoS_p}{1 + MoS_p} = \frac{0.51}{1.51} = 0.34\right),$$

where: MoS_p = margin of safety expressed as a percentage over the predicted phosphorus concentration or external load;

MoS_{lc} = margin of safety as a percentage of total loading capacity;

P = predicted phosphorus concentration (or external load).

7.5 Target Condition

As discussed above, the current steady state concentration of phosphorus in each lake must be reduced to a steady state concentration of 0.03 mg/l to avoid exceeding the 0.05 mg/l phosphorus criterion. Using the Reckhow (1979a) formulation, the target conditions were calculated by reducing the loads as necessary to make the upper bound predictions (which incorporate the Margin of Safety) equal to the target phosphorus concentration of 0.03 mg TP/l. The target condition for Ghost Lake was set equal to the current condition, since the upper bound prediction assuming current loads is already less than the target phosphorus concentration of 0.03 mg TP/l. The target condition for Lake Hopatcong was used to calculate the tributary load for the target condition of Lake Musconetcong. Overall reductions necessary to attain the target steady state concentration of total phosphorus in each lake were calculated by comparing the current condition to the target condition (Table 8).

Table 8 Current condition, reference condition, target condition and overall percent reduction for each lake

Lake	current condition [TP] (mg/l)	reference condition [TP] (mg/l)	upper bound target condition [TP] (mg/l)	target condition [TP] (mg/l)	% overall TP load reduction
Cranberry Lake	0.075	0.005	0.030	0.020	73%
Ghost Lake	0.016	0.006	0.024	0.016	0%
Lake Hopatcong	0.031	0.004	0.030	0.020	36%
Lake Musconetcong	0.030	0.011	0.030	0.020	34%

8.0 TMDL Calculations

8.1 Loading Capacity

The Reckhow (1979a) model was used to solve for loading rate given the upper bound target concentration of 0.03 mg/l (which incorporates the Margin of Safety). Reducing the current loading rates by the percentages in Table 8 yields the same results. The acceptable loading capacity for each lake is provided in Table 10.

8.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included at this time. Therefore, the loading capacities and accompanying WLAs and LAs must be attained in consideration of any new sources that may accompany future development. The primary means by which future growth could increase phosphorus load is through the development of forest land within the lakesheds. The implementation plan includes the development of Lake Restoration Plans that require the collection of more detailed information about each lakeshed. If the development of forest with the watershed of a particular lake is planned, the issue of reserve capacity to account for the additional runoff load of phosphorus may be revisited.

8.3 Allocations

USEPA regulations at 40 CFR § 130.2(i), state that "pollutant loadings may be expressed in terms of either mass per time, toxicity, or other appropriate measure." For lake nutrient TMDLs, it is appropriate to express the TMDL on a yearly basis. Long-term average pollutant loadings are typically more critical to overall lake water quality due to the storage and recycling mechanisms in the lake. Also, most available empirical lake models, such as the Reckhow model used in this analysis, use annual loads rather than daily loads to estimate in-lake concentrations.

The TMDLs for total phosphorus are therefore calculated as follows (Table 10):

TMDL = loading capacity
= Sum of the wasteload allocations (WLAs) + load allocations (LAs) + margin of safety + reserve capacity.

WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system." (Wayland, November 2002, p.1) While the Department does not have the data to actually delineate lakesheds according to stormwater drainage areas subject to NJPDES regulation, the land use runoff categories previously defined can be used to estimate between them. Therefore allocations are established according to source categories as shown in Table 9. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs, including Table 9, shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES. WLAs are hereby established for all NJPDES-regulated point sources, including stormwater, according to their source category. Quantifying WLAs and LAs according to source categories provides the best estimation defined as narrowly as data allow. However it is clearly noted that WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. The WLAs and LAs in Table 9 are not themselves "Additional Measures" under proposed N.J.A.C. 7:14A-25.6 or 25.8.

Table 9 Distribution of WLAs and LAs among source categories

Source category	TMDL allocation
Point Sources other than Stormwater	WLA
Nonpoint and Stormwater Sources	
medium / high density residential	WLA
low density / rural residential	WLA
commercial	WLA
industrial	WLA
Mixed urban / other urban	WLA
agricultural	LA
forest, wetland, water	LA
barren land	LA
air deposition onto lake surface	LA
septic systems	LA
internal load	LA
tributary load	LA

In order to attain the TMDLs, the overall load reductions shown in Table 8, or those determined through additional monitoring, must be achieved. Since loading rates have been defined for at least eight source categories, countless combinations of source reductions could be used to achieve the overall reduction target. The selected scenarios focus on land use and septic sources that can be affected by BMP implementation or NJPDES regulation, requiring equal percent reductions from each in order to achieve the necessary overall load reduction (Table 10). The Lake Restoration Plans developed for each lake as part of the TMDL implementation (section 10) may revisit the distribution of reductions among the various sources in order to better reflect actual implementation projects. The resulting TMDLs, rounded to two significant digits, are shown in Table 10 and illustrated in Figures 10 to 13.

The WLA of 5.5 kg TP/yr for Arthur Stanlick School was calculated by multiplying the current TP concentration limit of 1.0 mg TP/l by the 20-year planned flow of 0.004 MGD, and converting to units of kg/yr. This WLA represents about a 70% decrease from currently permitted annual TP load of 18 kg/yr; however, the actual current annual TP load is only 0.6 kg/yr (section 6.1). Since the WLA represents only 0.1% of the loading capacity for Lake Hopatcong, reduction of the currently permitted concentration limit is not justified. However a WLA was established for this facility in order to prevent the source from becoming significant by incorporating the 20-year planned flow into the next permit. The resulting TMDLs, rounded to two significant digits, are shown in Table 10 and illustrated in Figures 10 to 13.

Table 10 TMDL calculations for each lake (annual loads and percent reductions[a])

lake	Cranberry Lake		% reduction	Ghost Lake		% reduction
	kg TP/yr	% of LC		kg TP/yr	% of LC	
loading capacity (LC)	400	100%	n/a	33	100%	n/a
Point Sources other than Stormwater	n/a			n/a		
Nonpoint and Stormwater Sources						
medium / high density residential	12	3.0%	88%	0.00	0.0%	n/a
low density / rural residential	0.30	0.08%	88%	0.91	2.8%	0%
commercial	0.15	0.04%	88%	0.00	0.0%	n/a
industrial	0.00	0.00%	n/a	0.00	0.0%	n/a
Mixed urban / other urban	0.00	0.00%	n/a	0.00	0.0%	n/a
agricultural	0.23	0.06%	0%	0.27	0.81%	0%
forest, wetland, water	56	14%	0%	7.7	23%	0%
barren land	1.4	0.34%	0%	0.00	0.0%	n/a
air deposition onto lake surface	5.4	1.3%	0%	0.52	1.6%	0%
septic systems	87	22%	88%			
internal load	100	26%	0%	12	38%	0%
Other Allocations						
explicit Margin of Safety	140	34%	n/a	11	34%	n/a
Reserve Capacity	n/a			n/a		

lake	Lake Hopatcong		% reduction	Lake Musconetcong		% reduction
	kg TP/yr	% of LC		kg TP/yr	% of LC	
loading capacity (LC)	4800	100%	n/a	2200	100%	n/a
Point Sources other than Stormwater	5.5	0.11%	69%[b]	n/a		
Nonpoint and Stormwater Sources						
medium / high density residential	960	20%	47%	290	13%	41%
low density / rural residential	64	1.3%	47%	20	0.89%	41%
commercial	100	2.1%	47%	52	2.4%	41%
industrial	2.8	0.06%	47%	15	0.69%	41%
Mixed urban / other urban	110	2.3%	47%	50	2.3%	41%
agricultural	0.0	0.0%	n/a	0.52	0.02%	0%
forest, wetland, water	390	8.1%	0%	55	2.5%	0%
barren land	33	0.69%	0%	15	0.67%	0%
air deposition onto lake surface	68	1.4%	0%	8.9	0.41%	0%
septic systems	850	18%	47%	n/a		
internal load	600	12%	0%	150	6.9%	0%
tributary load	n/a			790	36%	36%
Other Allocations						
explicit Margin of Safety	1600	34%	n/a	740	34%	n/a
Reserve Capacity	n/a			n/a		

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 7.

b Percent reduction for point source is compared to currently permitted annual load, not actual current load.

Figure 10 **Phosphorus allocations for Cranberry Lake TMDL**

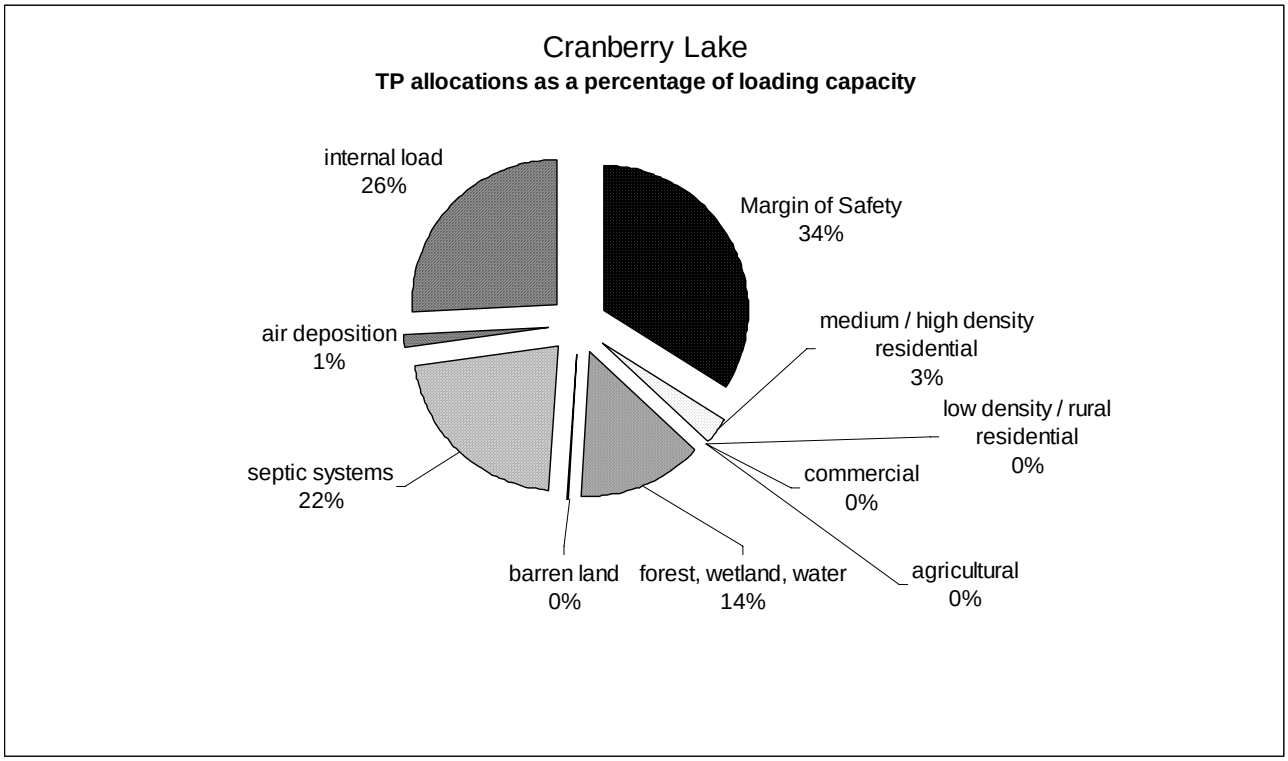


Figure 11 **Phosphorus allocations for Ghost Lake**

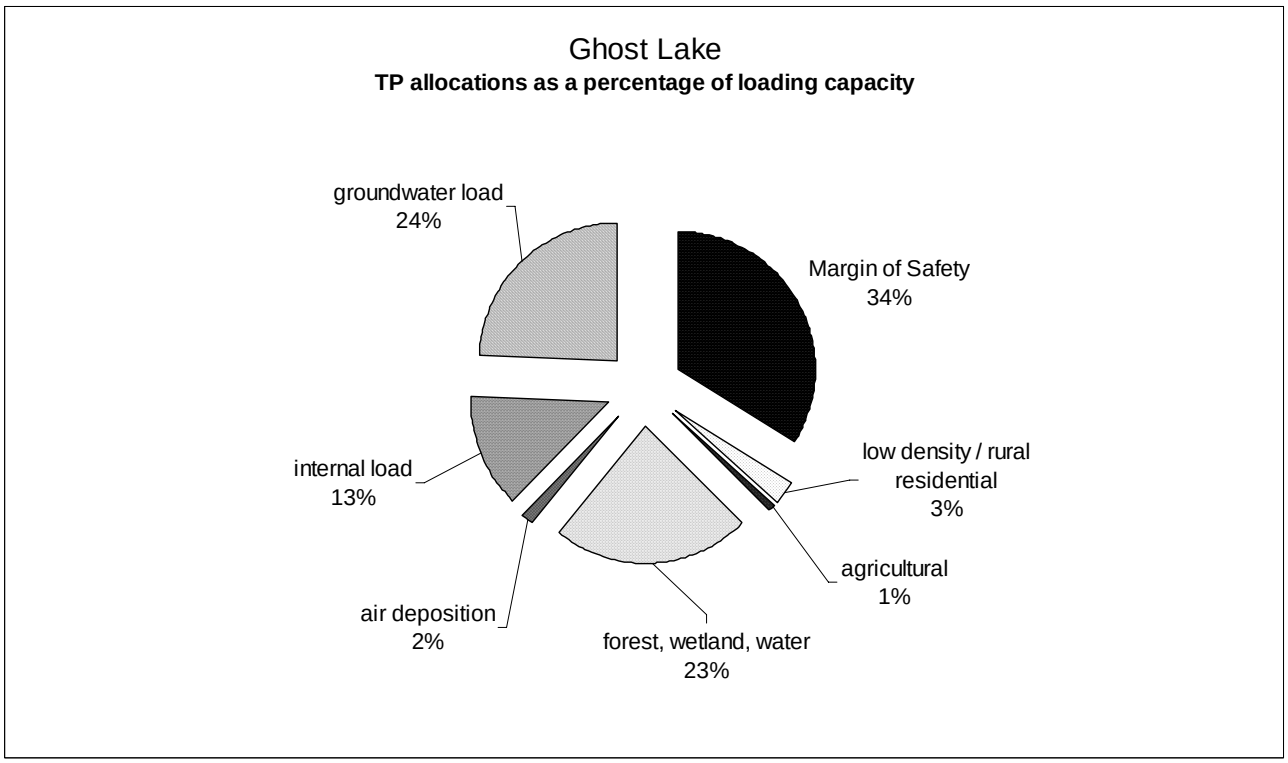


Figure 12 **Phosphorus allocations for Lake Hopatcong TMDL**

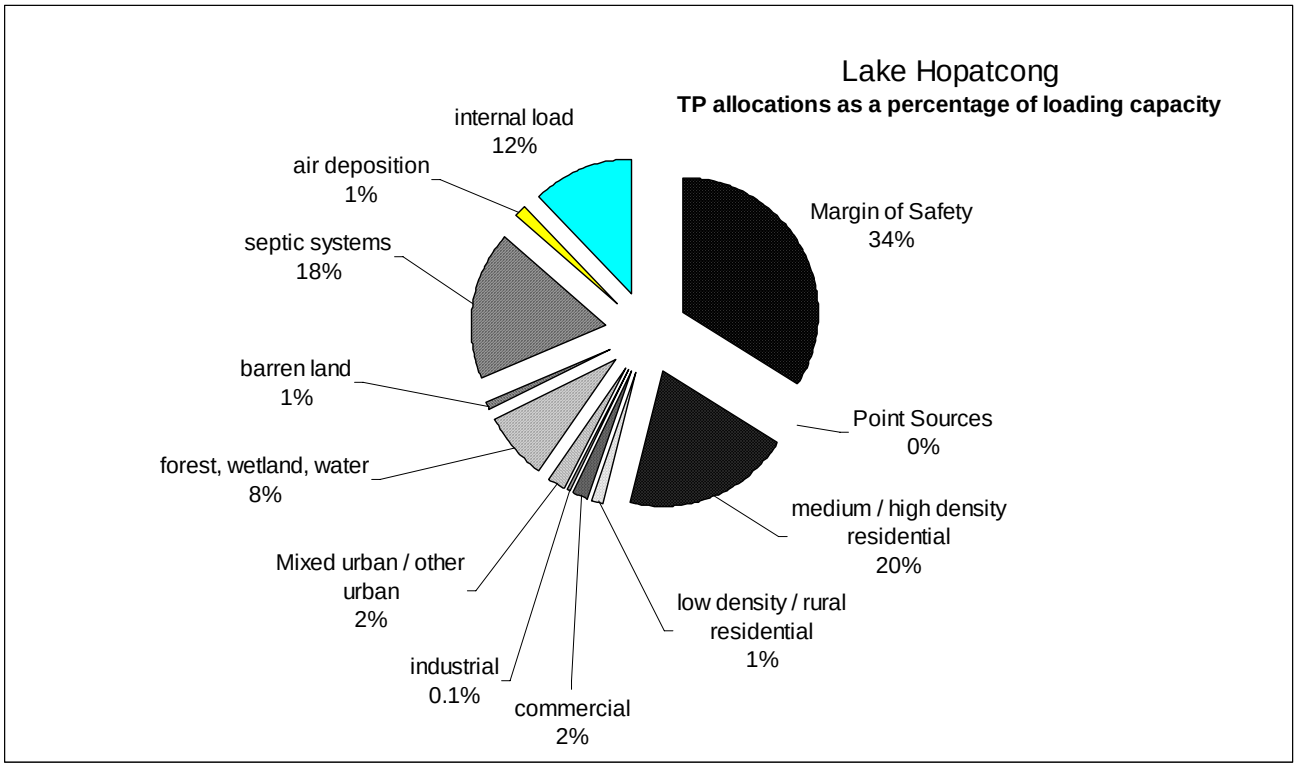
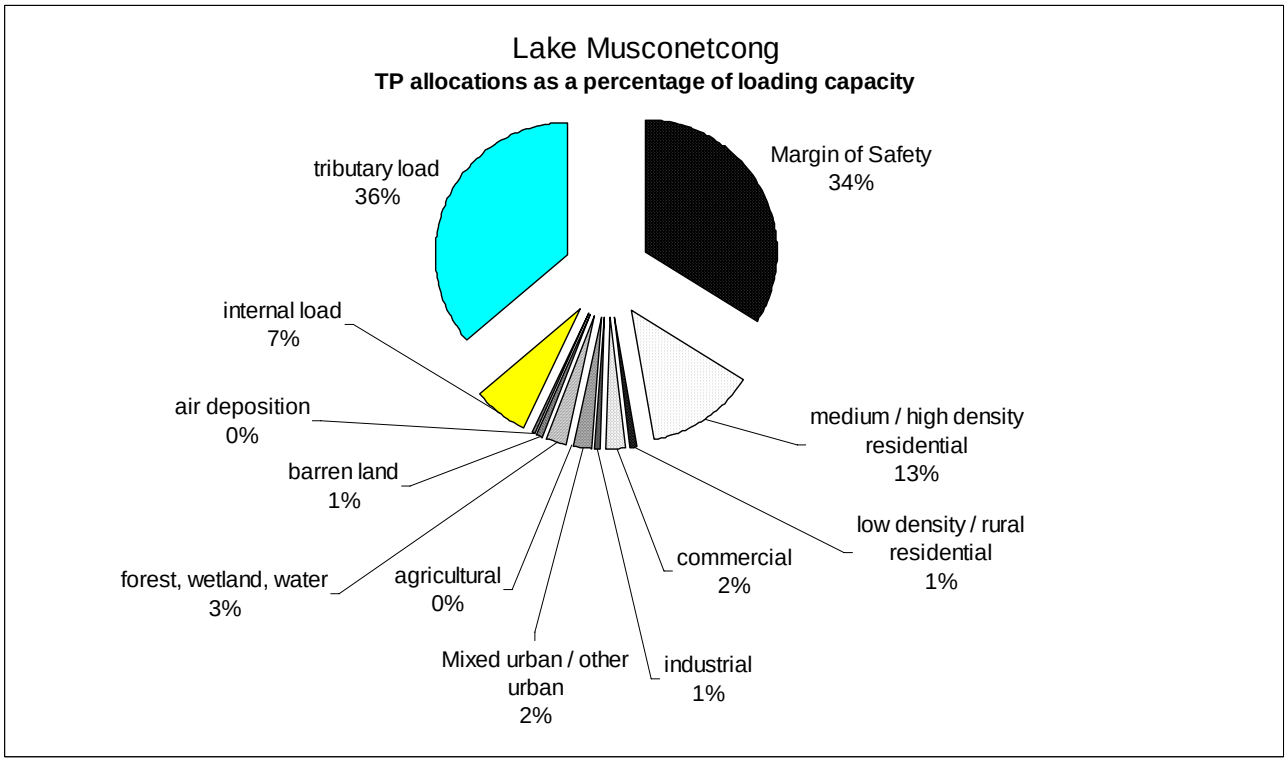


Figure 13 **Phosphorus allocations for Lake Musconetcong TMDL**



9.0 Follow-up Monitoring

In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will augment its ambient monitoring program to include lakes on a rotating schedule. The details of a new Lakes Monitoring Network will be published by December 31, 2003. Lakes for which remediation measures have been performed will be given top priority on whatever rotating schedule is developed.

Follow-up monitoring will include evaluations (qualitative using a field index or quantitative) of algal blooms (presence, severity, extent) and aquatic vegetation (density, extent, diversity). Measurements such as secchi depths, nutrient concentrations, and chlorophyll-*a* will be included, in addition to dissolved oxygen, temperature and pH profiles. Basic hydrologic and morphometric information will be measured as necessary to obtain current data, including discharge and bathymetry. The details as to what data will be collected by the Lakes Monitoring Network will be included in the network description.

10.0 Implementation

The next steps toward implementation are preparation of lake characterizations and lake restoration plans, where they have not already been developed. In the development of these plans, the loads by source will be revised, as necessary, to reflect refinements in source contributions. It will be on the basis of refined source estimates that specific strategies for reduction will be developed. These will consider issues such as cost and feasibility when specifying the reduction target for any source or source type. As appropriate, WLAs or other measures to be applied to traditional or stormwater point sources through NJPDES permits will be adopted by the Department as amendments to the applicable areawide Water Quality Management Plan.

The Department recognizes that TMDLs alone are not sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides the regulatory framework to effect those reductions. However, the nutrient load only affects the eutrophication potential of a lake. The implementation plan therefore calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake. The plans will consider in-lake measures that need to be taken to supplement the nutrient reduction measures required by the TMDL. In addition, the plans will consider the ecology of the lake and adjust the eutrophication indicator target as necessary to protect the designated uses.

For instance, with the exception of Lake Hopatcong, all of these lakes are shallow lakes, as defined by having a mean depth less than 3 meters. Even Lake Hopatcong includes many basins that behave like shallow lakes, such as Woodport Bay. For a lake to be shallow means that most of the lake volume is within the photic zone and therefore more able to support aquatic plant growth (Holdren *et al*, 2001). Shallow lakes are generally characterized by either

abundant submerged macrophytes and clear water or by abundant phytoplankton and turbid water. From an aquatic life and biodiversity perspective, it is desirable for shallow lakes to be dominated by aquatic plants rather than algae, especially phytoplankton. While lower nutrient concentrations favor the clear/plant state, either state can persist over a wide range of nutrient concentrations. Shallow lakes have ecological stabilizing mechanisms that tend to resist switches from clear/plant state to turbid/algae state, and vice-versa. The clear/plant state is more stable at lower nutrient concentrations and irreversible at very low nutrient concentrations; the turbid/algae state is more stable at higher nutrient concentrations. The Lake Restoration Plans for each lake will need to consider the ecological nuances of shallow and deep lakes.

The State of New Jersey has adopted a watershed approach to water quality management. That plan divides the state into five watershed management regions, one of which is the Northwest Region. The Department recognizes that lake restoration requires a watershed approach. Lake Restoration Plans will be used as a basis to address overfertilization and sedimentation issues in watersheds that drain to these sensitive lakes. In addition, the Department will direct research funds to understand and demonstrate biomanipulation and other techniques that can be applied in New Jersey lakes to promote the establishment of healthy and diverse aquatic plant communities in shallow lakes. Finally, public education efforts will focus on the benefits of aquatic plants in shallow lakes and the balance of aquatic life uses with recreational uses of these lakes. With the combination of New Jersey's strong commitment to the collection and use of high quality data to support environmental decisions and regulatory programs, including TMDLs, the Department is reasonably assured compliance with the total phosphorus criteria applicable to these eutrophic lakes.

10.1 Lake Characterization

Additional monitoring may be performed in order to develop the Lake Restoration Plans to implement these TMDLs. The level of characterization necessary to plan restoration will be specific to individual lakes depending on the remedial options being considered. During at least one or two summer trips, the following information may be collected as necessary.

- for shallow lakes, vegetation mapping using shore to center transects, measuring density and composition (emergents, rooted floaters, submergents, free-floating plants, submerged macro-algae)
- 1-5 mid-lake sampling stations as needed to characterize the lake
    - at least 2 samples per station per day; min 4 samples per trip
    - secchi depths
- chemistry (nutrients, chlorophyll-*a*, etc.)
    - surface, metalimnion, hypolimnion, and bottom if stratified
    - otherwise surface and bottom
- biology (integrated sample from mixed surface layer)
    - algal abundance and composition (greens, diatoms, blue-greens)
    - zooplankton abundance, composition and size ranges
- DO, temperature and pH profiles (hourly throughout day)

Where necessary, flow and water quality measurements of influent and effluent streams will be taken periodically from Spring to Fall, and fish abundance and composition will be assessed in early autumn.

The schedules for lake characterization and development of Lake Restoration Plans to implement these TMDLs are provided in Table 11.

Table 11 Implementation Schedule

Lake	Lake Characterization	Lake Restoration Plan
Cranberry Lake[a]	Summer 2004	Spring 2005
Ghost Lake[b]	Completed 2000 and 2001	Completed February 2002
Lake Hopatcong	Summer 2003	Spring 2004
Lake Musconetcong	Summer 2003	Spring 2004

a While Phase 2 remediation of Cranberry Lake is already underway, the TMDL implementation will focus on how successful the nutrient reduction efforts have been, and what additional measures are necessary to restore the lake.

b The Diagnostic / Feasibility study for Ghost Lake (Princeton Hydro, 2002) fulfills the TMDL requirements for lake characterization and lake restoration planning. While nutrient reductions are not required, the report specifies a management plan to restore the lake, including biomanipulation through fishery management.

10.2 Reasonable Assurance

Reasonable assurance for the implementation of these TMDLs has been considered for point and nonpoint sources for which phosphorus load reductions are necessary. These TMDLs obligate the Department to routinely monitor lake water quality as well as characterize and develop specific restoration plan for these particular lakes according to the schedule in Table 11. Moreover, stormwater sources for which WLAs have been established will be regulated as NJPDES point sources.

With the implementation of follow-up monitoring and development of Lake Restoration Plans through watershed management process, the Department is reasonably assured that New Jersey's Surface Water Quality Standards will be attained for these lakes. Activities directed in the watersheds to reduce nutrient loadings shall include a whole host of options, included but not limited to education projects that teach best management practices, approval of projects funded by CWA Section 319 Nonpoint Source (NPS) Grants, recommendations for municipal ordinances regarding feeding of wildlife, and pooper-scooper laws, and stormwater control measures.

11.0 Public Participation

Presently, the Upper Delaware Watershed public participation process is being managed by the Department under a contract with the North Jersey Resource Conservation and Development Council. It is comprised of the Project Work Group, an Action Now Committee, an Education and Outreach Committee, an Open Space and Farmland Preservation Committee, and a Characterization and Assessment Committee. It holds regular meetings and relies on its diverse partners and the general public to work on

watershed tasks and issues. In June 2002 the Department gave a presentation to the Upper Delaware Watershed Project Work Group on the New Jersey 2002 Integrated List of Waterbodies and the Water Quality Monitoring and Assessment Methodology, and also encouraged submittal of any comments.

In accordance with N.J.A.C. 7:15–7.2(g), these TMDLs are hereby proposed by the Department as an amendment to the Upper Delaware Water Quality Management Plan, Northeast Water Quality Management Plan, Upper Raritan Water Quality Management Plan, and Sussex County Water Quality Management Plan. N.J.A.C. 7:15-3.4(g)5 states that when the Department proposes to amend the areawide plan on its own initiative, the Department shall give public notice by publication in a newspaper of general circulation in the planning area, shall send copies of the public notice to the applicable designated planning agency, if any, and may hold a public hearing or request written statements of consent as if the Department were an applicant. The public notice shall also be published in the New Jersey Register.

Notice of these TMDLs was published January 21, 2003 pursuant to the above noted Administrative Code, in order to provide the public an opportunity to review the TMDLs and submit comments. The Department has determined that due to the level of interest in these TMDLs, a public hearing will be held. Public notice of the hearing, provided at least 30 days before the hearing, was published in the New Jersey Register and in two newspapers of general circulation and will be mailed to the applicable designated planning agency, if any, and to each party, if any, who was requested to issue written statement of consents for the amendment.

All comments received during the public notice period and at any public hearings will become part of the record for these TMDLs. All comments will be considered in the establishment of these TMDLs and the ultimate adoption of these TMDLs. When the Department takes final agency action to establish these TMDLs, the final decision and supporting documentation will be sent to U.S.E.P.A. Region 2 for review and approval pursuant to 303(d) of the Clean Water Act (33 U.S.C. 1313(d)) and 40 CFR 130.7.

Appendix A: References

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Appendix B: Database of Phosphorus Export Coefficients

In December 2001, the Department concluded a contract with the USEPA, Region 2, and a contracting entity, TetraTech, Inc., the purpose of which was to identify export coefficients applicable to New Jersey. As part of that contract, a database of literature values was assembled that includes approximately four-thousand values accompanied by site-specific characteristics such as location, soil type, mean annual rainfall, and site percent-impervious. In conjunction with the database, the contractor reported on recommendations for selecting values for use in New Jersey. Analysis of mean annual rainfall data revealed noticeable trends, and, of the categories analyzed, was shown to have the most influence on the reported export coefficients. Incorporating this and other contractor recommendations, the Department took steps to identify appropriate export values for these TMDLs by first filtering the database to include only those studies whose reported mean annual rainfall was between 40 and 51 inches per year. From the remaining studies, total phosphorus values were selected based on best professional judgement for eight land uses categories.

The sources incorporated in the database include a variety of governmental and non-governmental documents. All values used to develop the database and the total phosphorus values in this document are included in the below reference list.

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Appendix C: Summary of Reckhow (1979a) model derivation

The following general expression for phosphorus mass balance in lake assumes the removal of phosphorus from a lake occurs through two pathways, the outlet (M_o) and the sediments (ϕ):

$$V \cdot \frac{dP}{dt} = M_i - M_o - \phi \qquad \textbf{Equation 1}$$

where:
- V = lake volume (10^3 m^3)
- P = lake phosphorus concentration (mg/l)
- M_i = annual mass influx of phosphorus (kg/yr)
- M_o = annual mass efflux of phosphorus (kg/yr)
- ϕ = annual net flux of phosphorus to the sediments (kg/yr).

The sediment removal term is a multidimensional variable (dependent on a number of variables) that has been expressed as a phosphorus retention coefficient, a sedimentation coefficient, or an effective settling velocity. All three have been shown to yield similar results; Reckhow's formulation assumes a constant effective settling velocity, which treats sedimentation as an areal sink.

Assuming the lake is completely mixed such that the outflow concentration is the same as the lake concentration, the phosphorus mass balance can be expressed as:

$$V \cdot \frac{dP}{dt} = M_i - v_s \cdot P \cdot A - P \cdot Q \qquad \textbf{Equation 2}$$

where:
- v_s = effective settling velocity (m/yr)
- A = area of lake (10^3 m^2)
- Q = annual outflow (10^3 m^3/yr).

The steady-state solution of Equation 2 can be expressed as:

$$P = \frac{P_a}{v_s + z/T} = \frac{P_a}{v_s + Q_a} \qquad \textbf{Equation 3}$$

where:
- P_a = areal phosphorus loading rate (g/m^2/yr)
- z = mean depth (m)
- T = hydraulic detention time (yr)
- Q_a = Q/A = areal water load (m/yr).

Using least squares regression on a database of 47 north temperate lakes, Reckhow fit the effective settling velocity using a function of areal water load: $P = \frac{P_a}{11.6 + 1.2 \cdot Q_a}$. **Equation 4**

Appendix D: Derivation of Margin of Safety from Reckhow *et al* (1980)

As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. The model error analysis from Reckhow *et al* (1980) defined the following confidence limits:

$$P_L = P - h \cdot \left(10^{(\log P - 0.128)} - P\right)$$
$$P_U = P + h \cdot \left(10^{(\log P + 0.128)} - P\right)$$
$$\rho \geq 1 - \frac{1}{2.25 \cdot h^2}$$

where:
- P_L = lower bound phosphorus concentration (mg/l);
- P_U = upper bound phosphorus concentration (mg/l);
- P = predicted phosphorus concentration (mg/l);
- h = prediction error multiple
- ρ = the probability that the real phosphorus concentration lies within the lower and upper bound phosphorus concentrations, inclusively.

Assuming an even-tailed probability distribution, the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration is:

$$\rho_u = \rho + \frac{1-\rho}{2} = \rho + \frac{1}{2} - \frac{\rho}{2} = \rho \cdot \left(1 - \frac{1}{2}\right) + \frac{1}{2} = \frac{1}{2} \cdot \rho + \frac{1}{2}$$

Substituting for ρ as a function of h:

$$\rho_u = \frac{1}{2} \cdot \left(1 - \frac{1}{2.25 \cdot h^2}\right) + \frac{1}{2} = \frac{1}{2} - \frac{1}{4.5 \cdot h^2} + \frac{1}{2} = 1 - \frac{1}{4.5 \cdot h^2}$$

Solving for h as a function of the probability that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$\frac{1}{4.5 \cdot h^2} = 1 - \rho_u$$
$$h^2 = \frac{1}{4.5(1 - \rho_u)}$$
$$h = \sqrt{\frac{1}{4.5(1 - \rho_u)}}$$

Expressing Margin of Safety (MoS_p) as a percentage over the predicted phosphorus concentration yields:

$$MoS_p = \frac{P_U}{P} - 1 = \frac{P_U - P}{P}$$

Substituting the equation for $P_{U:}$

$$MoS_p = \frac{P + h \cdot \left(10^{(\log P + 0.128)} - P\right) - P}{P} = \frac{h \cdot \left(10^{(\log P + 0.128)} - P\right)}{P}$$

$$P \cdot MoS_p = h \cdot \left(10^{(\log P + 0.128)} - P\right)$$

$$\frac{P \cdot MoS_p}{h} = 10^{(\log P + 0.128)} - P$$

$$\frac{P \cdot MoS_p}{h} + P = 10^{(\log P + 0.128)}$$

Taking the log of both sides and solving for margin of safety:

$$\log\left(\frac{P \cdot MoS_p}{h} + P\right) = \log P + 0.128$$

$$\log\left(\frac{P \cdot MoS_p}{h} + P\right) - \log P = 0.128$$

$$\log\left(P\left(\frac{MoS_p}{h} + 1\right)\right) - \log P = 0.128$$

$$\log P + \log\left(\frac{MoS_p}{h} + 1\right) - \log P = 0.128$$

$$\log\left(\frac{MoS_p}{h} + 1\right) = 0.128$$

$$\frac{MoS_p}{h} + 1 = 10^{0.128}$$

$$\frac{MoS_p}{h} = 10^{0.128} - 1$$

$$MoS_p = h\left(10^{0.128} - 1\right)$$

Finally, substituting for *h* yields Margin of Safety (MoS_p) as a percentage over the predicted phosphorus concentration, expressed as a function of the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$MoS_p = \sqrt{1 \Big/ \left((1 - \rho_u) * 4.5\right)} \times \left(10^{0.128} - 1\right)$$

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Summary Project Completion Report
Cranberry Lake, Phase II Restoration Project
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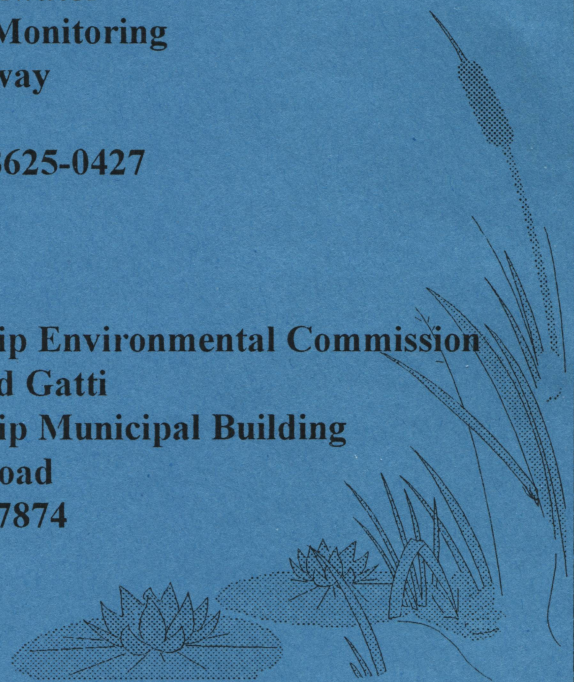
10 Mansfield Road
Stanhope, NJ 07874



Princeton
Hydro, LLC
80 Lambert Lane
Lambertville, NJ 08530

13 October 1998

Mr. Pat Goan
NJDEP
Bureau of Freshwater and Biological Monitoring
35 Arctic Parkway
P.O. Box 427
Trenton, NJ 08625-0427

Dear Mr. Goan:

Attached please find a Project Summary Report for the Cranberry Lake Phase II Project. The report summarizes the activities conducted as part of the Phase II EPA/NJDEP Grant with emphasis placed on the completion of project tasks in accordance with the Project Scope of Work and contractual agreement. Princeton Hydro has prepared and submitted the attached report on behalf of PBS&J.

To summarize, the Phase II project was administered by the Byram Township Environmental Commission. In-kind services were provided, for the most part, by the Township's administrative staff, DOT and Environmental Commission as well as volunteers from the Cranberry Lake Community Club (CLCC).

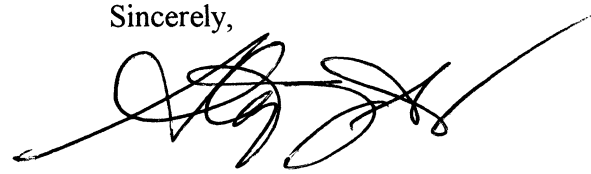
The Phase II project was a multi-task effort that focused on the reduction of Non-Point Source pollutant loading to the lake. This was accomplished through a series of storm water system retrofits or improvements. The project also examined the feasibility of alternative weed control strategies. This involved conducting demonstration type harvesting ands rotovating projects in select areas of the lake. The purpose of these demo projects was to document the utility of non-chemical weed control alternatives. In addition, the project provided an opportunity to further the public education efforts of the Township in respect to septic management, fertilizer control, and other "grass roots" initiatives intended to improve the quality of the lake. Finally, the project included a monitoring element that enabled the continued collection of information needed by the Township to assess the long-term effects of watershed development on the water quality of the lake and/or evaluate the cost-effectiveness of lake restoration and water quality enhancement initiatives.

I am forwarding a copy of the Project Summary Report to the Township. The delivery of the

Phone: 609.397.5335 Fax: 609.397.5333
E-Mail pHydro@worldnet.att.net

report will finalize the contractual responsibilities of Coastal/PBS&J on this project. If you have any comments, please feel free to call me.

Sincerely,



Stephen J. Souza, Ph.D.
President

cc: R. Gotti
F. Lubnow, Ph.D.
D. Vogt, P.E.

C:ss\mydocs\cranberry\summaryreport

pH
Princeton Hydro, LLC
80 Lambert Lane
Lambertville, NJ 08530
609.397.5335 (P)
609.397.5333 (F)

Consulting and Engineering Services
for Water & Wetland Resource

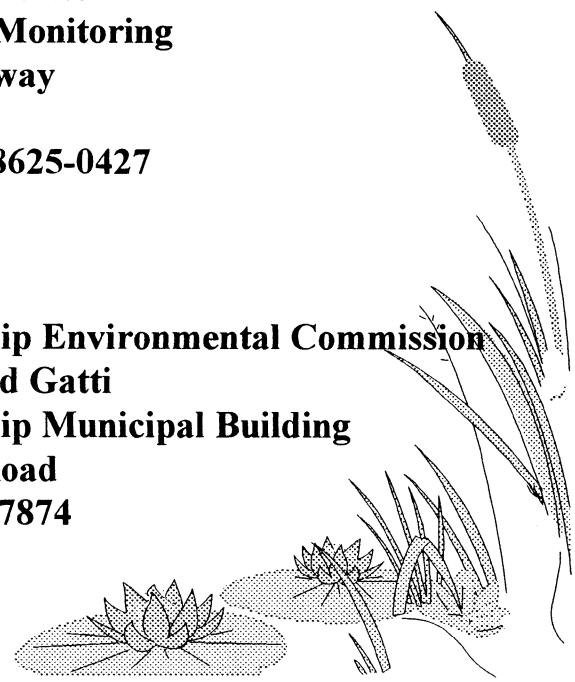
Summary Project Completion Report
Cranberry Lake, Phase II Restoration Project
Byram, New Jersey

Prepared For:

NJDEP
Bureau of Freshwater
and Biological Monitoring
35 Arctic Parkway
P.O. Box 427
Trenton, NJ 08625-0427

and

Byram Township Environmental Commission
C/O Mr. Ronald Gatti
Byram Township Municipal Building
10 Mansfield Road
Stanhope, NJ 07874



Introduction:

In 1992, upon completion of the Cranberry Lake, Phase I Diagnostic Feasibility Study, a grant application was submitted to the NJDEP for consideration for USEPA Phase II Implementation Funding. The grant application was accepted and an award of $390,000 was made to the Township for implementation of stormwater management, weed control, public education and water monitoring initiatives. The Township in turn, committed and provided $390,000 in in-kind services as match for the USEPA funding.

Phase II Scope of Work:

Specifically, as identified in the Phase II Grant Application, the proposed Scope of Work consisted of the following tasks:

1. Implementation of alternative weed control techniques to decrease the use and reliance upon herbicides to manage the lake's weed growth problems. This included the use of lake level manipulation, rotovation and weed harvesting

2. Retrofit of the existing stormwater collection system to decrease storm runoff related non-point source pollutant loading to the lake.

3. The design and construction of water quality swales and sedimentation basins to decrease storm runoff related non-point source pollutant loading to the lake.

4. Preparation of a GIS based Sensitive Land Use Management Plan the purpose of which was to provide the Township Planning Board and Environmental Commission with a definitive, objective means to evaluate the potential impacts of watershed development on the lake. The Plan could also be used to identify environmentally sensitive areas of the watershed and target these areas for special protection or land acquisition.

5. Development of Public Education brochures and newsletters that promoted and furthered the Township's Septic management efforts ad instructed individuals about their role and the types of actions that they could take to protect or enhance the quality of the lake.

The in-kind match, for the monies required to conduct the above scope of work, were to be provided specifically as follows:

1. Administrative and Fiscal Management of the grant monies; services to be provided by Township Administrator, Township Comptroller, and administrative clerical staff

2. Coordination and over site of the technical elements of the of scope of work; services to be provided by the Environmental Commission.

3. Implementation of the stormwater management upgrades and retrofits, including construction of water quality swales and new sedimentation basins; services to be provided by the Township DPW.

4. Maintenance of water quality inlets, sedimentation basins and water quality swales; services to be provided by the Township DPW.

5. Replacement of deteriorated bulhead and correction of associated soil erosion problem near at the CLCC club house; services, including materials and labor, provided by the CLCC.

6. Distribution of public education newsletters and brochures; services to be provided by the Environmental Commission.

Implementation of Phase II Scope of Work:

1. Weed Control: The Township has conducted two rotovating (hydrorake) projects, the focus of which has been to decrease the densities of water lilies and other emergent vegetation from the south end of the lake at the mouth the Allamuchy inlet. These projects, although labor intensive proved to be quite feasible. The hydro rake was able to create defined access channels that benefitted water circulation patterns in this end of the lake and provided much improved boat access for anglers and birders. I f implemented on a regular basis (e.g. once every two years) the hydrorake would eliminate the need for the wide-spread us of Rodeo (a herbicide) in this section of the lake. The annual Rodeo treatment and biannual hydrorake project should be comparable in cost.

The use of the harvester did not prove to be as definitively positive as did the hydrorake. The first year that harvesting was attempted, the herbicide application company apparently treated those areas of the lake that were scheduled to be harvested. The resulting lack of suitable weed densities precluded the initial harvesting effort. During the second attempt, weed densities lake wide were lower than ususal, either because of the repair of the dam or because of regional climatological conditions. When harvesting was actually conducted, it was found that water elevations and the occurrence of stumps and boulders precluded the use of the harvester in the shallow coves and the extreme northern end of the lake. The presence of docks and piers along the majority of the shoreline also impeded the operation of the harvester in close proximity to the shore. As such, it appears that harvesting is only feasible for use in the more open areas of the lake. For the shallow coves and along heavily developed shorelines, it appears that herbicides applications will continue to be conducted as the primary means of maintaining weed levels at non-nuisance densities in these areas. Although the harvesting effort was not as definitively effective as the hydrorake, the Township and the CLCC have been advised to continue using both the hydrorake and harvester, in combination with selective herbicide applications, to control the lake's weed problems.

2. Sensitive Land Management Plan: With assistance from the Environmental Commission a Sensitive Land Management Plan was prepared. The Plan identified and mapped the watershed's sensitive natural resources (erosion prone spoils, steep slope, wetlands, stream corridors, etc.). Overlapped on this natural resource database, was the Township's tax maps. This provided a lot and block reference that could be used by the Environmental Commission and the Planning to locate the sensitive natural resource areas. The GIS database also included a layer that identified all "buildable" lots and a ranking of these areas in respect to the total "buildable" acreage. Planning Board records were reviewed and pending developments were identified. The resource and development data were then used in concert to identify sections of the watershed where the development potential was high and where the natural resource attributes were sensitive to development. Guidance was provided in respect to different types of precautions that should be taken to limit environmental impact in those areas having high development potential and sensitive resources. The GIS nature of the database will facilitate the frequent update of the database by the Township. It also allows for multiple constraint analyses and the quantification of cumulative impacts. The Plan, including a series of maps and development guidance, was submitted to the Township and in turn distributed to the Planning Board and Environmental Commission in both electronic and hardcopy formats.

3. Public Education: To promote the Cranberry Lake septic management ordinance and stimulate grass root involvement in lake restoration and management initiatives a series of brochures/newsletters were produced. These public educational materials dealt with the following topics:

A. Septic Management - stressing proper septic system maintenance including pump-out, water conservation practices that minimize hydraulic shock to leach fields, use of septic system additives and proper disposal of house hold hazardous materials that could impact septic system operation

B. Lawn Care Practices for Lake Front Homes - stressing the careful use of pesticides and fertilizers and recommending the use of non-phosphorus fertilizers. Also included discussion of maintaining a lakeside vegetative buffer strip.

C. Use of Non-Phosphorus Detergents - used to supplement the septic management initiatives, this newsletter stressed the environmental benefits to the lake of using non-phosphorus detergents and wash products.

4. Stormwater Management: Over the four year time frame of the Phase II project, the Township engaged in a number of storm water management initiatives. The most significant of these involved the removal of over 50 existing stormwater catch basins, and their replacement with water quality basins. Each basin was constructed on site by DPW personnel. The basins are equipped with an 18" to 24" sump that is designed to trap and retain sediments, leaf litter and rod debris. The Township has been routinely cleaning the basins of accumulated material twice per year (late sporing and late fall). With assistance from the CLCC, a long standing shoreline erosion problem was corrected. This involved the upgrade of a timber bulkhead located in the vicinity of the CLCC club house. Another significant project involved the construction of a road side swale and catch basin

system for Rose Trail, a highly used access road to the lake. Another project of significance was the construction of dual chamber sedimentation basins (approximately 48' x 48") at Weaver House Cove and at Cabin Springs Cove.

5. Lake Lowering: Over the course of the project, the lake was lowered twice during the winter. One of the draw downs coincided with the State's repair of the dam and the lake's emergency overflow berm. The other was conducted by the Township, specifically as part of the Phase II project, for the The purpose of the draw down was to evaluate the benefits of this technique in the control of the lake's shallow water macrophytes. The in-field studies conducted in the spring and summer following each draw down identified that a retardation in the growth of near shore macrophytes did occur. However, the positive impacts were short-lived and the areas had to subsequently be treated with herbicides to satisfy the lake users demands for shoreline access and weed free bathing areas.

6. Water Quality Monitoring: Prior to the initiation of any field sampling or water quality monitoring, a QA/QC plan was prepared and submitted to NJDEP. The sampling plan proposed fro the lake was subsequently reviewed and approved. Once the QA/QC plan was approved, water quality monitoring was initiated. Basically, from 1993 through 1996 the lake was monitored on a monthly schedule, with data being collected at the same two in-lake stations monitored by Coastal as part of the original Phase I study. Focus was placed such *in-situ* parameters as dissolved oxygen, temperature, conductivity and pH (all of which monitored in profile from surface to bottom) and water chemistry parameters such as total phosphorus, nitrate-nitrogen, total suspended solids and chlorophyll. Observations were made of weed growth patterns and densities and phytoplankton and zooplankton data were collected on each of the monitoring dates. The results of these analyses were discussed in the Quarterly reports submitted to the State, as well as in a Water Quality Monitoring Report submitted at the close of the Phase II project to Byram Township.

The data collected over the course of the sampling program document that the lake continues to be a productive, eutrophic waterbody. Although algae blooms are typically non-problematic, weed densities often impede lake use and detract from the recreational use of the lake. The lake does stratify and during periods of stratification, deep water TP concentrations increase. This has the potential to fuel autumnal algal blooms at the time of turn-over. The data indicate that further efforts must be taken to reduce the lake's NPS load especially that associated with septic systems.

Satisfaction of In-Kind Match:

Documentation has been submitted by the Township along with the Attachment C that detail the in-kind match contributions provided over the course of the project. A considerable amount of labor was donated by the DPW in the installation/construction of the stormwater retrofits. In addition, maintenance of the inlets in respect to the removal of accumulated leaves, sediment and road grit, has also been constructed by the DPW as an in-kind service. The Township administrative staff, as proposed, contributed a considerable amount of time in the fiscal management of the project's and

the Environmental Commission was deeply involved in each of the project's technical elements. This was best exemplified in the role that they played in the coordination of the weed harvesting/hydroraking efforts, the preparation of the Sensitive Land Management Plan and the review and distribution of the public education newsletters. In total, the Township far exceed the required in-kind match.

Future Work:

As identified in the Phase I report, selective dredging of the lake's main coves should be conducted. Now that the drainage problems at Weaver House Cove are being addressed, it would be feasible to reclaim the filled-in areas of the cove, and the restoration of its water depth. A proposal was submitted to the NJDEP for funding. Along with this dredging, some additional work should be conducted in respect to the stabilization of the stream channel of the unnamed tributary that drains to the cove. This will involve the use of bioengineering techniques. Additional dredging should be conducted in the Cabin Spring section of the lake. Finally, work should continue pursuit to the implementation of septic management initiatives and intelligent land development activities, the use of non-herbicidal weed management strategies, and the education of the residents and users of Cranberry lake relative to their role in decreasing the rate and impacts of lake eutrophication.

It should be noted that the Township recently submitted a grant application to the State for monies to be used toward the dredging of Weaver House Cove and the bio-restoration of the inlet stream. The project was been selected by NJDEP for funding, and the project will be conducted, probably in 1999.

Kathleen Parish
Byram Township Environmental Commission Chair

RECEIVED
JUN - 2 2021
TOWNSHIP OF BYRAM
TAX ASSESSOR

Ms. Parrish,

I saw the article in this weeks' Township Journal regarding the environmental commission looking for input on the committee's proposal to limit impervious coverage percentages on homeowners property. One point mentioned in the article was the goal or objective of limiting run -off of pesticides and herbicides into lakes and rivers. I fully agree with this objective as Byram is known as the "Township of Lakes".

As past president / treasurer/ registrar of Lake Lackawanna the protection of our lake has always been a priority with me personally. Years before septic management was instituted by Byram for Lackawanna and Cranberry, I had developed a septic management program with Texagon for the same reasons. That being to promote septic system health while protecting the lake and saving residents money by negotiating a group discount for participation. I can say,as resident and council member Jack Gallagher mentioned in the article, most lake residents here are very aware of the importance of our lake health. In addition, very few residents use lawn fertilizers here anymore. We have continually stressed the importance of not using any products containing phosphorus, which promotes lake weed growth among other things. When I attended the HAB seminar last year at Lake Mohawk CC, speaker Steve Sousa from Princeton Hydro mentioned that big box stores (Depot, Lowes) no longer sell fertilizers containing phosphorus.

One major issue I personally have had is with stormwater run-off. Controlling what goes into a lake is something that can and should be managed, as it is the 1st line of defense against possible detrimental effects. Back in 2008, I compiled a list of all the storm catch basins that discharge into both Lake Lackawanna and Lubbers Run.. Lubbers Run by the way is a State trout stream. As you can see from the enclosed file, I counted 31 total drains that empty into either Lake Lackawanna or Lubbers Run. There are 20 drains with NO sediment traps. A sediment trap is designed to catch heavier solids which stay in the trap and do not float / enter the lake or stream. Typically cleaned out by the DPW on a timely basis. ALL of the storm drains going into Lake Lackawanna on the enclosed file were installed by Byram Township. The ones with no sediment traps are very old concrete pipes whereas anything entering them goes directly into the lake. Many have started to collapse in past years and have been repaired by the town DPW.

The drains on Lackawanna Drive (County road 607), have sediment traps and are cleaned / maintained by the County DPW on a regular basis. I have suggested in the past that Byram budget a few drains each year to be re-built with needed sediment traps. If such a schedule was implemented when proposed, I would not once again be raising this important issue. Everytime I receive a note in the mail from Byram speaking about lake health, in my opinion, the corrective issue starts with Byram and their antiquated storm drains.

Thank you for your time to review this letter and attached file. I hope once again that something will be done in the near future.

Sincerely,

Bill Koellhoffer

Bill Koellhoffer
87 Lake Drive
billyk5761@gmail.com
973-713-0247

Feb-08

LAKE LACKAWANNA STORM DRAINS - EXISTING

PRIORITY

RANK	LOCATION / ADDRESS	COMMENTS	Discharges into
	Page 1 of 1		
1	139 LAKE DRIVE	**THREE-> By Caddie Shak and both sides of Lake Dr (NO sediment traps)**	Lake Lackawanna
2	141 LAKE DRIVE	By Rafferty **(No sediment trap)**	Lake Lackawanna
3	145 LAKE DRIVE	By Falleni **(No sediment trap)**	Lake Lackawanna
4	209 / 210 LAKE DRIVE	**TWO drains here, by Zavist (No sediment traps)**	Lake Lackawanna
5	20 / 22 LAKE DRIVE	Next to Flora / Christiansen **(No sediment trap)**	Lake Lackawanna
6	21 LAKE DRIVE	Next to Aplaugh **(No sediment trap)**	Lake Lackawanna
7	36 & 38 RICHMOND ROAD	Next to David Rush & Roger Tucker-> **THREE** drains **(No sediment traps)**	Lake Lackawanna
8	5 BROWN DRIVE	On corner of Brown & Lake Drive	Lake Lackawanna
9	185 LAKE DRIVE	**TWO drains exist here (No sediment traps)**	Lake Lackawanna
10	189 LAKE DRIVE	Opposite 189 lake **(No sediment trap)**	Lake Lackawanna
11	212 LAKE DRIVE	**No sediment trap**	Lake Lackawanna
12	218 & 222 LAKE DRIVE	TWO drains, Opposite 218 & 222 Lake Drive	Lake Lackawanna
13	164 LAKE DRIVE	By Carreara **(No sediment trap)**	Lake Lackawanna
14	230 LAKE DRIVE	Opposite 239	Lake Lackawanna
15	237 / 8 LAKE DRIVE	**TWO drains, one on each side of Lake Drive**	Lake Lackawanna
16	239 LAKE DRIVE	Next to driveway	Lake Lackawanna
17	242 LAKE DRIVE	**TWO drains, one on each side of Lake Drive**	Lake Lackawanna
18	4 LAKE DRIVE	**TWO next to beach & across lake drive (No sediment traps)**	Lubbers Run
19	94 LACKAWANNA DRIVE	Corner of Lackawanna Drive & Heminover Street - Installed by Byram Township	Lubbers Run
20	25 RICHMOND ROAD	Corner of Heminover Street & Richmond Road - Two **drains - (one no sediment trap)**	Lubbers Run
21	HEMINOVER STREET	Near Lubbers Run **(No sediment trap)**	Lubbers Run
X	127 LAKE DRIVE	On golf course side, across from Utter's - drywell drain only	Ground Only
X	71 LAKE DRIVE	This is a drywell drain, no direct outlet to the lake, drains twds golf course	Ground Only

SUMMARY->

> 20 STORM DRAINS WITH **NO SEDIMENT TRAPS. OLD, OUTDATED, ALL INSTALLED BY BYRAM DPW**

> 11 STORM DRAINS WITH SEDIMENT TRAPS

> 31 TOTAL DRAINS GOING INTO LAKE LACKAWANNA OR LUBBERS RUN

> BYRAM SHOULD BUDGET 2-3 DRAINS PER YEAR AND REBUILD PER CURRENT STANDARDS TO SHOW TO

> COMMITMENT TO PROTECTING OUR LAKES. AND CLEAN OUT AS NECESSARY.

Amendment to the Sussex County Water Quality Management Plan and Upper Delaware Water Quality Management Plan

Total Maximum Daily Loads for Pathogens to Address 11 Lakes in the Northwest Water Region

Watershed Management Area 1
(Lake Winona, Lake Hopatcong, Green Valley Beach Campground, Forest Lake, Fox Hollow Lake, Lackawanna Lake, and Furnace Lake)
Watershed Management Area 2
(Crystal Springs Lake, Deer Trail Lake, Lake Mohawk, and Sleepy Valley Lake)

Proposed: July 16, 2007
Established: September 21, 2007
Approved: September 28, 2007
Adopted: October 19, 2009

Prepared by:
New Jersey Department of Environmental Protection
and

TETRA TECH, INC.

With assistance provided by:
United States Environmental Protection Agency, Region 2

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Figure 2. Pathogen impaired lakes in the Northwest Water Region by WMA. 11

EXECUTIVE SUMMARY

In accordance with Section 305(b) and 303(d) of the Federal Clean Water Act (CWA), the State of New Jersey, Department of Environmental Protection (Department) is required to assess the overall water quality of the State's waters and identify those waterbodies with a water quality impairment for which TMDLs may be necessary. A TMDL is developed to identify all the contributors of a pollutant of concern and the load reductions necessary to meet the Surface Water Quality Standards (SWQS) relative to that pollutant. The Department fulfills its assessment obligation under the CWA through the Integrated Water Quality Monitoring and Assessment Report, which includes the Integrated List of Waterbodies, issued biennially. On October 4, 2004 the Department adopted the *2004 Integrated List of Waterbodies* as an amendment to the Statewide Water Quality Management Plan (36 NJR 4543(a)), as part of the Department's continuing planning process pursuant to the Water Quality Planning Act at N.J.S.A. 58:11A-7 and the Water Quality Management Planning rules at N.J.A.C. 7:15-6.4(a). The *2004 Integrated List of Waterbodies* identifies eleven lakes as impaired with respect to pathogens in the Northwest Water Region.

The Department has recently adopted the *2006 Integrated Water Quality Monitoring and Assessment Report*, including the *2006 Integrated List of Waterbodies*, which identifies impairments based on HUC 14 Assessment Units rather than stream segments associated with discrete monitoring locations. This change in assessment methodology allows establishment of a stable base of assessment units for which the attainment or non-attainment status of all designated uses within each subwatershed or assessment unit will be identified. In addition, lakes are assessed and listed separately when impaired. The *2006 Integrated List of Waterbodies* identifies eleven lakes that are impaired with respect to pathogens in the Northwest Water Region. A lake is determined to be impaired if it does not fully support primary contact recreation as evidenced by beach closings in accordance with Health Department standards. The water quality trigger for beach closings is exceedance of 200 cfu/100 ml of fecal coliform (NJDOH, 2004). TMDLs are adopted for the impaired lakes listed in Table 1.

Table 1. Lakes in the Northwest Water Region impaired for pathogens for which TMDLs are adopted.

TMDL Number	WMA	Lake Assessment Unit Name	County(s)*
1	1	Lake Winona	Morris/Sussex
2	1	Lake Hopatcong	Morris/ Sussex
3	1	Green Valley Beach Campground	Sussex
4	1	Forest Lake	Sussex
5	1	Fox Hollow Lake	Sussex

TMDL Number	WMA	Lake Assessment Unit Name	County(s)*
6	1	Lackawanna Lake	Sussex
7	1	Furnace Lake	Warren
8	2	Crystal Springs Lake	Sussex
9	2	Deer Trail Lake	Sussex
10	2	Lake Mohawk	Sussex
11	2	Sleepy Valley Lake	Sussex

*The drainage area/lakeshed for each lake may encompass municipalities beyond the identified County in which the lake is located.

Nonpoint and stormwater point sources are the primary sources of fecal coliform loads to the impaired lakes. Source loads were estimated for land uses in each watershed using the Watershed Treatment Model (WTM) (WTM, 2001). The WTM model is a series of spreadsheets that quantifies the loading of pathogen indicators based on land use distribution, stream network length in the watershed, and annual rainfall. Traditional point sources, i.e., treatment facilities that have a sanitary waste component, were considered de minimus due to the use of effective disinfection practices by these facilities. TMDLs were developed based on an analysis of the existing pathogen indicator data compared to Health Department indicator criteria and the loading capacity has been allocated among the point and nonpoint sources.

This report establishes eleven TMDLs that were adopted as amendments to the appropriate area-wide water quality management plan in accordance with N.J.A.C. 7:15-3.4(g). This report was developed consistent with EPA's May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Sutfin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs. These TMDLs were approved by EPA on September 28, 2007, and will be adopted as amendments to the Sussex County and Upper Delaware Water Quality Management Plans in accordance with N.J.A.C. 7:15-3.4 (g).

1.0 INTRODUCTION

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey, Department of Environmental Protection (Department) is required biennially to prepare and submit to the EPA a report that identifies waters that do not meet or are not expected to meet water quality standards after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the Department is also

required biennially to prepare and submit to the EPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report. The Integrated Water Quality Monitoring and Assessment Report combines these two assessments and assigns waterbodies to one of five sublists on the Integrated List of Waterbodies. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and 2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants, or have had a TMDL or other enforceable management measure approved by EPA (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants, for which a TMDL may be required.

In the New Jersey 2004 *Integrated Water Quality Monitoring and Assessment Report* the water quality impairments were identified by segment name and pollutant(s) or non-attained designated use responsible for the finding that the segment was impaired. Each segment was assessed using the data from one or more discrete monitoring locations that were determined to be representative of the water quality in that segment. This impaired segment delineation method was changed in 2006.

The *New Jersey 2006 Integrated Water Quality Monitoring and Assessment Report* now identifies impairments based on designated use attainment and then lists the parameters responsible for the non-attainment of the designated use. The assessments are conducted for each of the seven categories of designated use, which include aquatic life, recreational use (primary and secondary contact), drinking water, fish consumption, shellfish harvesting (if applicable), agricultural water supply use and industrial water supply use. In addition, lakes are assessed and listed separately if impaired. In the Northwest Water Region, the *2006 Integrated List of Waterbodies* currently identifies eleven lakes as impaired for pathogens. These lakes do not fully support primary contact recreation as evidenced by beach closings and water quality data that demonstrate exceedance of the water quality criterion that triggers closings.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background, and surface water withdrawals. A TMDL quantifies the amount of a pollutant a waterbody can assimilate and still conform to applicable water quality standards and support designated uses. The TMDL or loading capacity is allocated to known point and nonpoint sources in the form of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

Recent EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. These TMDLs address the following required items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.

This report establishes eleven TMDLs for pathogens to address the impaired lakes in the Northwest Water Region. All of the impaired lakes were listed for fecal coliform and assigned a high priority on the *2004 Integrated List of Waterbodies* and a High priority ranking on the *2006 Integrated List of Waterbodies* Sublist 5. These TMDLs include management approaches to reduce pathogen contributions from various sources in order to attain applicable surface water quality standards and fully support the designated primary contact recreation use. These TMDLs affect the drainage areas of the impaired lakes due to the fact that the implementation measures must be applied to the contributing drainage areas, not just the impaired lakes. Following approval of the TMDLs by EPA, pathogens will be removed as a basis of impairment in the next Integrated List. In addition to the pathogen impairments, Lake Hopatcong was listed for mercury and unknown pollutants on the *2006 Integrated List*. These pollutants will be addressed in future TMDL efforts. A total phosphorus TMDL was approved by EPA in 2003 for Lake Hopatcong.

2.0 POLLUTANT OF CONCERN AND AREA OF INTEREST

The pollutant of concern for these TMDLs is pathogens. Standards are established in terms of indicator organisms which, when present in excess of the standard, suggest that the waterbody is not suitable for primary contact recreation because of an elevated risk of disease. New Jersey Surface Water Quality Standards (SWQS) include pathogen indicator criteria for the assessment of the recreational use (primary and secondary contact recreation) for all waterbodies. However, for lakes with bathing beaches, the New Jersey Health Department Standards N.J.A.C. 8:26-7.18 establish the basis for beach closings. These standards are more stringent than the Surface Water Quality Standards. As a result, the Health Department Standards will serve as the water quality target for these TMDLs. The Health Department Standards and SWQS are summarized as follows:

> **As stated in N.J.A.C. 8:26-7.18 Microbiological water quality standards for bathing beaches:**

The multiple-tube fermentation technique for fecal coliforms shall be conducted in accordance with the procedures set for in Method 9222D Fecal Coliform Membrane Filter Procedure or Method 9221E.2. Fecal Coliform MPN Procedure (A-1 medium) found in the 19th edition of "Standard Methods for the Examination of Water and Wastewater." American Public Health Association, incorporated herein by reference, as amended and supplemented. The estimated fecal coliform concentrations shall not exceed 200 fecal coliform per 100 milliliters.

As stated in N.J.A.C. 7:9B-1.14(d) of the New Jersey Surface Water Quality Standards Fresh Water 2 (FW2) waters:

1. Bacterial quality (Counts/100 ml)

    ii. Primary Contact Recreation:

        (2) E. Coli levels shall not exceed a geometric mean of 126/100 ml or a single sample maximum of 235/100 ml.

The lakes assessed as impaired based on water quality data and for which TMDLs have been developed are identified in Table 2 and depicted in Figures 1 and 2.

Table 2. Impaired Waterbodies as identified on the *2004 Integrated List of Waterbodies* and the *2006 Integrated List* for which Pathogen TMDLs are being adopted.

TMDL Number	WMA	Lake Assessment Unit Name	Lake Assessment Unit ID	2004 Status	2006 Status	County(s)*	Proposed Action
1	1	Lake Winona	Lake Winona-01	Sublist 5	Sublist 5	Morris/ Sussex	Adopt TMDL
2	1	Lake Hopatcong	Lake Hopatcong-01	Sublist 5	Sublist 5	Morris/ Sussex	Adopt TMDL
3	1	Green Valley Beach Campground	Green Valley Beach Campground-01	Sublist 5 (as Pequest River at Green Valley Beach Campground)	Sublist 5	Sussex	Adopt TMDL
4	1	Forest Lake	Forest Lake-01	Sublist 5	Sublist 5	Sussex	Adopt TMDL
5	1	Fox Hollow Lake	Fox Hollow Lake-01	Sublist 5	Sublist 5	Sussex	Adopt TMDL
6	1	Lackawanna Lake	Lackawanna Lake-01	Sublist 5	Sublist 5	Sussex	Adopt TMDL
7	1	Furnace Lake	Furnace Lake-01	Sublist 5	Sublist 5	Warren	Adopt TMDL
8	2	Crystal Springs Lake	Crystal Springs Pond -02	Sublist 5	Sublist 5	Sussex	Adopt TMDL
9	2	Deer Trail Lake	Deer Trail Lake-02	Sublist 5	Sublist 5	Sussex	Adopt TMDL

TMDL Number	WMA	Lake Assessment Unit Name	Lake Assessment Unit ID	2004 Status	2006 Status	County(s)*	Proposed Action
10	2	Lake Mohawk	Lake Mohawk-02	Sublist 5	Sublist 5	Sussex	Adopt TMDL
11	2	Sleepy Valley Lake	Sleepy Valley-02	Sublist 5	Sublist 5	Sussex	Adopt TMDL

*The drainage area/lakeshed for each lake may encompass municipalities beyond the identified County in which the lake is located.

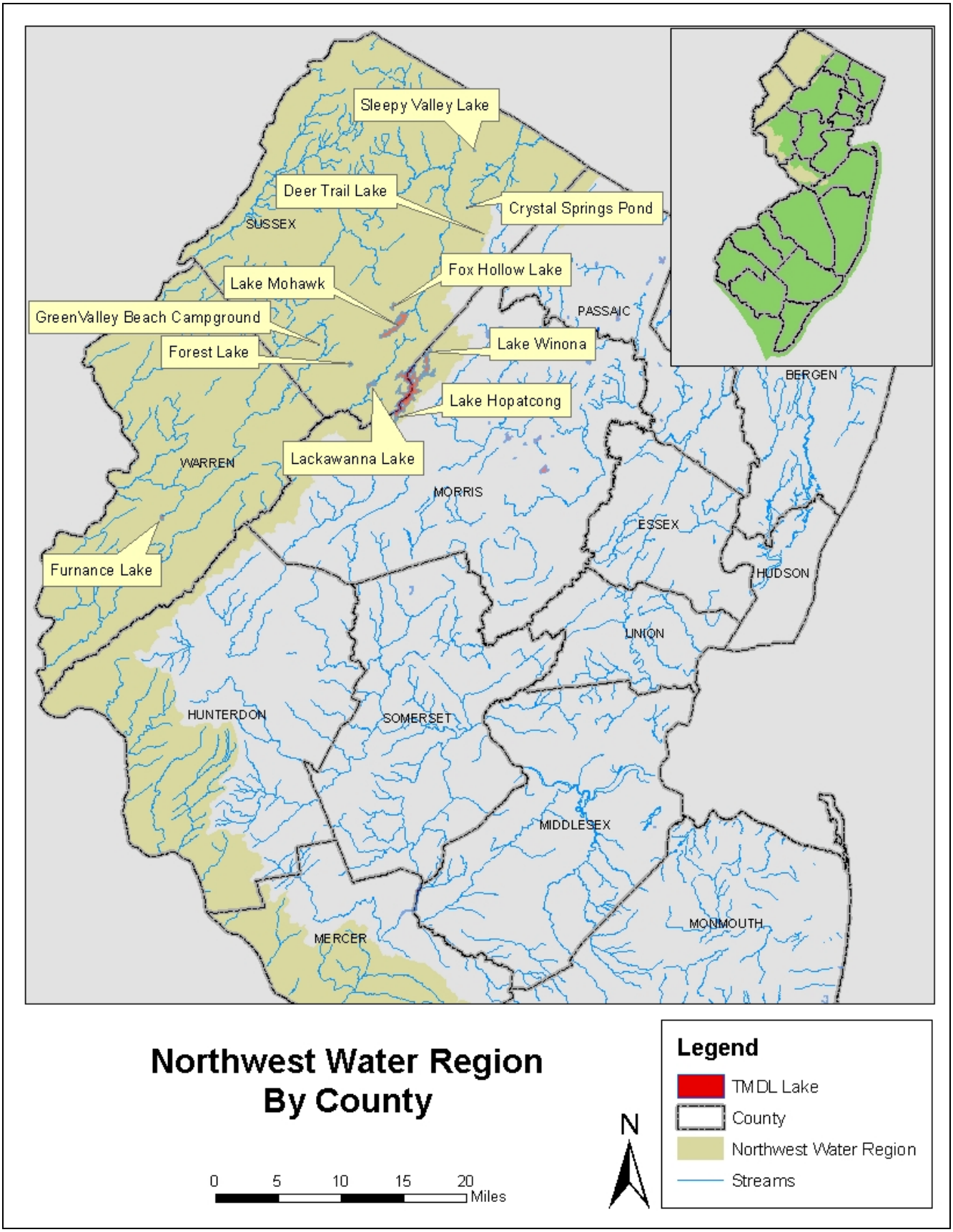

Figure 1. Pathogen impaired lakes in the Northwest Water Region by county.

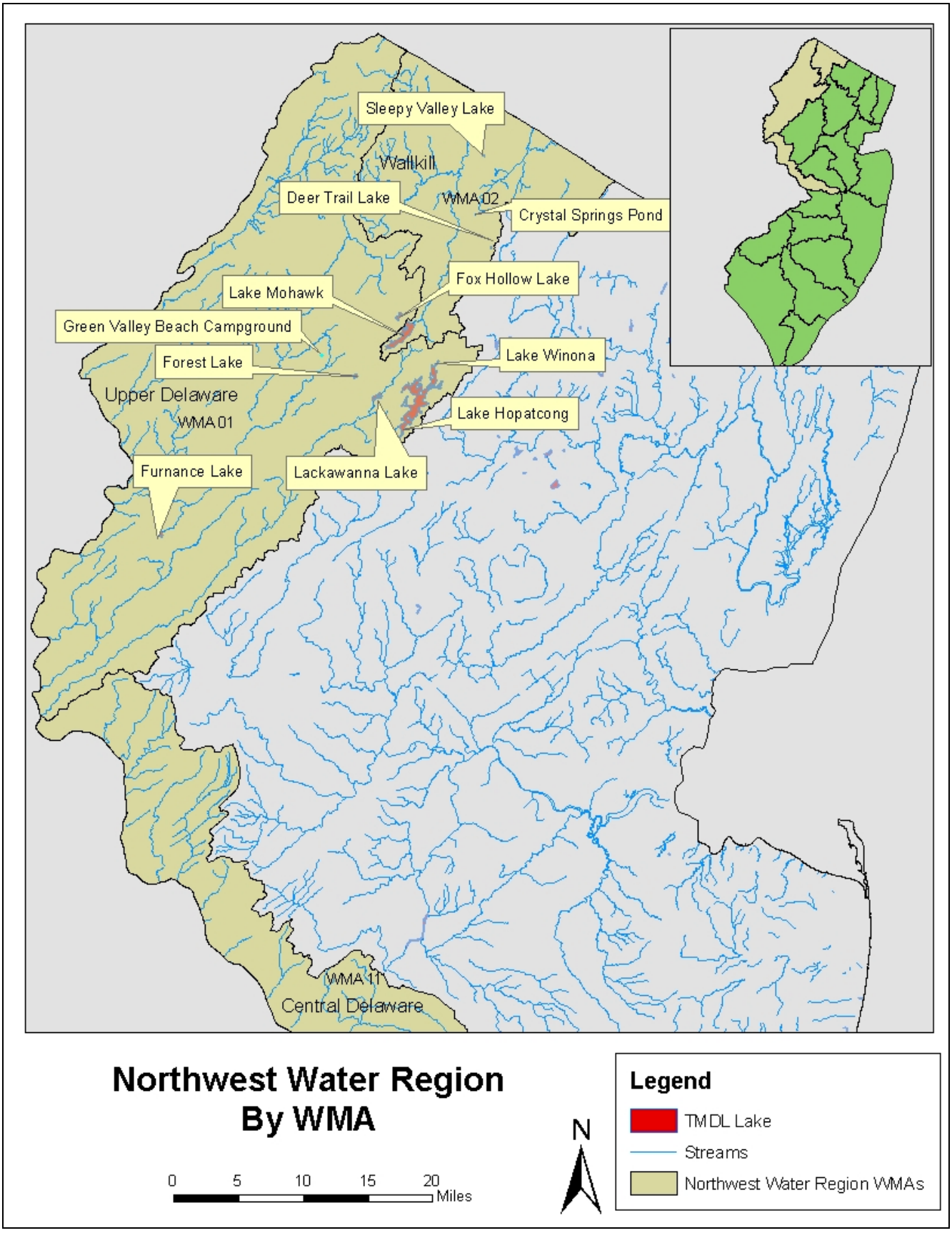

Figure 2. Pathogen impaired lakes in the Northwest Water Region by WMA.

Deer Trail Lake, Furnace Lake, Lackawanna Lake, Lake Hopatcong and Lake Winona are classified as Fresh Water 2 (FW2), Trout Maintenance (TM). All other impaired lakes addressed in this document are classified as FW2, Non-Trout (NT).

In all FW2 waters, the designated uses are (NJAC 7:9B-1.12):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

3.0 SOURCE ASSESSMENT

A source assessment was conducted to identify and characterize potential pathogen sources that may be impacting water quality in the listed waters. Both point and nonpoint sources were considered in TMDL development. Source assessment also includes the determination of the relative contribution of the primary bacteria sources to facilitate proper management responses through TMDL implementation. A variety of information was used to characterize possible pathogen sources including land use information gathered for each watershed, point source information, literature sources, and other available data.

3.2 Assessment of Point Sources

For TMDL development purposes, point sources include domestic and industrial wastewater treatment plants that discharge to surface waters, as well as surface water discharges of stormwater subject to regulation under the National Pollutant Discharge Elimination System (NPDES). This includes facilities with individual or general industrial stormwater permits, Tier A municipalities, and federal, interstate agency, state, and county facilities regulated under the New Jersey Pollutant Discharge Elimination System (NJPDES) municipal stormwater permitting program. Tier A municipalities are generally located within the more densely populated regions of the state or along the coast. These municipalities meet the population size requirements of EPA's Municipal Separate Storm Sewer System (MS4) program for regulating urban stormwater discharges. Stormwater point sources, like stormwater nonpoint sources, derive their pollutant loads from runoff from land surfaces and load reduction is accomplished through the use of best management practices (BMPs). The distinction is that stormwater point sources are regulated under the Clean Water Act (under the MS4 program). Stormwater point sources will be addressed through the management practices required through the MS4 permits.

Wastewater treatment facilities and Tier A municipalities that directly discharge to the pathogen impaired lakes in the Northwest Water Region are identified in Appendix B. Per Department NJPDES Regulation, N.J.A.C. 7:14A-12.5(a), "All wastewater that could contain pathogenic organisms such as fecal coliform and/or enterococci organisms shall be subject to continuous year round disinfection prior to discharge into surface waters." Therefore, loads from wastewater treatment facilities were considered de minimus, consistent with previous pathogen TMDLs developed by the Department. The NJPDES permit limits for these point sources will not be changed as a result of these TMDLs and will remain a 200 cfu/100 ml monthly geometric mean and a 400 cfu/100 ml weekly geometric mean.] Stormwater loads from Tier A MS4 systems are point sources that can be significant. These loads were estimated using the watershed loading methods described in the nonpoint source section, as they will be addressed through BMPs.

3.3 Assessment of Nonpoint Sources

Nonpoint sources that may affect lakes include stormwater discharges that are not subject to regulation under the Clean Water Act, including Tier B municipalities, direct stormwater runoff from land surfaces, as well as malfunctioning sewage conveyance systems, failing or inappropriately located septic systems, and direct contributions from wildlife, livestock and pets. Tier B municipalities are generally located in more rural, non-coastal regions of the state.

Watershed Treatment Model (WTM) (WTM, 2001), a steady-state spreadsheet model, was chosen to estimate nonpoint source bacteria loads for these TMDLs. WTM simulates loadings generated by watershed washoff processes. The WTM model was selected because it encompasses local rainfall data and stream length information to better tailor load estimates. In addition, it has been successfully applied in previous coastal TMDL studies, including the development of pathogen TMDLs for impaired shellfish waterbodies in New Jersey. The goal of applying WTM is to characterize all the point and nonpoint sources, as available data allows, in the existing system and to determine their relative contributions to the waterbody of interest. The loading values thus derived serve as the reference point from which reductions are made to meet TMDL targets.

The WTM model is a series of spreadsheets that quantifies the loading of pathogen indicators based on land use distribution, stream network length in the watershed, and annual rainfall. The model is designed as a planning level tool for watersheds that do not have sufficient data for complex modeling applications. Pathogen concentrations in runoff and receiving waters are highly variable due to many factors, therefore average annual land use loads derived using the WTM model are gross estimates. Although the WTM model has several tiers of data specificity, loading estimates can be calculated with simple land use data, as they were for these lake TMDLs. Land use loads are calculated on an annual basis by using a series of coefficients for runoff volume and pathogen loading derived from scientific literature. General land use categories are assigned either a coefficient that is then multiplied by an annual runoff volume to calculate an annual load (e.g., urban land uses) or an annual unit

area load that is applied as a function of land use (e.g., rural land uses). These coefficients are presented in Table 3 and discussed in the WTM user manual (Caraco, 2001). According to the WTM user manual, the urban loading coefficient was based on the median urban runoff value derived from Nationwide Urban Runoff Program (NURP) monitoring data (Pitt, 1998). Loading values for rural land uses were taken from Horner et. al., 1994. Note that barren land is not represented in the WTM model, therefore it was assumed that the forest loading value was reasonable for this land use type.

Table 3. Default WTM land use categories and loading variables.

WTM Land Use	Corresponding New Jersey Land Uses	Average % Impervious Cover	Fecal Coliform Conc. (MPN/100 ml) or Annual Load (billion/acre)
Low Density Residential	Low Density Residential, Rural Residential, Recreational Land, Athletic Fields	19	20,000
Medium Density Residential	Medium Density Residential, Mixed Residential, Mixed Urban or Built-Up, Other Urban or Built-Up, Military Reservations, No Longer Military	35	20,000
High Density Residential	High Density Residential	56	20,000
Commercial	Commercial Services	71	20,000
Roadway	Transportation/Communication/Utilities	39	20,000
Industrial	Industrial, Industrial/Commercial	78	20,000
Forest	Forest/Wetland	0	Load: 12 billion/acre
Rural	Agriculture	0	Load: 39 billion/acre
Barren (replaced "Vacant Lots" category in WTM)	Barren	2	Load: 12 billion/acre (estimated)

The watershed for each TMDL waterbody was delineated using the Hydrologic Unit Coverage (HUC-14 digit) developed by NJDEP, digital elevation model (DEM) data, the National Hydrography Dataset (NHD) stream coverage for New Jersey, and ArcHydro, a watershed delineation tool available as an extension for the ArcGIS geospatial mapping software suite. Land use data for each watershed was obtained from the 2002 land use coverage developed for New Jersey's WMAs. Land use categories were consolidated into broader groups for use in estimating land-based loads using the WTM model and for presenting the loading results. The percent impervious information for each land use category was derived from the percent impervious information in the Department's GIS land use coverage, averaged across similar land uses. The bacterial loads for urban areas in each watershed were calculated based on the default fecal coliform concentration literature value for urban land uses, the average percent impervious cover, and the annual runoff volume calculated by the WTM model. Agricultural, forest, and barren land use loads were calculated based on the specific loading rate for each category. The literature loading rate for forested land was applied to wetland areas to estimate a wetland land use load. Waterways were not included in loading calculations based on WTM model assumptions.

Direct contributions from illicit discharges, livestock, pets, and wildlife (e.g. seagulls, geese, and other waterfowl in particular) were not estimated based on the lack of site-specific information needed to represent these sources. Population estimates, bacteria production rates, and other information would be needed to estimate these sources. Bacteria may also be present in the sediment in some areas, as a result of contamination from stormwater, failing septic systems, malfunctioning sewer systems, agricultural runoff, and other sources. For these TMDLs, the loads contributed by wildlife, sediment, and the other sources were assumed to be included in the land use loading coefficients.

The drainage area and land use distribution of the impaired watersheds are presented in Table 4. Maps of the watershed land use distributions are presented in Appendix C.

Table 4. Land use area distributions for impaired watersheds in the Northwest Water Region.

WMA	Lake Assessment Unit ID	Agriculture		Barren Land		Forest		Urban		Water		Wetland		Total Area
		km²	%	km²	%	km²	%	km²	%	km²	%	km²	%	km²
1	Forest Lake-01	0.00	0.0	0.00	0.0	0.37	34.8	0.50	47.4	0.19	17.9	0.00	0.0	1.05
1	Fox Hollow Lake-01	0.05	1.3	0.02	0.5	1.27	35.0	1.28	35.1	0.40	10.9	0.63	17.3	3.64
1	Furnace Lake-01	0.89	12.7	0.07	1.0	4.09	58.1	1.04	14.7	0.24	3.4	0.71	10.1	7.04
1	Green Valley Beach Campground-01	0.05	40.8	0.00	0.0	0.01	12.3	0.04	37.4	0.01	8.6	0.00	0.9	0.12
1	Lackawanna Lake-01	0.47	1.4	0.36	1.1	22.35	65.2	5.89	17.2	1.80	5.2	3.44	10.0	34.31
1	Lake Hopatcong-01	0.01	0.0	1.00	1.5	31.90	48.5	16.81	25.6	10.91	16.6	5.11	7.8	65.73
1	Lake Winona-01	0.00	0.0	0.00	0.0	2.54	73.7	0.48	14.1	0.04	1.2	0.38	11.0	3.44
2	Crystal Springs Pond -02	0.00	0.0	0.01	3.7	0.03	9.5	0.24	83.8	0.01	3.0	0.00	0.0	0.28
2	Deer Trail Lake-02	0.00	0.0	0.00	0.0	0.60	72.5	0.17	20.4	0.04	5.1	0.02	2.0	0.83
2	Lake Mohawk-02	0.00	0.0	0.01	0.1	2.79	25.2	5.02	45.4	3.11	28.1	0.14	1.2	11.06
2	Sleepy Valley-02	0.00	0.0	0.02	0.5	1.80	54.0	0.91	27.2	0.25	7.6	0.36	10.7	3.34

4.0 WATER QUALITY ANALYSIS

Relating pathogen sources to concentrations of indicator organisms in the impaired waters is distinguished from quantifying that relationship for other pollutants given the inherent variability in population size and dependence not only on physical factors such as temperature and soil characteristics, but also on less predictable factors such as re-growth media. Since bacteria loads and concentrations can vary many orders of magnitude over short distances and over time at a single location, dynamic water quality models can be very difficult to calibrate. Options available to control nonpoint sources of bacteria typically include measures such as sewage infrastructure improvements, goose management strategies, pet waste ordinances, agricultural conservation management plans, and septic system replacement and maintenance. The effectiveness of these control measures is not easily measured relative to observed ambient concentrations. Given these considerations, detailed water quality modeling was not selected for determining the load reductions needed to attain standards and support the designated primary contact recreation use.

Fecal coliform data collected by county and township municipal health departments were used as the basis for TMDL development for the listed pathogen impaired lakes. These data were reviewed to identify potential data excursions in accordance with the Quality Assurance Project Plan (QAPP) that was developed for this study (QAPP, 2007). The percent reduction required to meet New Jersey bathing beach requirements was calculated based on comparing the maximum fecal coliform concentration recorded for each lake to the TMDL target (200 cfu/100 ml). The data available for each lake are included in Appendix D.

4.1 Seasonal Variation/Critical Conditions

The technical approach used to develop these TMDLs includes consideration of seasonal variability and critical conditions. The TMDL lakes are listed as impaired based on the designated primary contact bathing use. Water quality criteria for bathing beaches are established by the New Jersey Department of Health (NJDOH), which conducts monitoring at the municipal level in support of meeting the applicable criteria. Bathing beaches are typically in use during the late spring and summer months and data collection efforts are coordinated to coincide with this time period (May-September). TMDL loading reductions are based on the single sample maximum concentration identified in the record of observed in-lake water quality, therefore, TMDL development is based on the highest concentration observed for the time period of greatest exposure. Seasonal variability is of less importance because of the need to meet NJDOH bathing beach requirements during the summer critical condition period. TMDL loads are presented as average annual loads, which incorporate the summer critical condition period and the average load contributed during the other seasons.

4.2 Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality" (40 CFR 130.7(c)). For these TMDLs, both an implicit and explicit Margin of Safety (MOS) were incorporated. An implicit

MOS was incorporated by using conservative assumptions, including treating fecal coliform as a conservative substance (source loads were estimated without including die-off rates, soil incorporation, etc.) and using conservative methods to estimate land-based loads. In addition, a 5% explicit MOS was calculated for each lake.

5.0 TMDL CALCULATIONS

Pathogen load percent reductions were calculated by comparing the maximum fecal coliform concentration recorded for each lake to the TMDL target concentration (200 cfu/100 ml). Load capacities were the remaining loads after applying the required reductions on the current loads. In addition, 5% of the load capacity was reserved as the explicit MOS (see example below). The percent reduction specified for each lake was applied equally to pathogen sources in each watershed except in cases where load reductions could be met without reducing the loads contributed by forest, wetlands and barren lands: in such cases these loadings were not reduced in the TMDL allocation. In cases where load reductions on these land use sources were greater than or equal to 99.5%, the percent reduction specified for each lake was applied equally to all pathogen sources including forest and barren land loads.

Percent Reduction = (1 – TMDL target conc./max conc.) x 100
Load Capacity = (1 – percent reduction) * overall current load (using WTM)
MOS = 5% * Load capacity
Overall percent reduction = 1 – (Load capacity – MOS) / overall current load
Overall current load = agricultural and urban land use loads + forest, wetland and barren land loads

When $1 - \frac{Load\ Capacity - MOS - Forest, Wetland\ and\ Barren\ Land\ Load}{Agricultural\ and\ Urban\ LandUseLoad} \geq 99.5\%$,

Require the same percent reduction on Forest, Wetland and Barren land loads as on other land use loads;

Otherwise,

Zero percent reduction on Forest, Wetland and Barren lands loads

5.1 Wasteload Allocations and Load Allocations

WLAs were established for municipal stormwater discharges subject to regulation under the CWA. LAs were established for all stormwater sources that are not subject to regulation under the CWA and for all other nonpoint sources. Stormwater point sources that received a WLA were distinguished from stormwater sources receiving a LA on the basis of land use type and municipal tier designation (Tier A/Tier B).

This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured

within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system" (Wayland, November 2002, p.1). Therefore, allocations are established according to source categories as shown in Table 5. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial, and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES.

Table 5. Assignment of WLAs and LAs for stormwater point sources and nonpoint sources.

Land Use Source Category	Municipal Tier	TMDL Allocation Type
High density residential	A	WLA
Medium density residential (incl. mixed residential, mixed urban, other urban, military reservations, and no longer military)	A	WLA
Low density residential (incl. rural residential, recreational land, and athletic fields)	A	WLA
Commercial	A	WLA
Industrial	A	WLA
Roadways	A	WLA
High density residential	B	LA
Medium density residential (incl. mixed residential, mixed urban, other urban, military reservations, and no longer military)	B	LA
Low density residential (incl. rural residential, recreational land, and athletic fields)	B	LA
Commercial	B	LA
Industrial	B	LA
Roadways	B	LA
Agricultural	N/A	LA
Forest/Wetland	N/A	LA
Barren land	N/A	LA

A summary of the WLAs, LAs, and MOS is provided for each lake in Table 6 and source loads and allocations are presented in Table 7. As described above, when the loads contributed by forest/wetland/barren lands were not reduced in the TMDL allocation table, the load reduction for urban lands and agricultural lands was increased proportionally to meet the overall percent reduction required for each lake. Note that the overall percent reduction shown in Tables 6 and 7 takes into account the 5% explicit MOS if not based on the previously established stream Fecal Coliform TMDL.

In cases where impaired lakeshed is hydrologically connected to a streamshed addresssed in an established Fecal Coliform TMDL or to another impaired lakeshed, different approaches were utilized to calculate the load reduction for each "nested" watershed.

Lakeshed connected with the Fecal Coliform TMDL established streamshed

If the entire lakeshed is located within the impaired streamshed, the more stringent overall percent reduction between the lake and the stream is applied to the lakeshed. When the streamshed is part of the lakeshed, the rivershed is treated as an upper stream "lake" shed. The same approach, as described below for the nested lakesheds, was used to determine the adjusted load reduction for different areas.

Lakeshed connected with another impaired lakeshed

The following methodology was used to determine the adjusted percent reduction for the nested lake watersheds:

1. Existing pathogen loads calculated for each lake watershed (using WTM) were reduced based on the overall percent reduction that was calculated from the observed lake water quality data. The reduced load was termed the target load.
2. The target load for the upstream watershed was subtracted from the target load of the downstream watershed, giving a target load for the downstream (local) watershed area. The existing load for the downstream (local) watershed was calculated similarly.
3. If the target load for the downstream (local) watershed area was less than or equal to zero, the downstream lake's higher percent reduction needed to be applied to the upper stream lakeshed. This means that the entire drainage area of the downstream lake is ruled by the downstream lake's reduction percentage.
4. If the target load of the downstream (local) watershed area was higher than zero, the percent difference between the existing and target loads for the downstream (local) watershed was calculated. This adjusted percent reduction superseded the original downstream lake percent reduction and was used as the required percent reduction for the downstream (local) watershed area while the upstream lakeshed stayed with the original overall percent reduction. The adjusted percent reduction would be higher than the original overall percent reduction for the downstream lake when the upstream lake required a less percent reduction than the downstream lake and less than the original value if the upstream lake required a higher percent reduction than the downstream lake.

Table 6. TMDL calculations for pathogen impaired lakes in the Northwest Water Region.

WMA	Lake Assessment Unit ID	WLA (10^6 colonies/yr)	LA (10^6 colonies/yr)	MOS (10^6 colonies/ yr)	TMDL (10^6 colonies/ yr)	Overall % Reduction	% MOS	Reduction from associated Stream TMDL
1	Forest Lake-01	5.13E+02	1.72E+01	2.79E+01	5.58E+02	98.42%	5.00%	
1	Fox Hollow Lake-01[c]	1.48E+03	1.23E+02	8.46E+01	1.69E+03	98.00%	N/A	98%
1	Furnace Lake-01[c]	0.00E+00	5.47E+03	2.88E+02	5.76E+03	93.00%	N/A	93%
1	Green Valley Beach Campground-01	7.85E-02	2.28E+02	1.20E+01	2.40E+02	90.50%	5.00%	
1	Lackawanna Lake-01	2.23E+04	5.77E+03	1.48E+03	2.95E+04	92.96%	5.00%	
1	Lake Hopatcong-01[b]	4.37E+04	3.35E+03	2.48E+03	4.96E+04	96.79%[b]	5.00%	
1	Lake Winona-01[a]	8.92E+02	1.64E+02	5.56E+01	1.11E+03	98.10%	5.00%	
2	Crystal Springs Pond -02	0.00E+00	5.02E+03	2.64E+02	5.28E+03	75.32%	5.00%	
2	Deer Trail Lake-02	0.00E+00	3.08E+03	1.62E+02	3.24E+03	74.25%	5.00%	
2	Lake Mohawk-02[d]	5.25E+03	1.50E+02	2.84E+02	5.68E+03	98.27%	5.00%	90%
2	Sleepy Valley-02[c]	0.00E+00	3.30E+03	1.74E+02	3.48E+03	95.00%	N/A	95%

a. within the watershed of Lake Hopatcong and stays with its own reduction

b. Reduction on the local Lake Hopatcong watershed is less than the original overall percent reduction (96.83%) after taking into account Lake Winona's higher reduction.

c. lake shed located within a stream watershed and goes with the stream's reduction

- Fox Hollow Lake is nested with the watershed of Paulins Kill at Balesville, on which a reduction of 98% was required (NJDEP, 2003).
- Furnace Lake is nested with the watershed of Pequest River at Pequest, on which a reduction of 93% was required (NJDEP, 2003).
- Sleepy Valley is nested with the watershed of Wallkill River near Unionville, on which a reduction of 95% was required (NJDEP, 2003).

d. lake shed located within a stream watershed and stays with its own reduction

- Lake Mohawk is nested with the watershed of Wallkill River at Sparta, on which a reduction of 90% was required (NJDEP, 2003).

Table 7. Northwest Water Region land-based load allocations.

WMA	Lake Assessment Unit ID	Overall % Reduction	Agriculture			Barren Land			Forest/Wetland			Urban Total (WLA)			Urban Total (LA)		
			Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)
1	Forest Lake-01	98%	0.00E+00	98%	0.00E+00	0.00E+00	98%	0.00E+00	1.09E+03	98%	1.72E+01	3.24E+04	98%	5.13E+02	0.00E+00	98%	0.00E+00
1	Fox Hollow Lake-01	98%	4.62E+02	98%	9.25E+00	5.83E+01	98%	1.17E+00	5.64E+03	98%	1.13E+02	7.42E+04	98%	1.48E+03	0.00E+00	98%	0.00E+00
1	Furnace Lake-01	93%	8.61E+03	93%	6.03E+02	2.16E+02	93%	1.51E+01	1.42E+04	93%	9.96E+02	0.00E+00	93%	0.00E+00	5.51E+04	93%	3.86E+03
1	Green Valley Beach Campground-01	91%	4.68E+02	92%	3.61E+01	0.00E+00	0%	0.00E+00	4.67E+01	0%	4.67E+01	1.02E+00	92%	7.85E-02	1.89E+03	92%	1.45E+02
1	Lackawanna Lake-01	93%	4.50E+03	93%	3.17E+02	1.07E+03	93%	7.52E+01	7.65E+04	93%	5.38E+03	3.16E+05	93%	2.23E+04	0.00E+00	93%	0.00E+00
1	Lake Hopatcong-01	97%	1.01E+02	97%	3.25E+00	2.97E+03	97%	9.56E+01	1.01E+05	97%	3.25E+03	1.36E+06	97%	4.37E+04	0.00E+00	97%	0.00E+00
1	Lake Winona-01	98%	0.00E+00	98%	0.00E+00	0.00E+00	98%	0.00E+00	8.64E+03	98%	1.64E+02	4.70E+04	98%	8.92E+02	0.00E+00	98%	0.00E+00
2	Crystal Springs Pond -02	75%	0.00E+00	76%	0.00E+00	3.11E+01	0%	3.11E+01	7.87E+01	0%	7.87E+01	0.00E+00	76%	0.00E+00	2.02E+04	76%	4.91E+03
2	Deer Trail Lake-02	74%	0.00E+00	88%	0.00E+00	0.00E+00	0%	0.00E+00	1.84E+03	0%	1.84E+03	0.00E+00	88%	0.00E+00	1.01E+04	88%	1.24E+03
2	Lake Mohawk-02	98%	0.00E+00	98%	0.00E+00	2.67E+01	98%	4.61E-01	8.67E+03	98%	1.50E+02	3.04E+05	98%	5.25E+03	0.00E+00	98%	0.00E+00

WMA	Lake Assessment Unit ID	Overall % Reduction	Agriculture			Barren Land			Forest/Wetland			Urban Total (WLA)			Urban Total (LA)		
			Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)	Existing Load (10^6 colonies/yr)	Percent Reduction	Allocated Load (10^6 colonies/yr)
2	Sleepy Valley-02	95%	1.33E+01	95%	6.63E-01	4.65E+01	95%	2.32E+00	6.41E+03	95%	3.21E+02	0.00E+00	95%	0.00E+00	5.96E+04	95%	2.98E+03

5.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included for the lakes addressed in these TMDLs. Wastewater treatment facilities will continue to be required to achieve disinfection. Nonpoint source reduction strategies applied to land uses will be equally effective with respect to existing and future use of the land.

6.0 FOLLOW - UP MONITORING

Monitoring requirements for the listed lakes are established under NJDOH regulations for state bathing beaches. NJDOH regulations include sampling requirements before and during seasonal operation. Before bathing beaches are opened each year, NJDOH requires a pre-operational assessment, which includes

- A review of historical sampling and epidemiological data
- A field investigation of the bathing and surrounding areas to identify sources of potential contamination
- A sampling of waters in the bathing area and in areas of suspected sources of contamination

During the bathing season, NJDOH requires that bathing beach water be sampled one week prior to opening and at one-week intervals once in use. Samples are collected during periods of maximum user load and from depths used for bathing. In cases where water samples were found to meet the NJDOH water quality criterion for three consecutive months in the prior year, operators can apply for biweekly sampling responsibilities (NJDOH, 2004).

7.0 IMPLEMENTATION

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, citing criteria, operating methods, or other alternatives" (USEPA, 1993).

Development of effective management measures depends on accurate source assessment. Coliform bacteria are contributed to the environment from a number of categories of sources including human, domestic or captive animals, agricultural practices, and wildlife. Coliform bacteria from these sources can reach waterbodies directly, through overland runoff, or through sewage or stormwater conveyance facilities. Each potential source will respond to one or more management strategies designed to eliminate or reduce that source of coliform bacteria. Each management strategy has one or more entities that can take lead responsibility to effect the strategy. Various funding sources are available to assist in accomplishing the management strategies. The Department will address the sources of impairment by matching strategies with sources, selecting responsible entities and aligning available resources to effect implementation.

For example, the stormwater discharged to the impaired waterbodies through "municipal separate storm sewer systems" (MS4s) are regulated under the Department's Municipal Stormwater Regulation Program. Under these rules and associated general permits, many municipalities (and various county, State, and other agencies) are required to implement various control measures that should substantially reduce bacteria loadings, including measures to eliminate "illicit connections" of domestic sewage and other waste to the MS4s. Measures that are currently in effect include ordinances to manage pet waste, prohibit feeding of unconfined wildlife on public property, clean catch basins, perform good housekeeping at maintenance yards, and provide related public education and employee training. These measures are required in accordance with the Department's Municipal Stormwater Regulation program. The Department has provided State funds as well as a portion of its Clean Water Act 319(h) pass through grant funds to assist municipalities in meeting these requirements.

Sewage conveyance facilities are potential sources of fecal coliform in that equipment failure or operational problems may result in the release of untreated sewage. These sources, once identified, can be eliminated through appropriate corrective measures that can be affected through the Department's enforcement authority. Inadequate on-site sewage disposal can also be a source of fecal coliform. Systems that were improperly designed, located or maintained may result in surfacing of effluent; illicit remedies such as connections to storm sewers or streams add human waste directly to waterbodies. Once these problems have been identified through local health departments, sanitary surveys, or other means, alternatives to address the problems can be evaluated and the best solution implemented. The New Jersey Environmental Infrastructure Financing Program, which includes New Jersey's State Revolving Fund, provides low interest loans to assist in correction of water quality problems related to stormwater and wastewater management.

Geese are migratory birds that are protected by the Migratory Bird Treaty Act of 1918 and other Federal and State Laws. Resident Canada geese do not migrate, but are nevertheless protected by this and other legislation. The United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS)-Wildlife Services program reports that the 1999 estimated population of non-migratory geese in New Jersey was 83,000. Geese may produce up to 1½ pounds of fecal matter a day and when the congregate in large numbers they can represent a locally significant source of coliform bacteria. This may warrant taking steps to reduce populations in areas with excessive populations.

Because geese are free to move about and commonly graze and rest on large grassy areas associated with schools, parks, golf courses, corporate lawns, and cemeteries, measures to reduce populations, where necessary, are best developed and conducted at the community level through a community-based goose damage management program. USDA's Wildlife Services program recommends that a community prepare a written Canada Goose Damage Management Plan that may include the following actions:

- Initiate a fact-finding and communication plan
- Enact and enforce a "no feeding" ordinance (already required per MS4 permits)
- Conduct goose damage control activities such as habitat modification

- Review and update land use policies
- Reduce or eliminate goose reproduction (permit required)
- Hunt geese to reinforce nonlethal actions (permit required)

Procedures such as handling nests and eggs, capturing and relocating birds, and the hunting of birds require a depredation permit from either the USDA APHIS Wildlife Services or U.S. Fish and Wildlife Services. Procedures requiring permits should be a last resort after a community has exhausted the other listed measures. The Department's draft guide *Management of Canada Geese in Suburban Areas, March 2001,* which may be found at www.state.nj.us/dep/watershedmgt under publications, provides extensive guidance on how to modify habitat to serve as a deterrent to geese as well as other prevention techniques such as education through signage and ordinances.

In coastal areas, other waterfowl are naturally present in significant numbers and vary seasonally with migratory patterns. Other wildlife contributions may include deer populations, which have been identified as a potential fecal coliform source in the impaired watersheds. The forested and low-density residential areas that provide deer habitat can be found in close proximity to the impaired watersheds. Deer have been evaluated in fecal coliform TMDLs by other States (e.g. Alabama and South Carolina) and could be a fecal coliform source in New Jersey. Management measures to reduce coliform bacteria contributed by wildlife are not generally practicable, but could respond to measures such as improved riparian buffers.

Agricultural activities are another example of potential sources of coliform bacteria. Possible contributors are direct contributions from livestock permitted to traverse streams and stream corridors, manure management from feeding operations, or use of manure as a soil fertilizer/amendment. Implementation of conservation management plans and best management practices are the best means of controlling agricultural sources of coliform bacteria. Several programs are available to assist farmers in the development and implementation of conservation management plans and best management practices. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

- **The Environmental Quality Incentive Program (EQIP)** is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

- **The Conservation Reserve Program (CRP)** is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter

strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP).

- **The Conservation Reserve Enhancement Program** The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, have established a $100 million dollar CREP agreement. The program matches $23 million of State money with $77 million from the Comodity Credit Corporation within USDA. Through CREP, financial incentives are offered for agricultural landowners to voluntarily implement conservation practices on agricultural lands. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). There will be a ten-year enrollment period, with CREP leases ranging between 10-15 years. The State intends to augment this program thereby making these leases permanent easements. The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

Management strategies are summarized below in Table 8.

Table 8. Implementation management strategies.

Source Category	Responses	Potential Responsible Entity	Funding options
Human Sources			
Inadequate (per design, operation, maintenance, location, density) on-site disposal systems	Sanitary surveys, septic management programs/ordinances	Municipality	CWA 604(b) for confirmation of inadequate condition; Environmental Infrastructure Financing Program for construction of selected option
Inadequate or improperly maintained stormwater facilities; illicit connections	Measures required under Municipal Stormwater permitting program including any additional measures determined in the future to be needed through TMDL process	Municipality, State and County regulated entities, stormwater utilities	CWA 319(h); Environmental Infrastructure Financing Program for construction of selected option
Malfunctioning sewage conveyance facilities	Identify through source trackdown and repair	Owner of malfunctioning facility--compliance issue	User fees
Domestic/captive animal sources			
Pets	Pet waste ordinances	Municipalities for ordinance adoption and compliance	State source and CWA 319(h) assistance to municipalities to implement municipal stormwater regulations

Source Category	Responses	Potential Responsible Entity	Funding options
Horses, livestock, zoos	Confirm through source trackdown: SCD/NRCS develop conservation management plans	Property owner	EQIP, CRP, CREP
Agricultural practices	Confirm through source trackdown; SCD/NRCS develop conservation management plans, exercise CAFO/AFO authority if applicable	Property owner	EQIP, CRP, CREP
Wildlife			
Locally excessive populations of resident Canada geese or other waterfowl	Feeding ordinances; Goose Management BMPs	Municipality for ordinance; local community groups for BMPs	State source; CWA 319(h)
Indigenous wildlife	Confirm through trackdown; riparian buffer restoration; consider revising designated uses	State	State source

7.1 Specific Projects

In addition to the more generalized strategies described previously, a number of projects have been undertaken which are expected to aid in achieving the load reductions assigned to the impaired waterbodies. Ongoing activities to develop and implement watershed restoration plans are expected to result in additional specific projects to reduce pollutant loads.

Table 9. Northwest Water Region Outreach and Restoration Projects

WMA	FY	Funding Source	Recipient	Project Title	Grant Amount
1	2005	319(h)	Lake Hopatcong Commission	Implementation of Nonpoint Source Management Measures to Reduce the Phosphorus and Sediment Loads Entering Lake Hopatcong	$910,440
1	2006	CBT	Princeton Hydro, LLC	Refined Phosphorus TMDL and Restoration Plan for Lake Hopatcong and Lake Musconetcong	$94,000
1	2007	319(h)	Sussex County Municipal Utilities Authority, Wallkill River Watershed Management Group	Watershed Restoration Plan for the Paulins Kill Headwaters to Balesville: Three Phased Approach (Fox Hollow Lake)	$464,025

8.0 REASONABLE ASSURANCE

With the implementation of source reduction measures such as reducing the number of failing septic systems, leaching sewer lines, and controlling agricultural runoff, the Department has reasonable assurance that a significant improvement in the support of primary contact recreation in the impaired lakes will be attained. The results from on-going existing monitoring programs will be evaluated to determine effectiveness of the identified measures and if additional measures are needed.

9.0 PUBLIC PARTICIPATION

The Water Quality Management Planning Rules at N.J.A.C. 7:15-7.2 require the Department to initiate a public process prior to the development of each TMDL and to allow public input to the Department on policy issues affecting the development of the TMDL. Further, the Department shall adopt each TMDL as an amendment to the appropriate area-wide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g). As part of the public participation process for the development and implementation of the subject TMDLs, the Department solicited information from stakeholder groups and from the general public directly and through a web posting beginning in October 2006. Additionally in November 2006, the list of impaired lakes was distributed to the New Jersey volunteering monitoring community, through the Watershed Watch Network. The Watershed Watch Network is a program acting as an umbrella for all of the volunteer monitoring programs within New Jersey. Interested parties had the opportunity to supply the Department with information about each via e-mail. The Department specifically solicited information regarding potential sources and/or current non point sources of pollution reduction projects within the impaired watersheds. Information received regarding potential sources of fecal contamination were assessed in the development of these TMDLs.

10.0 AMENDMENT PROCESS

Notice proposing these TMDLs appeared in the July 16, 2007 New Jersey Register and in a newspaper of general circulation in order to provide the public an opportunity to review the TMDL document and submit formal comments. In addition, a public hearing was held on August 17, 2007 at the New Jersey Department of Environmental Protection Public Hearing Room, 401 E. State St., Trenton, NJ 08608. There was an informal presentation from 1:00 p.m. to 2:00 p.m., followed by the public hearing from 2:00 p.m. until the end of testimony, whichever was earlier. One person attended the hearing and no testimony was given. Notice of the proposal and hearing was provided to affected counties, municipalities and lake associations in the watershed.

There were no comments received during the public notice period or at the public hearing. This TMDL was approved by EPA on September 28, 2007 and was adopted on October 19, 2009 as an amendment to the Sussex County and Upper Delaware Water Quality Management Plans in accordance with New Jersey's Water Quality Management Planning Rules at N.J.A.C. 7:15-3.4 (g).

APPENDIX A: REFERENCES

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APPENDIX B: NJPDES WASTEWATER TREATMENT FACILITIES, TIER A MUNICIPALITIES, TIER B MUNICIPALITIES

Northwest Water Region Wastewater Treatment Facilities

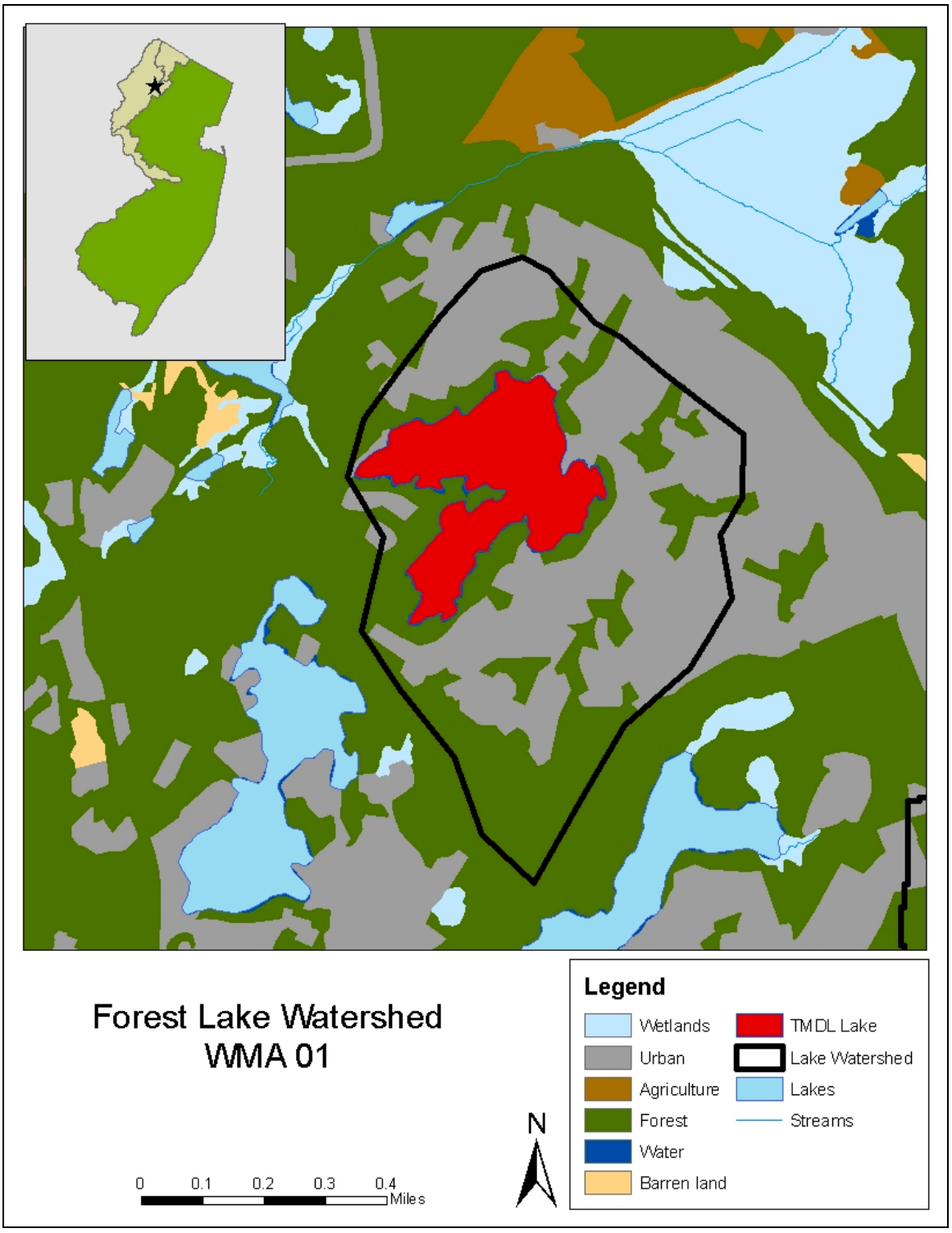
NJPDES ID	Facility Name	Pipe	FC Limit	Permit Category*	Receiving Waters/Associated Lake
NJ0021105	Jefferson Twp - Arthur Stanlick School	001A	NA	A	Lake Shawnee via unnamed trib/Lake Hopatcong
NJ0027049	Pope John XXIII High School	001A	NA	A	Fox Hollow Lake via unnamed trib

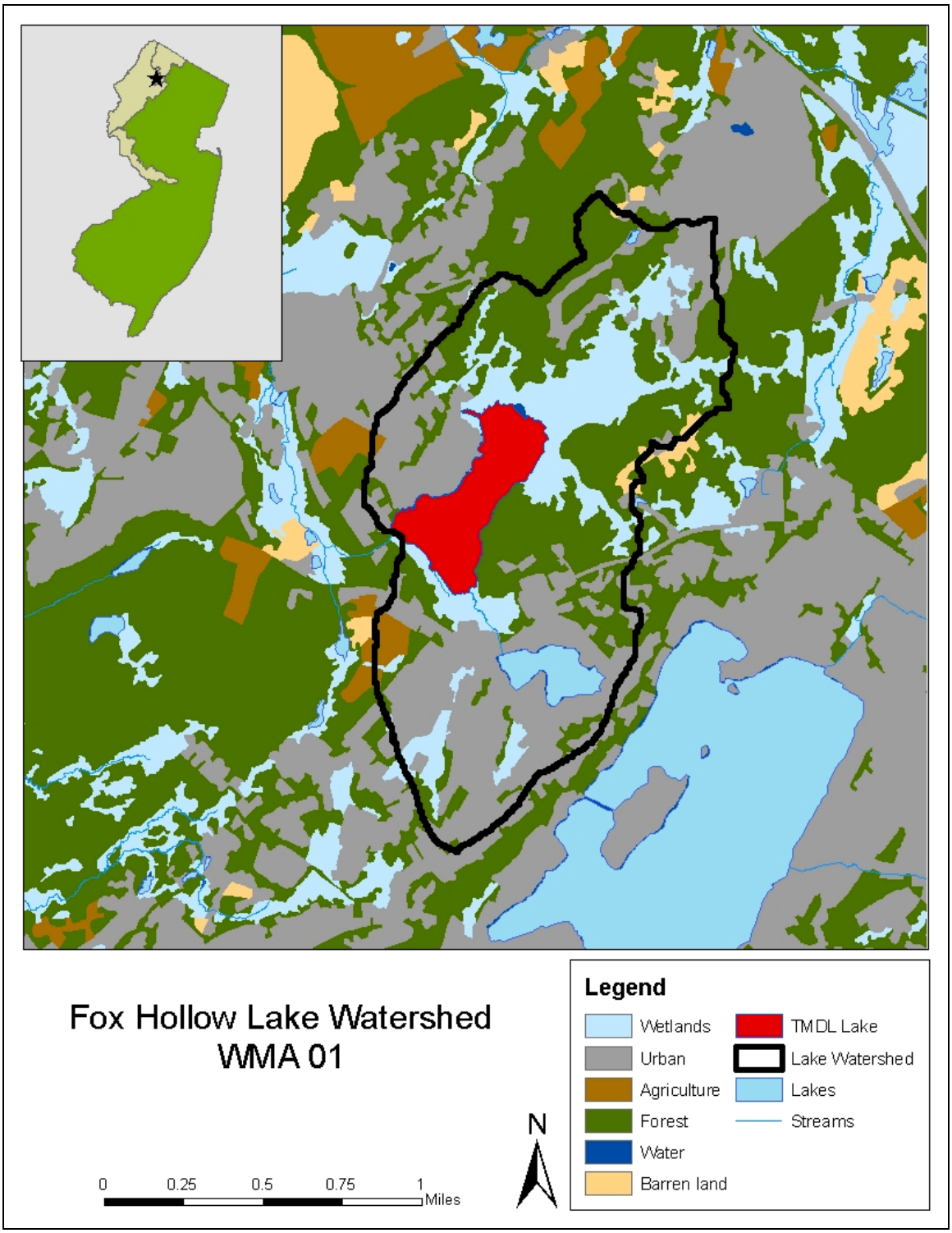
*Permit Categories: A = Sanitary Surface Water Discharge

Northwest Water Region Tier A and Tier B Municipalities

Tier	Watershed	Municipality	WMA	Permit #
A	Fox Hollow	Sparta Twp	1	NJG0148059
	Green Valley Beach Campground	Andover Twp	1	NJG0153290
	Lake Hopatcong	Sparta Twp	1	NJG0148059
		Jefferson Twp	1	NJG0151793
		Hopatcong Boro	1	NJG0147931
		Mount Arlington Boro	1	NJG0153265
		Roxbury Twp	1	NJG0152641
	Lackawanna Lake	Sparta Twp	1	NJG0148059
		Hopatcong Boro	1	NJG0147931
		Byram Twp	1	NJG0149209
	Forest Lake	Andover Twp	1	NJG0153290
		Byram Twp	1	NJG0149209
	Lake Winona	Sparta Twp	1	NJG0148059
		Jefferson Twp	1	NJG0151793
	Lake Mohawk	Sparta Twp	2	NJG0148059
		Andover Twp	2	NJG0153290
		Byram Twp	2	NJG0149209
B	Furnace Lake	White Twp	1	NJG0149683
		Oxford Twp	1	NJG0151904
		Washington Twp	1	NJG0150690
	Green Valley Beach Campground	Green Twp	1	NJG0152943
	Deer Trail Lake	Hardyston Twp	2	NJG0152269
	Crystal Springs Lake	Hardyston Twp	2	NJG0152269

APPENDIX C: LAKE WATERSHED MAPS

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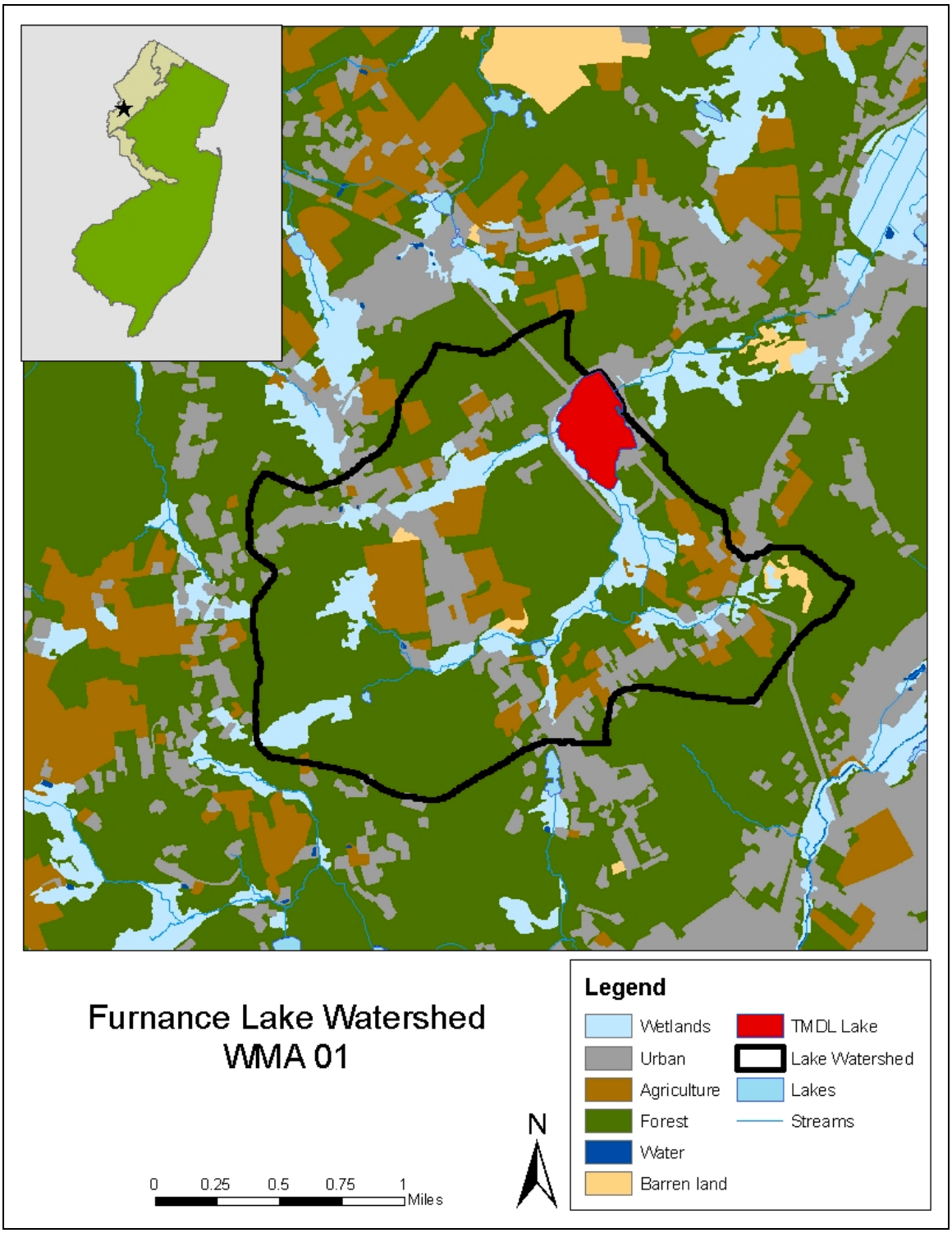
Lakes
Streams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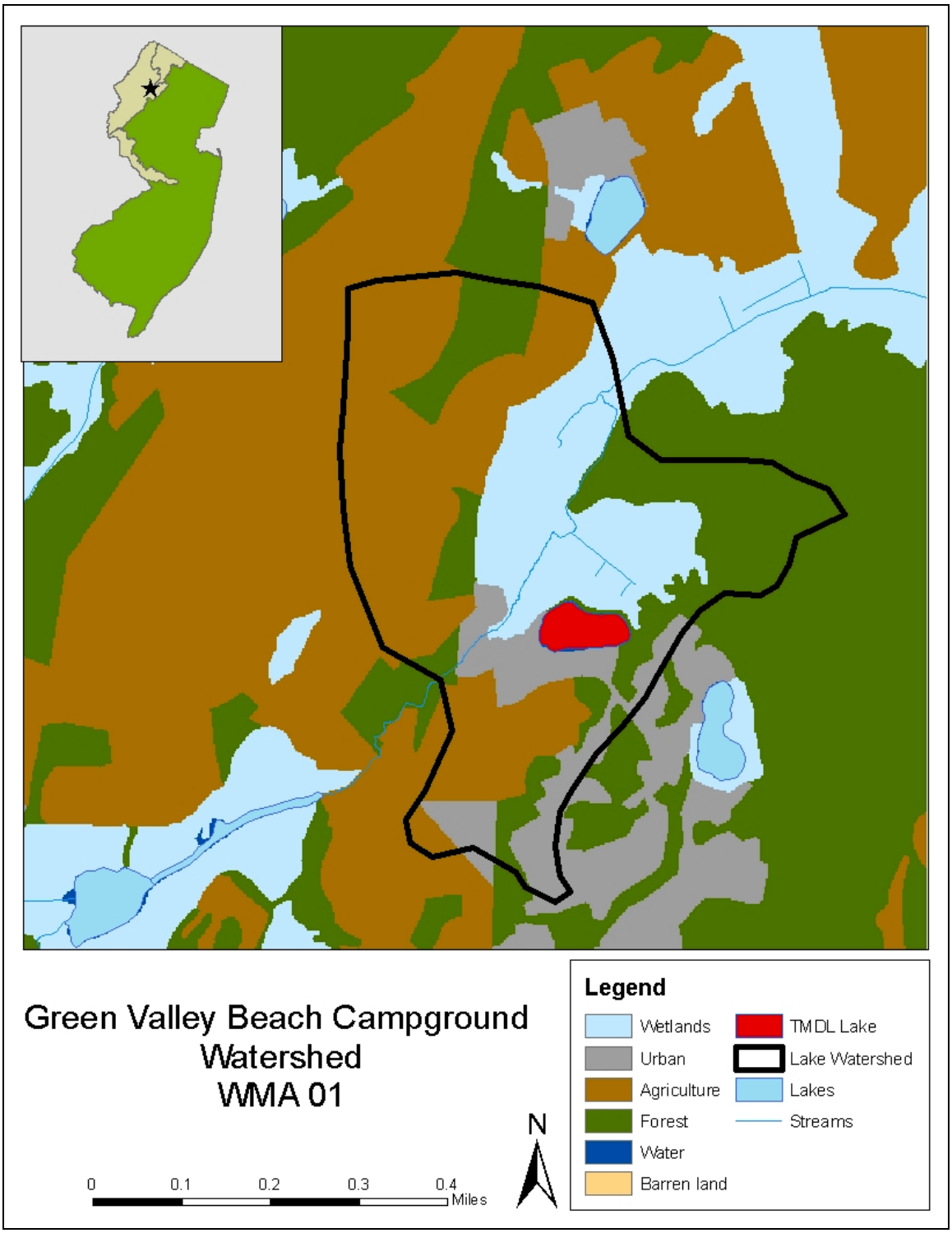
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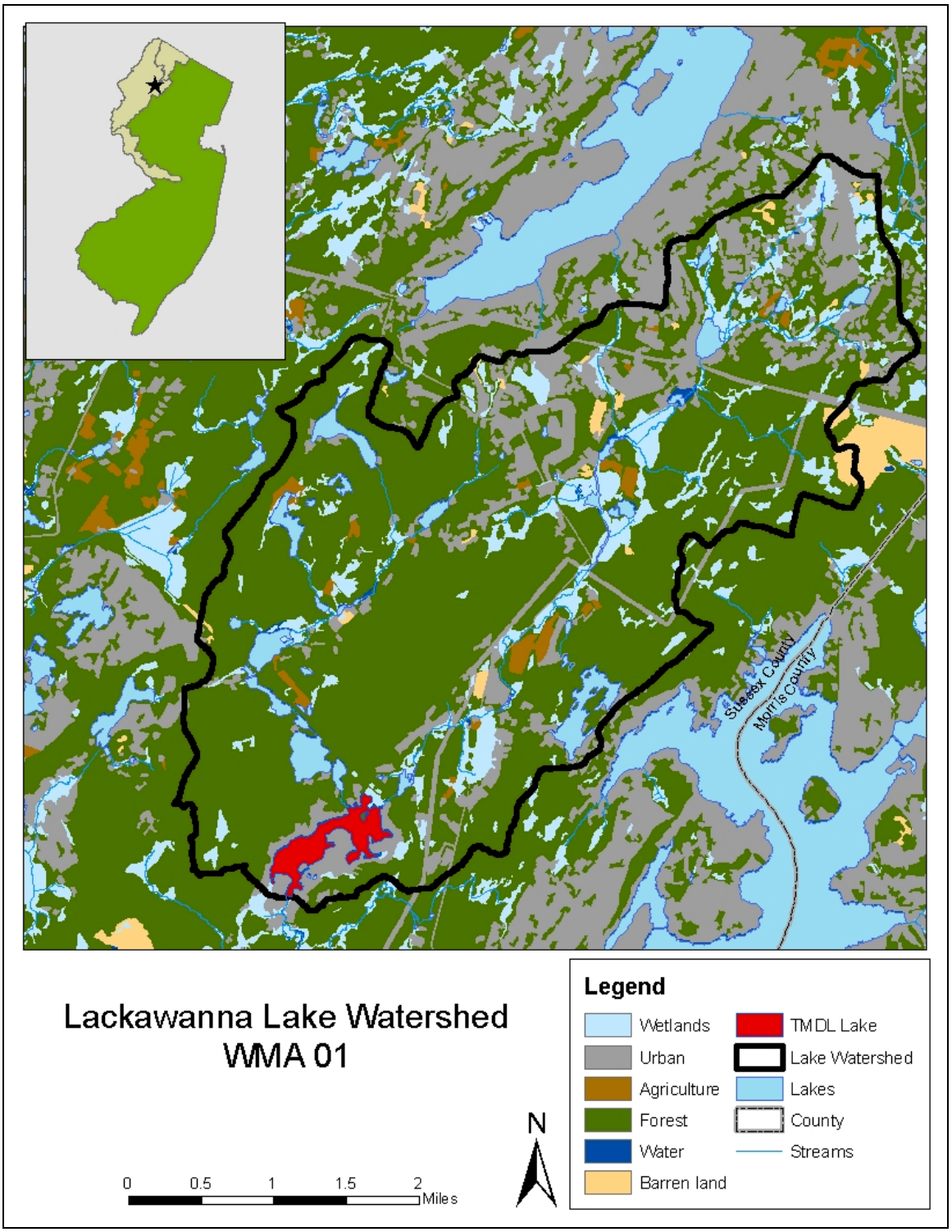
Lakes
Streams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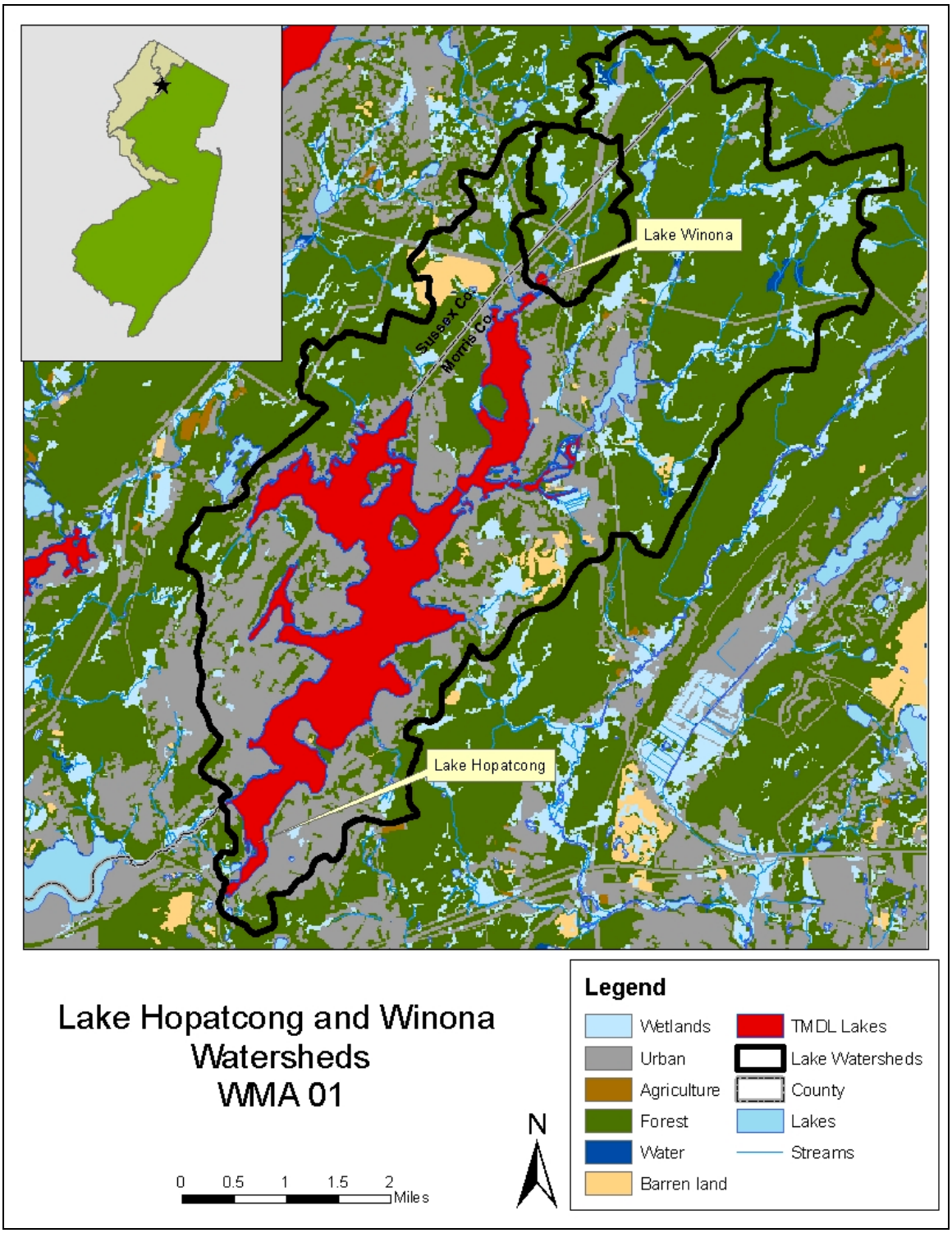
Lakes
County
Streams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Sussex Co.
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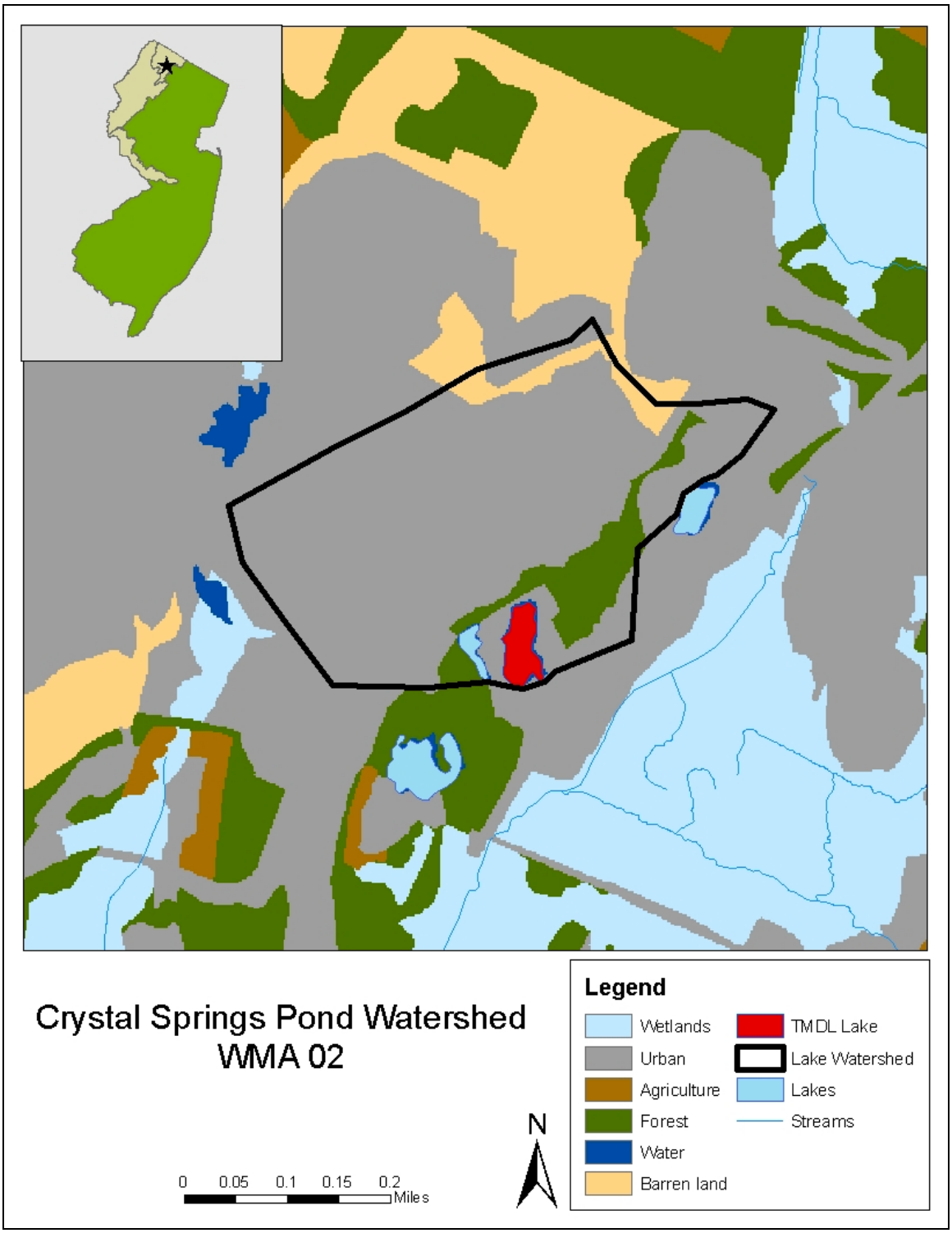
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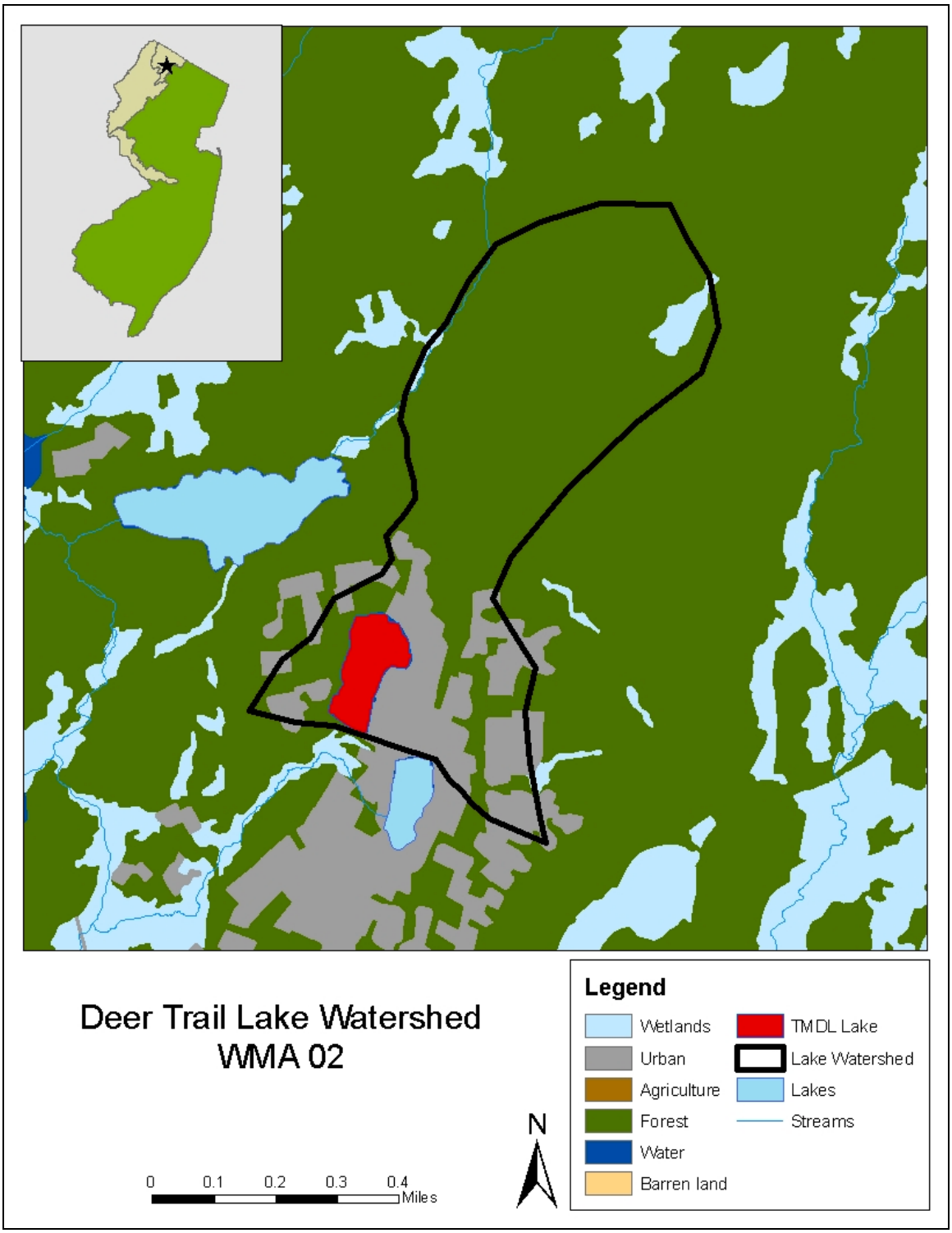
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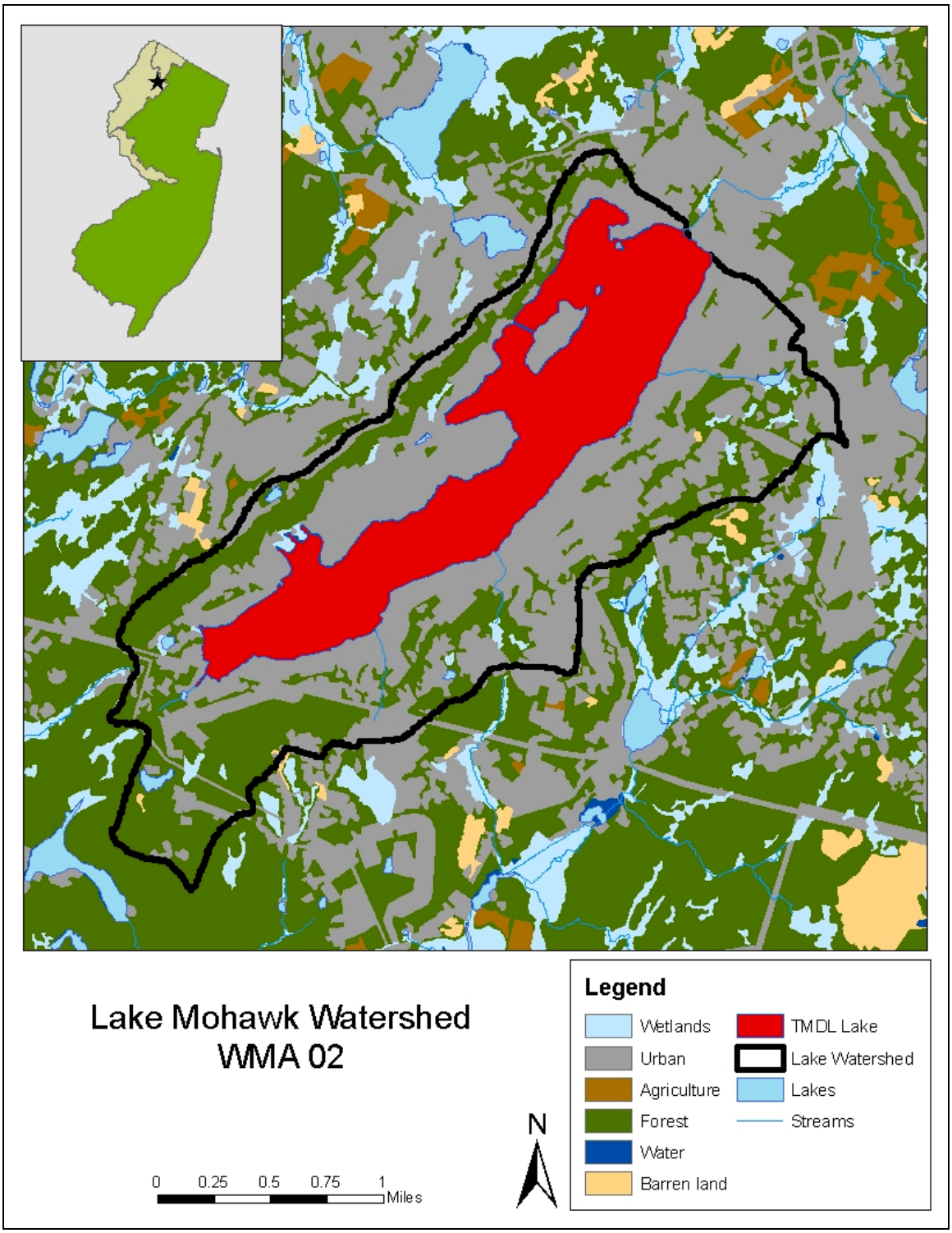
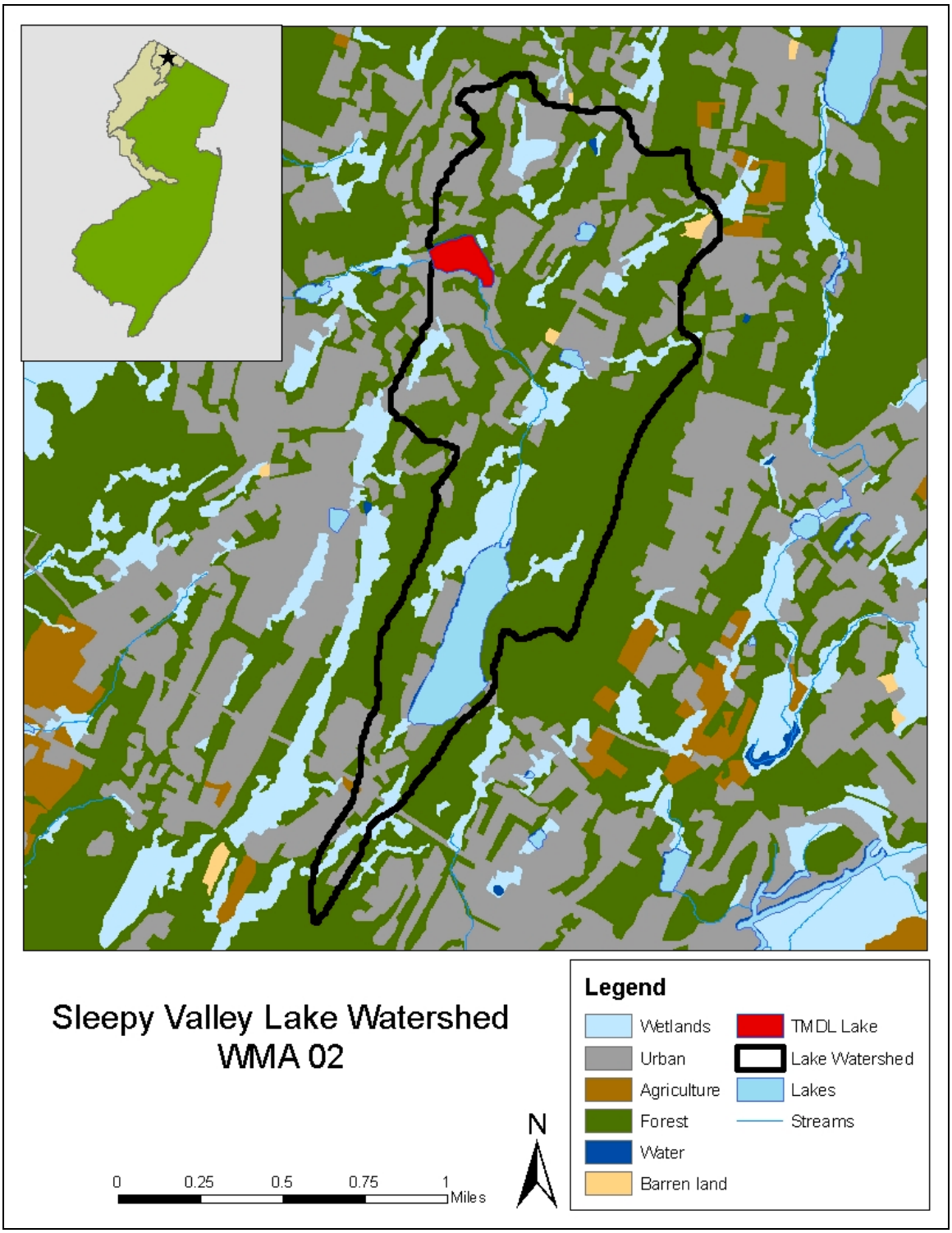
TMDL Lake
Lake Watershed
Lakes
Streams


Lake Mohawk Watershed
WMA 02
0 0.25 0.5 0.75 1
Miles
N
Legend
Wetlands
Urban
Agriculture
Forest
Water
Barren land
TMDL Lake
Lake Watershed
Lakes
Streams


Sleepy Valley Lake Watershed
WMA 02
0
0.25
0.5
0.75
1
Miles
N
Legend
Wetlands
Urban
Agriculture
Forest
Water
Barren land
TMDL Lake
Lake Watershed
Lakes
Streams

APPENDIX D: NORTHWEST WATER REGION WATER QUALITY DATA

* Highlighted values are greater than 200 cfu/100 ml of fecal coliform bacteria

WMA 01

Forest Lake			
Stats:			
count	333	mean+3stdev	2657
median	10	% Reduction	98%
max	12000		
stdev	834	**no data excluded**	
mean	154		
mean+3stdev	2657		

DATA			
Station	**Date**	**Value**	**Remark**
SXL190402	05/18/98	2	K
SXL190402	06/03/98	2	K
SXL190402	06/17/98	2	K
SXL190402	07/01/98	30	
SXL190402	07/13/98	50	
SXL190402	07/31/98	30	
SXL190402	08/10/98	98	
SXL190402	08/17/98	1	
SXL190402	09/01/98	20	
SXL190403	05/18/98	2	K
SXL190403	06/03/98	20	
SXL190403	06/17/98	350	
SXL190403	06/20/98	2	K, RESAMPLE
SXL190403	06/22/98	2	K, RESAMPLE
SXL190403	07/01/98	60	
SXL190403	07/13/98	2	K
SXL190403	07/13/98	2	K
SXL190403	07/31/98	30	
SXL190403	07/31/98	2	K
SXL190403	08/14/98	40	
SXL190403	09/01/98	2	K
SXL190404	05/18/98	2	K
SXL190404	06/03/98	2	K
SXL190404	06/17/98	40	
SXL190404	07/01/98	2	K
SXL190404	07/13/98	20	
SXL190404	07/31/98	2	K
SXL190404	08/14/98	2	K
SXL190404	09/01/98	30	
SXL190405	05/18/98	150	
SXL190405	06/03/98	30	
SXL190405	06/17/98	120	
SXL190405	07/01/98	70	
SXL190405	07/13/98	20	
SXL190405	07/31/98	2	K
SXL190405	08/14/98	2	K
SXL190405	09/01/98	2	K
FOREST LAKE: BOARDWALK BEACH	05/24/99	190	
SXL190402	06/11/99	20	
SXL190402	06/18/99	10	K
SXL190402	07/05/99	10	K
SXL190402	07/22/99	20	
SXL190402	08/05/99	10	
SXL190402	08/17/99	10	K
SXL190402	08/02/99	40	
FOREST LAKE: COVE BEACH	05/24/99	10	
SXL190403	06/11/99	10	K
SXL190403	06/18/99	20	
SXL190403	07/05/99	10	K
SXL190403	07/22/99	10	K
SXL190403	08/05/99	10	K
SXL190403	08/17/99	10	K
SXL190403	09/02/99	30	
FOREST LAKE: HARBOR VIEW BEACH	05/24/99	**12000**	
SXL190404	05/28/99	680	beach closed, RESAMPLE
SXL190404	06/01/99	780	beach closed, RESAMPLE
SXL190404	06/11/99	10	K, RESAMPLE
SXL190404	06/18/99	10	K
SXL190404	06/25/99	10	K
SXL190404	07/05/99	10	K
SXL190404	07/09/99	10	K
SXL190404	07/15/99	10	K
SXL190404	07/22/99	10	
SXL190404	07/26/99	10	
SXL190404	08/05/99	20	
SXL190404	08/13/99	10	K
SXL190404	08/17/99	50	
SXL190404	08/27/99	180	
SXL190404	09/02/99	10	K
FOREST LAKE: MAIN BEACH	05/24/99	130	
SXL190405	06/11/99	160	
SXL190405	06/18/99	10	K
SXL190405	07/05/99	10	K
SXL190405	07/22/99	40	
SXL190405	08/05/99	10	
SXL190405	08/17/99	20	
SXL190405	09/02/99	20	

SXL190402	05/12/00	10	K
SXL190402	06/23/00	10	
SXL190402	06/27/00	10	K
SXL190402	07/05/00	20	
SXL190402	07/11/00	10	K
SXL190402	07/18/00	10	
SXL190402	08/01/00	40	
SXL190402	08/08/00	10	
SXL190402	08/15/00	40	
SXL190402	08/29/00	10	
SXL190403	05/12/00	10	K
SXL190403	06/23/00	10	K
SXL190403	06/27/00	10	K
SXL190403	07/05/00	10	K
SXL190403	07/11/00	20	
SXL190403	07/18/00	10	K
SXL190403	08/01/00	30	
SXL190403	08/08/00	10	K
SXL190403	08/15/00	100	
SXL190403	08/29/00	10	K
SXL190404	05/12/00	70	
SXL190404	06/23/00	10	K
SXL190404	06/27/00	10	K
SXL190404	07/05/00	40	
SXL190404	07/11/00	10	K
SXL190404	07/18/00	30	
SXL190404	08/01/00	20	
SXL190404	08/08/00	30	
SXL190404	08/15/00	20	
SXL190404	08/29/00	10	K
SXL190405	05/12/00	40	
SXL190405	06/23/00	10	K
SXL190405	06/27/00	10	K
SXL190405	07/05/00	10	K
SXL190405	07/11/00	10	K
SXL190405	07/18/00	60	

SXL190405	08/01/00	20	
SXL190405	08/08/00	10	
SXL190405	08/29/00	20	
Boardwalk Beach	05/17/01	10	K
Boardwalk Beach	06/07/01	10	K
Boardwalk Beach	06/15/01	10	K
Boardwalk Beach	06/19/01	10	K
Boardwalk Beach	06/26/01	10	K
Boardwalk Beach	07/12/01	10	K
Boardwalk Beach	07/24/01	10	K
Boardwalk Beach	07/29/01	10	K
Boardwalk Beach	08/01/01	10	K
Boardwalk Beach	08/07/01	10	K
Boardwalk Beach	08/16/01	10	K
Boardwalk Beach	08/23/01	8	
Cove Beach	05/17/01	10	K
Cove Beach	06/07/01	80	
Cove Beach	06/15/01	10	
Cove Beach	06/19/01	20	
Cove Beach	06/26/01	10	
Cove Beach	07/12/01	40	
Cove Beach	07/24/01	10	K
Cove Beach	07/29/01	380	
Cove Beach	08/01/01	10	K
Cove Beach	08/07/01	10	K
Cove Beach	08/16/01	140	
Harbor View Beach	05/17/01	10	K
Harbor View Beach	06/07/01	20	
Harbor View Beach	06/15/01	70	
Harbor View Beach	06/19/01	640	Beach closed voluntarily
Harbor View Beach	06/26/01	200	Beach reopened 6/29
Harbor View Beach	07/12/01	20	

Harbor View Beach	07/24/01	10	K
Harbor View Beach	07/29/01	10	K
Harbor View Beach	08/01/01	20	
Harbor View Beach	08/07/01	70	
Harbor View Beach	08/16/01	2400	Voluntary closure
Harbor View Beach	08/21/01	10	K
Main Beach	05/17/01	10	K
Main Beach	06/07/01	10	K
Main Beach	06/15/01	190	
Main Beach	06/19/01	200	
Main Beach	06/26/01	150	
Main Beach	07/12/01	10	
Main Beach	07/24/01	10	K
Main Beach	07/29/01	10	K
Main Beach	08/01/01	10	K
Main Beach	08/07/01	30	
Main Beach	08/16/01	40	
BOARDWALK BEACH	05/16/02	20	
BOARDWALK BEACH	05/31/02	10	K
BOARDWALK BEACH	06/05/02	50	
BOARDWALK BEACH	06/10/02	10	
BOARDWALK BEACH	06/25/02	10	K
BOARDWALK BEACH	06/28/02	10	
BOARDWALK BEACH	07/02/02	10	
BOARDWALK BEACH	07/15/02	10	K
BOARDWALK BEACH	07/26/02	10	K

BOARDWALK BEACH	07/31/02	10	K
BOARDWALK BEACH	08/13/02	20	
BOARDWALK BEACH	08/15/02	10	K
BOARDWALK BEACH	08/19/02	60	
BOARDWALK BEACH	08/22/02	40	
BOARDWALK BEACH	08/26/02	30	
COVE BEACH	05/16/02	50	
COVE BEACH	05/31/02	260	
COVE BEACH	06/05/02	10	K, RESAMPLE
COVE BEACH	06/10/02	10	
COVE BEACH	06/25/02	100	
COVE BEACH	06/28/02	310	
COVE BEACH	07/02/02	10	RESAMPLE
COVE BEACH	07/15/02	30	
COVE BEACH	07/26/02	10	
COVE BEACH	07/31/02	10	K
COVE BEACH	08/13/02	310	RESAMPLE
COVE BEACH	08/15/02	4900	RESAMPLE, CLOSED
COVE BEACH	08/19/02	40	RESAMPLE
COVE BEACH	08/22/02	130	
COVE BEACH	08/26/02	300	
HARBOR VIEW BEACH	05/16/02	10	K
HARBOR VIEW BEACH	05/31/02	10	
HARBOR VIEW BEACH	06/05/02	260	
HARBOR VIEW BEACH	06/10/02	20	RESAMPLE
HARBOR VIEW BEACH	06/25/02	40	
HARBOR VIEW BEACH	06/28/02	190	
HARBOR VIEW BEACH	07/02/02	30	

HARBOR VIEW BEACH	07/11/02	370	
HARBOR VIEW BEACH	07/15/02	10	RESAMPLE
HARBOR VIEW BEACH	07/26/02	140	
HARBOR VIEW BEACH	07/31/02	10	
HARBOR VIEW BEACH	08/13/02	10	
HARBOR VIEW BEACH	08/15/02	80	
HARBOR VIEW BEACH	08/19/02	160	
HARBOR VIEW BEACH	08/22/02	160	
HARBOR VIEW BEACH	08/26/02	100	
MAIN BEACH	05/16/02	10	K
MAIN BEACH	05/31/02	10	K
MAIN BEACH	06/05/02	100	
MAIN BEACH	06/10/02	30	
MAIN BEACH	06/25/02	220	HEAVY RAINS
MAIN BEACH	07/02/02	100	
MAIN BEACH	07/11/02	10	
MAIN BEACH	07/15/02	10	K
MAIN BEACH	07/26/02	80	
MAIN BEACH	07/31/02	20	
MAIN BEACH	08/13/02	40	
MAIN BEACH	08/15/02	5100	
MAIN BEACH	08/19/02	920	RESAMPLE
MAIN BEACH	08/22/02	200	RESAMPLE
MAIN BEACH	08/26/02	200	RESAMPLE
Forest Lake:Boardwalk Beach	05/30/03	10	K
	06/09/03	10	K
	06/16/03	10	K
	06/24/03	10	K
	06/27/03	10	

	06/30/03	80	
	07/07/03	20	
	07/24/03	10	
	08/11/03	40	
	08/20/03	20	
	08/25/03	60	
Forest Lake:Cove Beach	05/30/03	10	K
	06/09/03	10	K
	06/16/03	10	K
	06/24/03	10	K
	06/27/03	10	
	06/30/03	30	
	07/07/03	10	K
	07/24/03	230	
	07/29/03	10	K
	08/05/03	10	
	08/11/03	230	
	08/20/03	30	
	08/25/03	10	K
Forest Lake:Harborview Beach	05/30/03	40	
	06/09/03	10	K
	06/16/03	10	K
	06/24/03	10	K
	06/27/03	30	
	06/30/03	30	
	07/07/03	50	
	07/24/03	90	
	07/29/03	10	K
	08/05/03	60	
	08/11/03	60	
	08/20/03	3000	
	08/25/03	30	

Forest Lake:Main Beach	05/30/03	10	K
	06/09/03	20	
	06/16/03	70	
	06/24/03	330	
	06/27/03	140	
	06/30/03	70	
	07/07/03	80	
	07/24/03	60	
	07/29/03	10	
	08/05/03	10	
	08/11/03	80	
	08/20/03	10	
	08/25/03	60	
Forest Lake: Boardwalk	05/17/04	10	
	06/02/04	10	K
	06/09/04	1100	
	06/11/04	20	
	06/16/04	80	
	06/23/04	40	
	06/29/04	10	K
	07/06/04	10	K
	07/15/04	10	K
	07/20/04	10	
	07/26/04	10	K
	08/03/04	10	K
	08/10/04	10	K
	08/18/04	10	K
	08/25/04	10	K
Forest Lake: Cove	05/17/04	10	K
	06/02/04	10	K
	06/09/04	40	
	06/11/04	590	
	06/16/04	10	K
	06/23/04	30	

	06/29/04	30	
	07/06/04	40	
	07/15/04	10	K
	07/20/04	10	K
	07/26/04	10	K
	08/03/04	10	K
	08/10/04	10	K
	08/18/04	10	K
	08/25/04	30	
Forest Lake: Harborview	05/17/04	10	K
	06/02/04	40	
	06/09/04	510	preseason testing
	06/11/04	300	preseason testing
	06/16/04	40	
	06/23/04	10	K
	06/29/04	10	
	07/06/04	10	K
	07/15/04	40	
	07/20/04	10	
	07/26/04	10	K
	08/03/04	10	
	08/10/04	10	K
	08/18/04	10	
	08/25/04	110	
Forest Lake: Main	05/17/04	10	
	06/02/04	50	
	06/09/04	4900	
	06/11/04	50	
	06/16/04	90	
	06/23/04	110	
	06/29/04	30	
	07/06/04	40	
	07/15/04	100	
	07/20/04	10	K
	07/26/04	10	K

	08/03/04	30	
	08/10/04	10	K
	08/18/04	10	
	08/25/04	10	

Fox Hollow Lake			
count	116	mean+3stdev	2755
median	20	%reduction	80%
Max	9300		
stdev	868	**1 value excluded (9300)**	
mean	152	**Excluded. Next highest value in dataset is 1000. Also, there was no remark code and resample concentration is 50 (9300 possibly a data entry error)**	
mean+3stdev	2755		

STATION	DATE	VALUE	REMARK
SXL115	5/26/1998	10	K
SXL115	6/1/1998	100	
SXL115	6/8/1998	20	
SXL115	6/15/1998	370	
SXL115	6/17/1998	70	RESAMPLE
SXL115	6/22/1998	10	K
SXL115	6/29/1998	10	K
SXL115	7/6/1998	40	
SXL115	7/13/1998	10	K
SXL115	7/20/1998	40	
SXL115	7/27/1998	310	
SXL115	7/29/1998	170	RESAMPLE
SXL115	8/3/1998	40	
SXL115	8/10/1998	10	K
SXL115	8/17/1998	560	
SXL115	8/19/1998	120	RESAMPLE
SXL115	8/24/1998	20	
SXL115	8/31/1998	100	
Fox Hollow	5/24/1999	10	
SXL115	6/1/1999	10	K
SXL115	6/7/1999	10	K
SXL115	6/14/1999	40	
SXL115	6/21/1999	150	
SXL115	6/28/1999	10	
SXL115	7/6/1999	30	

SXL115	7/12/1999	10	K
SXL115	7/19/1999	20	
SXL115	7/26/1999	**310**	
SXL115	7/28/1999	**260**	Resample
SXL115	8/2/1999	**630**	
SXL115	8/4/1999	170	Resample
SXL115	8/9/1999	40	
SXL115	8/16/1999	30	
SXL115	8/23/1999	10	K
SXL115	8/30/1999	50	
Fox Hollow Lake	5/22/2000	70	
SXL115	5/30/2000	10	
SXL115	6/5/2000	10	K
SXL115	6/12/2000	170	
SXL115	6/19/2000	60	
SXL115	6/26/2000	30	
SXL115	7/5/2000	70	
SXL115	7/10/2000	10	K
SXL115	7/17/2000	20	
SXL115	7/24/2000	10	K
SXL115	7/31/2000	170	
SXL115	8/7/2000	**9300**	
SXL115	8/9/2000	50	Resample
SXL115	8/16/2000	20	
SXL115	8/21/2000	10	
SXL115	8/28/2000	70	
Fox Hollow Lake			
	5/23/2001	170	
	6/4/2001	8	
	6/11/2001	330	
	6/14/2001	112	
	6/18/2001	2	K
	6/25/2001	4	
	7/2/2001	96	
	7/9/2001	28	
	7/16/2001	18	
	7/23/2001	30	
	7/30/2001	40	
	8/6/2001	114	
	8/13/2001	4	
	8/20/2001	30	
	8/27/2001	18	

	5/20/2002	20	
	5/29/2002	20	
	6/3/2002	10	K
	6/10/2002	1000	
	6/14/2002	50	Resample
	6/17/2002	30	
	6/24/2002	360	
	6/26/2002	10	K
	7/1/2002	20	
	7/8/2002	50	
	7/15/2002	10	
	7/22/2002	10	
	7/29/2002	10	K
	8/5/2002	50	
	8/12/2002	10	
	8/19/2002	80	
	8/26/2002	40	
FOX HOLLOW LAKE	5/21/2003	10	
	5/28/2003	40	
	6/2/2003	10	
	6/9/2003	30	
	6/16/2003	**260**	
	6/18/2003	40	Resample
	6/23/2003	20	
	6/30/2003	140	
	7/7/2003	10	
	7/14/2003	10	K
	7/21/2003	10	
	7/28/2003	10	
	8/4/2003	30	
	8/11/2003	10	
	8/18/2003	10	K
	8/25/2003	10	K
FOX HOLLOW LAKE	5/24/2004	10	K
	6/2/2004	10	K
	6/7/2004	10	K
	6/14/2004	90	
	6/17/2004	10	K
	6/18/2004	20	
	6/21/2004	10	K
	6/28/2004	10	
	7/7/2004	10	

	7/12/2004	50	
	7/21/2004	10	
	7/26/2004	10	K
	8/2/2004	10	K
	8/9/2004	10	
	8/16/2004	10	
	8/23/2004	50	
	8/30/2004	10	

Furnace Lake			
count	122	mean+3stdev	589
median	30	%reduction	76%
max	840		
stdev	162	**no data excluded**	
mean	103		
mean+3stdev	589		

STATION	DATE	VALUE	REMARKS
WC3	5/5/1998	160	
WC3	5/26/1998	90	
WC3	6/2/1998	1	
WC3	6/9/1998	10	
WC3	6/16/1998	140	
WC3	6/23/1998	40	
WC3	6/30/1998	260	
WC3	7/7/1998	40	
WC3	7/14/1998	1	
WC3	7/21/1998	1	
WC3	7/28/1998	1	
WC3	8/4/1998	10	
WC3	8/11/1998	50	
WC3	8/18/1998	30	
WC3	8/25/1998	1	
WC3	9/1/1998	10	
WC3	5/11/1999	10	
WC3	5/18/1999	10	
WC3	5/25/1999	30	
WC3	6/1/1999	10	
WC3	6/8/1999	20	
WC3	6/15/1999	90	
WC3	6/22/1999	100	
WC3	6/29/1999	380	
WC3	7/2/1999	10	
WC3	7/6/1999	30	

WC3	7/13/1999	50	
WC3	7/20/1999	190	
WC3	7/27/1999	400	
WC3	7/29/1999	10	
WC3	8/3/1999	10	
WC3	8/10/1999	50	
WC3	8/17/1999	120	
WC3	8/24/1999	20	
WC3	8/31/1999	10	
Furnace Lake Beach	5/16/2000	180	
Furnace Lake Beach	5/23/2000	60	
Furnace Lake Beach	5/30/2000	80	
Furnace Lake Beach	6/5/2000	10	
Furnace Lake Beach	6/12/2000	420	
Furnace Lake Beach	6/14/2000	180	
Furnace Lake Beach	6/19/2000	50	
Furnace Lake Beach	6/27/2000	10	
Furnace Lake Beach	7/3/2000	70	
Furnace Lake Beach	7/10/2000	40	
Furnace Lake Beach	7/20/2000	550	
Furnace Lake Beach	7/24/2000	10	
Furnace Lake Beach	7/27/2000	180	
Furnace Lake Beach	7/31/2000	580	
Furnace Lake Beach	8/3/2000	10	
Furnace Lake Beach	8/7/2000	710	
Furnace Lake Beach	8/9/2000	10	
Furnace Lake Beach	8/15/2000	20	
Furnace Lake Beach	8/21/2000	170	
Furnace Lake Beach	8/28/2000	30	67.45346506

	5/17/2001	10	
	5/24/2001	90	
	5/31/2001	10	
	6/4/2001	10	
	6/11/2001	10	
	6/18/2001	20	
	6/25/2001	10	
	7/2/2001	10	
	7/9/2001	40	
	7/16/2001	10	
	7/23/2001	100	
	7/30/2001	30	
	8/6/2001	840	
	8/8/2001	410	
	8/9/2001	470	
	8/13/2001	10	
	8/13/2001	20	
	8/20/2001	20	
	8/20/2001	130	
	8/27/2001	20	33.73
FURNACE LAKE BEACH	6/24/2002	10	
	7/1/2002	10	
	7/8/2002	10	
	7/15/2002	10	
	7/22/2002	10	
	7/29/2002	10	
	8/5/2002	30	
	7/12/2002	180	
	8/19/2002	10	
	8/26/2002	10	**14.90**
Furnace Lake Beach	5/12/2003	40	
	5/20/2003	490	
	5/22/2003	10	
	5/27/2003	10	
	6/2/2003	80	
	6/9/2003	120	
	6/16/2003	40	
	6/23/2003	180	
	6/30/2003	30	
	7/7/2003	10	
	7/14/2003	30	
	7/21/2003	30	

	7/28/2003	60	
	8/4/2003	180	
	8/11/2003	100	
	8/18/2003	70	
	8/25/2003	40	**51.10**
FURNACE LAKE BEACH	05/24/04	40	
	06/01/04	10	
	06/07/04	600	
	06/10/04	10	
	06/16/04	20	
	06/23/04	30	
	06/29/04	10	
	07/06/04	10	
	07/13/04	110	
	07/19/04	120	
	07/29/04	190	
	08/02/04	600	
	0/03/2004	120	
	08/09/04	20	
	08/17/04	20	
	08/23/04	10	
	08/30/04	230	
	08/31/04	270	
	09/01/04	210	
	09/02/04	60	55.66

Green Valley Beach CG			
count	55	mean+3stdev	1855
median	50	% Reduction	91%
max	2000		
stdev	535	**no data excluded**	
mean	249		
mean+3stdev	1855		

STATION	DATE	VALUE	REMARK
	5/20/2003	10	
	6/26/2003	60	
	8/4/2003	160	
	5/7/2002	4	
	5/21/2002	30	
	5/28/2002	40	

	6/5/2002	10	
	6/11/2002	240	
	6/18/2002	120	RESAMPLE
	6/18/2002	120	
	6/26/2002	150	
	7/3/2002	60	
	7/8/2002	30	
	7/16/2002	30	
	7/23/2002	90	
	7/30/2002	130	
	8/6/2002	50	
	8/13/2002	10	K
	8/20/2002	10	K
	8/27/2002	10	K
	5/22/2001	2000	L not being used
	7/31/2001	10	
	8/7/2001	20	
	8/21/2001	420	lake not being used
SXL190801	5/24/2000	250	
SXL190801	5/26/2000	10	K
SXL190801	6/1/2000	80	
SXL190801	6/7/2000	180	
SXL190801	6/13/2000	3	
SXL190801	6/21/2000	2000	L
SXL190801	6/26/2000	2000	L, beach closed
SXL190801	6/27/2000	1330	
SXL190801	6/29/2000	1	K, resample beach reopened
SXL190801	7/5/2000	140	
SXL190801	7/11/2000	230	
SXL190801	7/18/2000	130	
SXL190801	7/25/2000	120	
SXL190801	8/1/2000	190	
SXL190801	8/7/2000	10	K
SXL190801	8/8/2000	90	
SXL190801	8/15/2000	10	K
SXL190801	8/22/2000	10	K
SXL190801	12/13/4611	700	
SXL190801	3/3/4612	40	RESAMPLE
SXL190801	3/10/4612	140	
SXL190801	3/17/4612	20	
SXL190801	3/24/4612	NEG	
SXL190801	3/31/4612	2000	L
SXL190801	6/15/4612	10	
SXL190801	6/23/4612	NEG	
SXL190801	6/30/4612	NEG	
SXL190801	7/7/4612	NEG	
SXL190801	9/21/4612	N20	
SXL190801	10/5/4612	10	
SXL190801	10/12/4612	70	
SXL190801	10/19/4612	50	
SXL190801	7/2/1998	40	
SXL190801	8/6/1998	2	K
SXL190801	8/27/1998	20	
SXL190801	9/3/1998	10	

Lake Lackawanna			
count	91	mean+3stdev	1051
median	60	%reduction	93%
max	2700		
stdev	306	**no data excluded**	
mean	134		
mean+3stdev	1051		

STATION	**DATE**	**VALUE**	**REMARK**
SXL190408	5/30/1998	730	
SXL190408	6/4/1998	90	RESAMPLE
SXL190408	6/5/1998	40	RESAMPLE
SXL190408	6/17/1998	510	
SXL190408	6/23/1998	30	RESAMPLE
SXL190408	6/25/1998	2	K
SXL190408	6/29/1998	90	
SXL190408	7/6/1998	290	
SXL190408	7/8/1998	60	RESAMPLE
SXL190408	7/13/1998	150	
SXL190408	7/20/1998	50	
SXL190408	7/27/1998	50	
SXL190408	8/3/1998	40	
SXL190408	8/10/1998	70	
SXL190408	8/18/1998	130	
SXL190408	8/31/1998	70	
SXL190408	9/1/1998	60	
LAKE LACKAWANNA: SPEERS BEACH	6/9/1999	30	
SXL190408	6/18/1999	20	
SXL190408	6/26/1999	20	
SXL190408	7/7/1999	120	
SXL190408	7/16/1999	10	K
SXL190408	7/22/1999	30	
SXL190408	7/29/1999	60	
SXL190408	8/6/1999	10	K
SXL190408	8/12/1999	60	
SXL190408	8/23/1999	30	
SXL190408	6/7/2000	430	
SXL190408	6/9/2000	10	K
SXL190408	6/22/2000	200	
SXL190408	6/27/2000	770	
SXL190408	7/2/2000	70	
SXL190408	7/14/2000	80	
SXL190408	7/21/2000	50	
SXL190408	8/3/2000	170	
SXL190408	8/8/2000	120	
SXL190408	8/16/2000	20	
SXL190408	8/22/2000	10	K
SXL190408	8/22/2000	10	K
Speers Beach	5/24/2001	2700	not presently in use
Speers Beach	5/30/2001	40	
Speers Beach	6/7/2001	130	
Speers Beach	6/9/2001	50	
Speers Beach	6/12/2001	30	
Speers Beach	6/19/2001	200	
Speers Beach	6/22/2001	40	
Speers Beach	6/29/2001	40	
Speers Beach	7/5/2001	100	
Speers Beach	7/12/2001	220	
Speers Beach	7/16/2001	70	
Speers Beach	7/24/2001	10	
Speers Beach	7/30/2001	10	
Speers Beach	8/7/2001	260	
Speers Beach	8/16/2001	100	
Speers Beach	8/23/2001	50	
Speers Beach	8/23/2001	50	
SPEERS BEACH	5/14/2002	130	
SPEERS BEACH	6/17/2002	170	
SPEERS BEACH	6/25/2002	210	
SPEERS BEACH	7/11/2002	30	
SPEERS BEACH	7/15/2002	30	
SPEERS BEACH	7/26/2002	20	

SPEERS BEACH	7/31/2002	80	
SPEERS BEACH	8/8/2002	30	
SPEERS BEACH	8/20/2002	30	
SPEERS BEACH	8/26/2002	200	
Lake Lackawanna:Speers Beach	5/27/2003	60	
	5/29/2003	200	
	6/17/2003	80	
	6/27/2003	20	
	6/30/2003	360	
	7/2/2003	70	
	7/7/2003	210	
	7/24/2003	80	
	7/28/2003	40	
	8/5/2003	70	
	8/11/2003	30	
Lake Lackawanna: Spears Beach	5/13/2004	90	
	6/9/2004	40	
	6/16/2004	20	
	6/23/2004	480	
	6/29/2004	50	
	7/6/2004	160	
	7/15/2004	70	
	7/20/2004	10	
	7/26/2004	10	
	8/3/2004	20	
	8/3/2004	20	
	8/10/2004	20	
	8/18/2004	40	
	8/25/2004	140	

Lake Hopatcong			
Stats with state Park			
count	825	mean+3stdev	1170
Median	20	%reduction	97%
max	6000		
stdev	357	**no data excluded**	
mean	98		
mean+3stdev	1170		

STATION	**DATE**	**VALUE**	**REMARK**
SXL191201	06/03/98	2	
SXL191201	06/17/98	5	

SXL191201	07/01/98	12	
SXL191201	07/15/98	1	
SXL191201	07/29/98	3	
SXL191201	08/05/98	1	K
SXL191201	08/19/98	1	
SXL191202	07/01/98	106	
SXL191202	07/15/98	22	
SXL191202	07/29/98	2	
SXL191202	08/12/98	18	
SXL191202	08/26/98	64	
SXL191202	09/09/98	41	
SXL191203	07/08/98	4	
SXL191203	07/22/98	29	
SXL191203	08/05/98	90	
SXL191203	08/19/98	28	
SXL191204	06/03/98	1	
SXL191204	06/17/98	15	
SXL191204	07/01/98	3	
SXL191204	07/15/98	1	K
SXL191204	07/29/98	2	
SXL191204	08/12/98	8	
SXL191204	08/26/98	3	
SXL191205	06/24/98	15	
SXL191205	07/08/98	4	
SXL191205	07/22/98	14	
SXL191205	08/05/98	26	
SXL191207	06/09/98	40	
SXL191207	07/02/98	10	K
SXL191207	07/06/98	30	
SXL191207	07/23/98	100	
SXL191207	08/20/98	10	K
SXL191208	06/09/98	50	
SXL191208	06/25/98	30	
SXL191208	07/02/98	200	
SXL191208	07/06/98	10	K
SXL191208	07/23/98	10	K
SXL191208	08/20/98	10	K
SXL191209	06/09/98	50	
SXL191209	07/02/98	9	
SXL191209	07/06/98	10	K
SXL191209	07/23/98	50	
SXL191209	08/20/98	10	K
SXL191210	07/03/98	20	
SXL191211	07/08/98	500	
SXL191211	07/10/98	168	RESAMPLE

SXL191211	07/22/98	179	
SXL191211	08/26/98	550	
SXL191211	08/28/98	65	RESAMPLE
SXL191212	07/08/98	16	
SXL191212	07/22/98	50	
SXL191212	08/05/98	22	
SXL191212	08/19/98	27	
SXL191213	07/08/98	6	
SXL191213	07/22/98	18	
SXL191213	08/05/98	15	
SXL191213	08/19/98	15	
SXL191213	09/02/98	12	
SXL191214	07/21/98	20	
SXL191214	08/21/98	20	
SXL191215	06/17/98	750	
SXL191215	06/19/98	7	RESAMPLE
SXL191215	07/01/98	875	
SXL191215	07/06/98	122	RESAMPLE
SXL191215	07/15/98	7	
SXL191215	07/22/98	106	
SXL191215	08/05/98	111	
SXL191216	06/24/98	99	
SXL191216	07/08/98	2	K
SXL191216	07/22/98	75	
SXL191216	08/05/98	13	
SXL191216	08/19/98	14	
SXL191217	06/24/98	1900	
SXL191217	06/26/98	2500	RESAMPLE
SPERRY SPRINGS	05/26/99	7	
SXL191201	06/09/99	16	
SXL191201	06/23/99	2	
SXL191201	07/07/99	2	
SXL191201	08/18/99	4	
SHADY LAWN BEACH CLUB	06/09/99	331	
SXL191202	06/10/99	2	RESAMPLE
SXL191202	06/23/99	100	
SXL191202	07/07/99	146	
SXL191202	07/21/99	248	
SXL191202	07/22/99	50	RESAMPLE
SXL191202	08/18/99	98	
SXL191202	09/01/99	44	
BECK LANE PROPERTIES	05/26/99	9	
SXL191204	06/09/99	5	

SXL191204	06/23/99	1	
SXL191204	07/07/99	1	K
SXL191204	08/18/99	2	
SXL191204	09/01/99	18	
ELBA POINT HOMEOWNERS	06/23/99	1	K
SXL191205	07/07/99	10	
SXL191205	08/04/99	17	
WILDWOOD SHORES POA	06/28/99	50	
SXL191207	07/13/99	20	
SXL191207	08/11/99	10	K
SXL191207	08/26/99	220	
WILDWOOD SHORES POA	06/28/99	80	
SXL191208	07/13/99	10	K
SXL191208	08/11/99	10	
SXL191208	08/26/99	340	
WILDWOOD SHORES POA	06/28/99	30	
SXL191209	07/13/99	10	K
SXL191209	08/11/99	10	K
SXL191209	08/26/99	350	
HOPATCONG GARDENS COMM. CLUB	07/01/99	10	
SXL191210	07/09/99	30	
SXL191210	07/18/99	10	
SXL191210	07/24/99	10	K
SXL191210	07/30/99	1800	
SXL191210	08/12/99	10	
SXL191210	08/29/99	30	
CRESCENT COVE	06/24/99	76	
SXL191211	07/07/99	212	
SXL191211	07/09/99	1	RESAMPLE K
SXL191211	07/22/99	1	K
SXL191211	08/04/99	1	K
SXL191211	08/18/99	102	
RANDAL BEACH CLUB	07/07/99	18	
SXL191213	07/21/99	18	
SXL191213	08/04/99	5	
SXL191213	08/18/99	1	K
SXL191213	09/01/99	54	
DOX INC	07/01/99	10	
SXL191214	08/19/99	120	
INGRAM COVE	06/09/99	130	

COMMUNITY			
SXL191215	06/16/99	1	K
SXL191215	06/30/99	394	
SXL191215	07/14/99	36	RESAMPLE
SXL191215	07/28/99	68	
HOMESTEAD BEACH	06/23/99	21	
SXL191216	07/07/99	12	
SXL191216	07/22/99	18	
SXL191216	08/04/99	36	
SXL191216	08/18/99	114	
SHAWNEE DOCK ASSOCIATION	08/12/99	10	K
SXL191218	08/19/99	10	
SXL191218	08/29/99	50	
BYRAM BAY COMMUNITY CLUB	06/10/99	64	
SXL191219	07/08/99	200	L
SXL191219	07/12/99	28	RESAMPLE
SXL191219	07/29/99	20	
COLONY CLUB	06/30/99	24	
SXL191220	07/14/99	1	K
SXL191220	07/28/99	1	K
SXL191220	08/11/99	1	K
SXL191220	08/25/99	6	
SXL191220	09/08/99	6	
SPERRY SPRINGS	05/24/00	10	K
SXL191201	06/07/00	60	
SXL191201	06/21/00	70	
SXL191201	07/05/00	10	K
SXL191201	07/19/00	10	
SXL191201	08/02/00	120	
SXL191201	08/16/00	90	
SHADY LAWN BEACH CLUB	06/05/00	30	
SXL191202	06/19/00	10	K
SXL191202	07/05/00	20	
SXL191202	07/17/00	520	
SXL191202	08/07/00	40	
SXL191202	08/21/00	30	
SXL191202	08/28/00	1600	TNTC
SXL191202	08/30/00	10	K
BECK LANE PROPERTIES	05/24/00	20	
SXL191204	06/07/00	20	
SXL191204	06/21/00	20	
SXL191204	07/05/00	10	K

SXL191204	07/19/00	10	K
SXL191204	08/02/00	1200	
SXL191204	08/07/00	370	
SXL191204	08/16/00	450	
SXL191204	08/28/00	10	K
ELBA POINT HOMEOWNERS	06/05/00	2	
SXL191205	06/20/00	8	
SXL191205	07/03/00	16	
SXL191205	07/19/00	2	K
SXL191205	08/01/00	48	
SXL191205	08/15/00	152	
SXL191205	08/29/00	12	
WILDWOOD SHORES POA Pebble	07/14/00	10	
SXL191207	07/30/00	40	
SXL191207	08/01/00	10	K
SXL191207	08/09/00	20	
SXL191207	08/17/00	10	
SXL191207	08/25/00	10	K
SXL191207	08/30/00	10	K
WILDWOOD SHORES POA lines	07/14/00	10	K
SXL191208	08/09/00	50	
SXL191208	08/17/00	20	
SXL191208	08/25/00	10	
SXL191208	08/30/00	10	
WILDWOOD SHORES POA Bass Rock	07/14/00	10	K
SXL191209	08/09/00	10	K
SXL191209	08/17/00	10	K
SXL191209	08/25/00	10	
SXL191209	08/30/00	10	K
HOPATCONG GARDENS COMM. CLUB	06/04/00	30	
SXL191210	06/21/00	20	
SXL191210	07/01/00	20	
SXL191210	07/21/00	70	
SXL191210	08/17/00	60	
CRESCENT COVE	06/29/00	288	
SXL191211	07/05/00	28	
SXL191211	07/19/00	24	
SXL191211	08/03/00	164	
SXL191211	08/21/00	44	
RANDAL BEACH CLUB	06/28/00	10	

SXL191213	07/12/00	20	
SXL191213	07/26/00	10	K
SXL191213	08/09/00	10	K
SXL191213	08/21/00	40	
DOX INC	07/02/00	150	
SXL191214	07/21/00	10	K
SXL191214	08/17/00	10	
SXL191214	08/22/00	10	K
INGRAM COVE COMMUNITY	05/25/00	144	
SXL191215	06/05/00	114	
SXL191215	06/20/00	20	
SXL191215	07/03/00	14	
SXL191215	07/19/00	28	
SXL191215	08/01/00	364	
SXL191215	08/03/00	280	
SXL191215	08/08/00	44	
SXL191215	08/15/00	184	
SXL191215	08/29/00	192	
HOMESTEAD BEACH	06/09/00	32	
SXL191216	06/21/00	20	
SXL191216	07/05/00	88	
SXL191216	07/19/00	64	
SXL191216	08/02/00	40	
SXL191216	08/21/00	112	
SHAWNEE DOCK ASSOCIATION	07/02/00	10	K
SXL191218	07/08/00	20	
SXL191218	07/21/00	50	
SXL191218	07/30/00	10	K
SXL191218	08/17/00	20	
SXL191218	08/22/00	100	
BYRAM BAY COMMUNITY CLUB	05/24/00	22	
SXL191219	06/22/00	76	
SXL191219	08/03/00	20	
SXL191219	08/17/00	40	
COLONY CLUB	07/19/00	10	
SXL191220	08/02/00	70	
SXL191220	08/16/00	500	followed flood conditions
SXL191220	08/28/00	160	
	06/05/01	10	K
	06/09/01	10	K

	06/19/01	70	
	06/25/01	80	
	07/12/01	50	
	07/16/01	20	
	07/30/01	20	
	08/06/01	10	K
	06/11/01	10	
	06/25/01	120	
	07/09/01	50	
	07/23/01	40	
	08/06/01	50	
	08/20/01	110	
	05/30/01	30	
	06/13/01	10	K
	06/27/01	20	
	07/10/01	200	
	07/25/01	10	K
	08/08/01	200	
	08/22/01	10	
	06/15/01	148	
	06/21/01	2	
	07/03/01	92	
	07/19/01	22	
	08/02/01	4	
	08/13/01	68	
Pebble Beach Ave	05/29/01	40	
Pebble Beach Ave	06/10/01	10	
Pebble Beach Ave	06/27/01	10	
Pebble Beach Ave	07/12/01	10	
Pebble Beach Ave	07/17/01	30	
Pebble Beach Ave	07/25/01	10	K
Pebble Beach Ave	08/03/01	10	K
Lines Ave	05/29/01	10	K
Lines Ave	06/10/01	210	
Lines Ave	07/12/01	20	
Lines Ave	07/17/01	10	K
Lines Ave	07/25/01	20	
Lines Ave	08/03/01	10	K
Lines Ave	08/16/01	40	

Bass Rock Road	05/29/01	30	
Bass Rock Road	06/10/01	20	
Bass Rock Road	06/27/01	10	K
Bass Rock Road	07/12/01	10	K
Bass Rock Road	07/17/01	10	
Bass Rock Road	07/25/01	10	
Bass Rock Road	08/03/01	10	K
Bass Rock Road	08/16/01	40	
	05/29/01	20	
	05/24/01	3	
	07/02/01	30	
	07/18/01	10	
	08/01/01	10	
	08/15/01	210	
	08/29/01	50	
	05/29/01	70	
	06/05/01	80	
	06/09/01	30	
	06/19/01	10	
	07/05/01	10	K
	07/30/01	10	K
	08/23/01	10	
	06/05/01	20	
	06/09/01	10	K
	06/19/01	110	
	06/25/01	150	
	07/05/01	70	
	07/12/01	40	
	07/16/01	10	K
	07/30/01	60	
	08/06/01	420	
	08/23/01	250	
	06/26/01	28	
	07/12/01	72	
	07/24/01	12	
	08/08/01	54	
	08/22/01	40	
	05/29/01	40	
	06/05/01	10	
	06/09/01	10	K
	06/19/01	40	
	06/25/01	60	
	07/05/01	20	
	07/12/01	20	
	07/16/01	10	K

	08/07/01	10	K
	08/23/01	10	K
	06/21/01	2	
	07/10/01	7	
	07/31/01	13	
	08/21/01	6	
	06/20/01	10	
	07/02/01	600	
	07/09/01	30	
	07/18/01	10	K
	08/01/01	20	
	08/15/01	530	
	08/29/01	810	
MAXIM DRIVE	05/28/02	10	K
MAXIM DRIVE	05/31/02	60	
MAXIM DRIVE	06/06/02	930	
MAXIM DRIVE	06/09/02	10	
MAXIM DRIVE	06/17/02	40	
MAXIM DRIVE	06/25/02	60	
MAXIM DRIVE	07/05/02	50	
MAXIM DRIVE	07/08/02	40	
MAXIM DRIVE	07/15/02	10	K
MAXIM DRIVE	08/12/02	10	K
MAXIM DRIVE	08/20/02	20	
W. SHORE DRIVE	06/26/02	50	
W. SHORE DRIVE	07/01/02	10	K
W. SHORE DRIVE	07/10/02	TNTC	
W. SHORE DRIVE	07/12/02	50	
W. SHORE DRIVE	07/24/02	70	
W. SHORE DRIVE	08/07/02	60	
W. SHORE DRIVE	08/21/02	17	
108 MAXIM DRIVE	06/03/02	20	
108 MAXIM DRIVE	06/17/02	70	
108 MAXIM DRIVE	07/01/02	10	K
108 MAXIM DRIVE	07/15/02	10	K
108 MAXIM DRIVE	07/29/02	4	

108 MAXIM DRIVE	08/12/02	10	K
ITHANELL ROAD	05/31/02	150	
ITHANELL ROAD	06/09/02	20	
ITHANELL ROAD	06/17/02	10	K
ITHANELL ROAD	06/25/02	20	
ITHANELL ROAD	07/05/02	5600	
ITHANELL ROAD	07/08/02	100	
ITHANELL ROAD	07/15/02	10	
ITHANELL ROAD	08/26/02	140	
19 PEBBLE BCH RD	06/08/02	30	
19 PEBBLE BCH RD	06/17/02	10	
19 PEBBLE BCH RD	07/05/02	40	
19 PEBBLE BCH RD	07/09/02	30	
19 PEBBLE BCH RD	07/16/02	10	
19 PEBBLE BCH RD	07/24/02	10	K
19 PEBBLE BCH RD	07/31/02	10	
19 PEBBLE BCH RD	08/07/02	10	K
19 PEBBLE BCH RD	08/15/02	60	
19 PEBBLE BCH RD	08/20/02	240	
19 PEBBLE BCH RD	08/27/02	10	K
31 LINES AVENUE	06/08/02	10	K
31 LINES AVENUE	06/17/02	30	
31 LINES AVENUE	07/05/02	70	
31 LINES AVENUE	07/09/02	310	
31 LINES AVENUE	07/12/02	50	
31 LINES	07/24/02	10	K

AVENUE			
31 LINES AVENUE	07/31/02	10	
31 LINES AVENUE	08/15/02	30	
31 LINES AVENUE	08/20/02	180	
31 LINES AVENUE	08/27/02	20	
3 BASS LAKE ROAD	06/08/02	80	
3 BASS LAKE ROAD	06/17/02	20	
3 BASS LAKE ROAD	06/26/02	60	
3 BASS LAKE ROAD	07/05/02	10	K
3 BASS LAKE ROAD	07/09/02	20	
3 BASS LAKE ROAD	07/16/02	10	K
3 BASS LAKE ROAD	07/24/02	10	K
3 BASS LAKE ROAD	07/31/02	80	
3 BASS LAKE ROAD	08/15/02	20	
3 BASS LAKE ROAD	08/20/02	100	
3 BASS LAKE ROAD	08/27/02	10	K
	06/14/02	240	
	06/18/02	122	
	06/24/02	139	
	07/01/02	330	
	07/03/02	460	
	07/08/02	105	
	07/15/02	91	
	07/24/02	200	
	07/29/02	100	
	08/01/02	34	
	08/01/02	1	K
	08/12/02	210	
	08/19/02	60	
	08/26/02	200	
	08/29/02	600	L
	07/05/02	20	
	07/08/02	10	K
	07/26/02	10	K

	07/31/02	40	
	08/12/02	10	K
	08/26/02	50	
COVE ROAD	05/31/02	10	
COVE ROAD	06/06/02	980	
COVE ROAD	06/09/02	10	
COVE ROAD	06/25/02	40	
COVE ROAD	07/05/02	160	
COVE ROAD	07/08/02	160	
COVE ROAD	07/31/02	40	
COVE ROAD	08/12/02	10	
COVE ROAD	08/20/02	240	
COVE ROAD	08/26/02	140	
MARINERS ROAD	06/11/02	18	
MARINERS ROAD	06/21/02	86	
MARINERS ROAD	07/10/02	150	
MARINERS ROAD	07/23/02	62	
MARINERS ROAD	08/08/02	24	
MARINERS ROAD	08/21/02	68	
18 CHINCOPEE AVE	06/04/02	10	
18 CHINCOPEE AVE	06/17/02	10	K
18 CHINCOPEE AVE			INACTIVE
	05/22/02	4	
	06/07/02	122	
	06/27/02	12	
	07/12/02	22	
	07/30/02	5	
	08/09/02	17	
	08/28/02	18	
Sperry Springs-Maxim Drive	05/29/03	10	K
	06/03/03	10	
	06/09/03	30	
	06/24/03	40	
	06/30/03	40	
	07/07/03	10	K
	07/14/03	40	
	07/21/03	30	
	07/28/03	10	K

	08/05/03	10	K
	08/11/03	10	K
	08/18/03	10	K
	08/25/03	10	
Shady Lawn Beach Club	07/02/03	10	K
	07/16/03	70	
	07/30/03	20	
	08/13/03	380	
	08/18/03	160	
	08/27/03	20	
Beck Lane Properties	05/28/03	10	
	06/11/03	110	
	06/25/03	10	
	07/08/03	10	K
	07/23/03	70	K
	08/06/03	30	
	08/20/03	12	
Elba Point Homeowners	05/14/03	10	
	05/30/03	10	K
	06/03/03	10	
	06/09/03	10	K
	06/24/03	20	
	06/30/03	10	K
	07/07/03	6000	L
	07/09/03	10	K
	07/14/03	20	
	07/21/03	20	
	07/28/03	10	
	08/05/03	310	
	08/08/03	110	
	08/11/03	130	
	08/18/03	20	
	08/25/03	10	K
Wildwood Shores POA Pebble Beach Rd	05/30/03	10	K
	06/03/03	70	
	06/09/03	10	
	06/27/03	10	K
	07/21/03	150	
	08/13/03	10	K
Wildwood	05/30/03	10	

Shores POA Lines Ave			
	06/03/03	50	
	09/06/03	10	K
	06/27/03	10	
	07/21/03	50	
	08/13/03	10	K
Wildwood Shores POA Bass Lake Rd	05/30/03	20	
	06/03/03	40	
	06/09/03	10	
	06/27/03	10	K
	07/21/03	40	
	08/13/03	30	
Crescent Cove	06/03/03	180	
	06/27/03	190	
	07/01/03	260	
	07/03/03	600	K
	07/07/03	10	L
	07/15/03	500	
	07/17/03	20	
	07/22/03	10	
	07/28/03	70	
	08/04/03	110	
	08/12/03	60	K
	08/18/03	20	
	08/25/03	20	
DOX Inc.	07/07/03	10	K
	07/14/03	20	
	07/21/03	10	K
	07/28/03	10	
	08/05/03	10	
	08/11/03	10	K
	08/18/03	20	
	08/25/03	20	
Ingram Cove Community	05/29/03	210	
	06/03/03	10	K
	06/09/03	20	
	06/24/03	10	K
	06/30/03	40	
	07/07/03	30	
	07/14/03	100	
	07/21/03	70	
	07/28/03	90	

	08/05/03	450	
	08/11/03	300	
	08/18/03	20	
	08/25/03	140	
Homestead Beach	06/23/03	20	
	07/08/03	82	
	07/25/03	144	
	08/13/03	94	
	08/25/03	20	
Byram Bay Community	06/06/03	34	
	07/03/03	36	
	07/18/03	32	
	08/06/03	52	
	08/20/03	53	
	08/29/03	13	
Sperry Springs	06/16/04	2100	
	06/18/04	10	
	06/23/04	10	
	06/29/04	280	
	07/01/04	10	K
	07/06/04	10	K
	07/15/04	90	
	07/20/04	30	
	07/26/04	50	
	08/03/04	10	K
	08/10/04	40	
	08/18/04	10	
	08/25/04	40	
Shady Lawn	06/02/04	20	
	06/16/04	10	K
	06/30/04	20	
	07/14/04	100	K
	07/28/04	20	
	08/11/04	20	
	08/25/04	40	
Beck Lane	05/17/04	10	
	06/02/04	20	
	06/16/04	10	K
	06/30/04	10	
	07/14/04	10	
	07/28/04	10	K
	08/11/04	10	K
	08/25/04	20	

Elba Point	05/17/04	10	
	06/02/04	20	
	06/22/04	20	
	06/30/04	20	
	07/14/04	10	K
	07/28/04	10	
	08/11/04	40	
	08/25/04	10	
Wildwood Shores Pebble Beach	06/01/04	10	
	06/10/04	10	K
	06/14/04	10	K
	06/22/04	10	
	07/07/04	10	K
	07/20/04	10	K
	08/02/04	10	K
	08/19/04	10	
	08/30/04	10	K
Wildwood Shores Lines Ave	06/01/04	10	K
	06/10/04	30	
	06/14/04	10	
	06/22/04	20	
	07/07/04	20	
	07/20/04	50	
	08/02/04	90	
	08/19/04	30	
	08/30/04	10	K
Wildwood Shores Bass Rock Lane	06/10/04	10	K
	06/14/04	10	
	06/22/04	10	
	07/07/04	10	K
	07/20/04	10	K
	08/02/04	10	K
	08/19/04	10	
	08/30/04	10	K
Crescent Cove	07/15/04	600	L
	07/07/04	70	
	07/15/04	600	L
	07/20/04	200	
	07/29/04	110	
	08/02/04	20	

	08/09/04	100	
	08/17/04	40	
	08/24/04	130	
Dox Inc.	07/06/04	10	K
	07/20/04	40	
	08/03/04	10	K
	08/18/04	10	
Ingram Cove Community	06/16/04	20	
	06/23/04	380	
	06/29/04	100	
	07/06/04	1	K
	07/15/04	40	
	07/20/04	130	
	07/23/04	130	
	07/26/04	430	
	08/10/04	40	
	08/25/04	120	
Homestead Beach	06/21/04	14	
	07/06/04	311	
	07/08/04	66	
	07/19/04	156	
	08/03/04	38	
	08/16/04	18	
Byram Beach Community Club	05/26/04	36	
	06/09/04	48	
	07/08/04	7	
	07/23/07	18	
	08/11/04	23	
	08/26/04	26	
Beach Center	05/18/98	16	
	05/26/98	10	
	06/01/98	60	
	06/08/98	6	
	06/15/98	2	
	06/22/98	1	
	06/29/98	12	
	07/06/98	1	K
	07/13/98	29	
	07/20/98	4	
	07/27/98	1	K
	08/03/98	46	
	08/10/98	24	

	08/17/98	6	
	08/24/98	4	
	08/31/98	23	
Beach Center	05/22/00	10	
Beach Center	05/30/00	1	
Beach Center	06/05/00	1	
Beach Center	06/12/00	110	
Beach Center	06/19/00	4	
Beach Center	06/26/00	52	
Beach Center	07/05/00	18	
Beach Center	07/10/00	52	
Beach Center	07/17/00	5	
Beach Center	07/24/00	110	
Beach Center	07/31/00	11	
Beach Center	08/07/00	1	
Beach Center	08/16/00	69	
Beach Center	08/21/00	1700	
Beach Center	08/23/00	52	
Beach Center	08/28/00	7	
	05/21/01	1	k
	05/29/01	6	
	06/04/01	3	
	06/11/01	7	
	06/18/01	5	
	06/25/01	2	
	07/02/01	22	
North	05/21/02	3	
North	05/31/02	9	
North	06/04/02	280	
North	06/06/02	1100	
North	06/07/02	390	
North	06/10/02	11	
North	06/18/02	14	
North	06/24/02	158	
North	07/02/02	100	
North	07/05/02	36	
North	07/08/02	101	
North	07/19/02	2380	
North	07/26/02	10	k
North	08/02/02	290	
North	08/05/02	10	
North	08/09/02	60	
North	08/16/02	80	
North	08/23/02	20	
North	08/30/02	110	

South	07/05/02	1	k
South	07/19/02	320	
South	07/26/02	10	k
South	08/02/02	360	
South	08/05/02	20	
South	08/09/02	40	
South	08/16/02	10	
South	08/23/02	70	
South	08/30/02	40	
North	05/23/03	10	
North	05/27/03	10	
North	06/02/03	10	
North	06/09/03	10	
North	06/16/03	10	
North	06/23/03	10	
North	07/01/03	70	
North	07/07/03	10	
North	07/15/03	20	
North	07/22/03	50	
North	07/28/03	20	
North	08/04/03	100	
North	08/18/03	20	
North	08/25/03	60	
South	05/23/03	10	
South	05/27/03	10	
South	06/02/03	10	
South	06/09/03	10	
South	06/16/03	10	
South	06/23/03	80	
South	07/01/03	200	
South	07/07/03	50	
South	07/15/03	10	
South	07/22/03	80	
South	07/28/03	10	
South	08/04/03	10	
South	08/18/03	10	
South	08/25/03	10	
North	05/18/04	10	
	05/24/04	20	
	06/03/04	10	k
	06/10/04	30	
	06/14/04	20	
	06/22/04	100	
	06/29/04	200	
	07/07/04	50	

	07/13/04	600	L
	07/14/04	50	
	07/20/04	180	
	07/26/04	10	k
	08/02/04	50	
	08/09/04	10	k
	08/17/04	20	
	08/23/04	30	
	08/30/04	10	
South	05/18/04	30	
	05/24/04	20	
	06/03/04	10	k
	06/10/04	10	
	06/14/04	30	
	06/22/04	30	
	06/29/04	150	
	07/07/04	90	
	07/13/04	70	
	07/20/04	330	
	07/23/04	30	
	07/26/04	10	k
	08/02/04	30	
	08/09/04	20	
	08/17/04	80	
	08/23/04	40	
	08/30/04	60	
North	08/29/05	70	
	08/22/05	10	k
	08/15/05	90	
	08/08/05	210	
	08/10/05	80	resample
	08/01/05	110	
	07/25/05	80	
	07/18/05	70	
	07/11/05	20	
	07/05/05	70	
	06/30/05	70	
	06/23/05	60	
	06/13/05	10	
	04/09/08	10	
	06/06/05	40	
	06/01/05	10	k
	05/26/05	10	k
	05/24/05	80	
	05/16/05	10	k

South	08/29/05	70	
	08/22/05	80	
	08/15/05	110	
	08/08/05	290	
	08/10/05	160	resample
	08/01/05	60	
	07/25/05	110	
	07/18/05	160	
	07/11/05	40	
	07/05/05	30	
	06/30/05	70	
	06/23/05	20	
	06/13/05	10	
	06/06/05	10	k
	06/01/05	10	k
	05/26/05	10	k
	05/24/05	530	
	05/16/05	10	

Lake Winona			
count	48	mean+3stdev	6920
median	75	% Reduction	98%
max	10000		
Stdev	2046	**no data excluded**	
mean	781		
mean+3stdev	6920		

Station	**Date**	**Value**	**Remarks**
Lake Winona Civic Association	06/22/99	10	
	06/29/99	14	
	07/08/99	3	
	07/15/99	44	
	07/19/99	4	
	07/26/99	26	
	08/04/99	1	
	08/09/99	1	K
	08/16/99	106	
	08/23/99	408	
	09/03/99	4	
	06/25/02	100	
	07/05/02	10	
	07/09/02	360	
	07/11/02	10	k
	07/15/02	90	
	07/26/02	20	
	07/31/02	130	
	08/13/02	10	k
	08/20/02	240	
	08/22/02	90	
	08/26/02	60	
Lake Winona Civic Association	05/30/03	550	
	06/03/03	100	
	06/09/03	90	
	06/15/03	90	
	06/24/03	40	
	06/30/03	10	k
	07/07/03	10	
	07/14/03	30	
	07/21/03	50	
	07/28/03	20	
	08/05/03	350	
	08/18/03	30	
	08/25/03	10	k
Lake Winona Civic Association	06/16/04	450	
	06/17/04	60	
	06/25/04	240	
	06/29/04	6700	
	07/01/04	10000	
	07/15/04	550	
	07/20/04	440	
	07/22/04	1100	
	07/26/04	50	
	08/03/04	6000	
	08/10/04	6000	
	08/18/04	300	
	08/25/04	2500	

WMA 02

Crystal Springs			
count	9	mean+3stdev	988
Median	250	%reduction	74%
Max	770		
stdev	254	**no data excluded**	
mean	227		
mean+3stdev	988		

STATION	**DATE**	**VALUE**	**REMARK**
SXHR136	07/27/00	**770**	
SXHR136	08/03/00	**360**	
SXHR136	08/14/00	**250**	
SXHR136	08/16/00	**300**	Resample
SXHR136	08/24/00	**320**	
SXHR136	08/29/00	10	
SXLHR136	06/08/99	10	K
SXLHR136	06/30/99	10	K
SXLHR136	08/04/99	10	K

Deer Trail Lake			
count	16	mean+3stdev	653
Median	7	%reduction	73%
Max	738		
stdev	190	**no data excluded**	
mean	84		
mean+3stdev	653		

STATION	**DATE**	**VALUE**	**REMARK**
SXL191112	07/07/98	1	
SXL191112	07/13/98	2	
SXL191112	07/28/98	5	
SXL191112	08/04/98	7	
SXL191112	08/11/98	9	
SXL191112	09/02/98	1	
	07/02/01	180	
	07/10/01	6	
	07/17/01	12	
	07/24/01	26	
	07/31/01	258	
	08/03/01	738	
	08/07/01	2	K
	08/15/01	82	
	08/22/01	2	K
	08/27/01	6	

Lake Mohawk			

count	1134	mean+3stdev	1516
median	20	% Reduction	98%
max	11000		
Stdev	476	**no data excluded**	
mean	89		
mean+3stdev	1516		

STATION	DATE	VALUE	REMARK
SXL102	05/18/98	10	K
SXL102	05/26/98	10	K
SXL102	06/01/98	210	
SXL102	06/03/98	10	K, RESAMPLE
SXL102	06/08/98	10	K
SXL102	06/15/98	50	
SXL102	06/22/98	10	K
SXL102	06/29/98	10	K
SXL102	07/06/98	10	K
SXL102	07/13/98	1200	
SXL102	07/16/98	30	RESAMPLE
SXL102	07/20/98	50	
SXL102	07/27/98	60	
SXL102	08/03/98	10	K
SXL102	08/10/98	280	
SXL102	08/12/98	90	RESAMPLE
SXL102	08/17/98	10	K
SXL102	08/24/98	100	
SXL102	08/31/98	220	
SXL102	09/02/98	60	
SXL103	05/18/98	30	
SXL103	05/26/98	10	K
SXL103	06/01/98	50	
SXL103	06/08/98	10	K
SXL103	06/15/98	10	K
SXL103	06/22/98	30	
SXL103	06/29/98	10	K
SXL103	07/06/98	10	K
SXL103	07/13/98	10	K
SXL103	07/20/98	10	K
SXL103	07/27/98	10	K
SXL103	08/03/98	10	K
SXL103	08/10/98	10	K
SXL103	08/17/98	10	K
SXL103	08/24/98	10	K
SXL103	08/31/98	10	K
SXL104	05/18/98	20	
SXL104	05/26/98	10	K
SXL104	06/01/98	100	
SXL104	06/08/98	10	K
SXL104	06/15/98	50	
SXL104	06/22/98	10	K
SXL104	06/29/98	10	K
SXL104	07/06/98	10	K
SXL104	07/13/98	30	
SXL104	07/20/98	40	
SXL104	07/27/98	20	
SXL104	08/03/98	10	K
SXL104	08/10/98	10	K
SXL104	08/17/98	10	K
SXL104	08/24/98	10	K
SXL104	08/31/98	10	K
SXL105	05/18/98	20	
SXL105	05/26/98	10	K
SXL105	06/01/98	650	
SXL105	06/03/98	40	RESAMPLE
SXL105	06/08/98	10	K
SXL105	06/15/98	20	
SXL105	06/22/98	20	
SXL105	06/29/98	10	K
SXL105	07/06/98	40	
SXL105	07/13/98	10	K
SXL105	07/20/98	10	K
SXL105	07/27/98	120	
SXL105	08/03/98	30	
SXL105	08/10/98	10	K
SXL105	08/17/98	10	K
SXL105	08/24/98	20	
SXL105	08/31/98	10	K
SXL106	05/18/98	360	
SXL106	05/20/98	40	RESAMPLE
SXL106	05/26/98	410	
SXL106	05/28/98	10	K
SXL106	06/01/98	290	
SXL106	06/03/98	50	RESAMPLE
SXL106	06/08/98	10	K
SXL106	06/15/98	50	
SXL106	06/22/98	10	K
SXL106	06/29/98	40	
SXL106	07/06/98	10	K
SXL106	07/13/98	10	K
SXL106	07/20/98	50	
SXL106	07/27/98	50	
SXL106	08/03/98	10	K
SXL106	08/10/98	20	
SXL106	08/17/98	30	
SXL106	08/24/98	70	
SXL106	08/31/98	60	
SXL108	05/18/98	130	
SXL108	05/26/98	130	
SXL108	06/01/98	90	
SXL108	06/03/98	70	
SXL108	06/08/98	210	
SXL108	06/15/98	20	RESAMPLE
SXL108	06/17/98	200	
SXL108	06/22/98	10	K
SXL108	06/29/98	10	K
SXL108	07/06/98	10	K
SXL108	07/13/98	30	
SXL108	07/20/98	10	K
SXL108	07/27/98	10	K
SXL108	08/03/98	10	K
SXL108	08/10/98	40	
SXL108	08/17/98	660	
SXL108	08/19/98	220	RESAMPLE
SXL108	08/24/98	70	
SXL108	08/31/98	10	K
SXL109	05/18/98	10	K
SXL109	05/26/98	10	K
SXL109	06/01/98	90	
SXL109	06/08/98	50	
SXL109	06/15/98	120	
SXL109	06/22/98	20	
SXL109	06/29/98	40	
SXL109	07/06/98	10	K
SXL109	07/13/98	10	K
SXL109	07/20/98	10	K
SXL109	07/27/98	20	
SXL109	08/03/98	10	K
SXL109	08/10/98	20	
SXL109	08/17/98	20	
SXL109	08/24/98	110	
SXL109	08/31/98	10	K
SXL111	05/18/98	20	
SXL111	05/26/98	10	K
SXL111	06/01/98	80	
SXL111	06/08/98	20	
SXL111	06/15/98	1200	
SXL111	06/17/98	120	RESAMPLE
SXL111	06/22/98	20	
SXL111	06/29/98	70	
SXL111	07/06/98	40	

SXL111	07/13/98	80	
SXL111	07/27/98	50	
SXL111	08/03/98	10	K
SXL111	08/10/98	10	K
SXL111	08/17/98	270	
SXL111	08/19/98	10	K, RESAMPLE
SXL111	08/24/98	160	
SXL111	08/31/98	60	
SXL112	05/18/98	10	K
SXL112	05/26/98	10	K
SXL112	06/01/98	160	
SXL112	06/08/98	10	K
SXL112	06/15/98	10	K
SXL112	06/22/98	10	K
SXL112	06/29/98	10	K
SXL112	07/06/98	30	
SXL112	07/13/98	60	
SXL112	07/20/98	20	
SXL112	07/27/98	10	K
SXL112	08/03/98	10	K
SXL112	08/10/98	10	K
SXL112	08/17/98	10	K
SXL112	08/24/98	10	K
SXL112	08/31/98	30	
SXL113	05/18/98	10	K
SXL113	05/26/98	10	K
SXL113	06/01/98	80	
SXL113	06/08/98	10	K
SXL113	06/15/98	50	
SXL113	06/22/98	10	K
SXL113	06/29/98	10	K
SXL113	07/06/98	10	K
SXL113	07/13/98	10	K
SXL113	07/20/98	20	
SXL113	07/27/98	50	
SXL113	08/03/98	30	
SXL113	08/10/98	10	K
SXL113	08/17/98	10	K
SXL113	08/24/98	10	K
SXL113	08/31/98	10	K
1	05/24/99	10	K
SXL101	06/01/99	**210**	
SXL101	06/03/99	12	Resample
SXL101	06/04/99	1	Resample
SXL101	06/07/99	20	
SXL101	06/14/99	10	K
SXL101	06/23/99	150	

SXL101	06/28/99	130	
SXL101	07/06/99	160	
SXL101	07/12/99	10	
SXL101	07/19/99	**280**	
SXL101	07/21/99	10	Resample
SXL101	07/26/99	40	
SXL101	08/02/99	10	K
SXL101	08/09/99	10	K
SXL101	08/16/99	50	
SXL101	08/23/99	90	
SXL101	08/30/99	40	
2	05/24/99	**380**	
SXL102	05/26/99	**240**	Resample
SXL102	05/27/99	84	Resample
SXL102	06/01/99	120	
SXL102	06/07/99	50	
SXL102	06/14/99	10	
SXL102	06/21/99	90	
SXL102	06/28/99	50	
SXL102	07/06/99	**270**	
SXL102	07/08/99	47	Resample
SXL102	07/09/99	4	Resample
SXL102	07/12/99	10	K
SXL102	07/19/99	40	
SXL102	07/26/99	**590**	
SXL102	07/28/99	120	Resample
SXL102	08/02/99	20	
SXL102	08/09/99	20	
SXL102	08/16/99	10	K
SXL102	08/23/99	100	
SXL102	08/30/99	30	
3	05/24/99	**4600**	
SXL103	05/26/99	70	Resample
SXL103	06/01/99	10	K
SXL103	06/07/99	10	K
SXL103	06/14/99	10	K
SXL103	06/21/99	10	K
SXL103	06/28/99	10	
SXL103	07/06/99	10	K
SXL103	07/12/99	50	
SXL103	07/19/99	10	K
SXL103	07/26/99	20	
SXL103	08/02/99	10	K
SXL103	08/09/99	50	
SXL103	08/16/99	10	
SXL103	08/23/99	10	K
SXL103	08/30/99	10	K

4	05/24/99	90	
SXL104	06/01/99	10	K
SXL104	06/07/99	20	
SXL104	06/14/99	30	
SXL104	06/21/99	30	
SXL104	06/28/99	90	
SXL104	07/06/99	**530**	
SXL104	07/08/99	29	Resample
SXL104	07/09/99	12	Resample
SXL104	07/12/99	10	
SXL104	07/19/99	20	
SXL104	07/26/99	60	
SXL104	08/02/99	10	K
SXL104	08/09/99	110	
SXL104	08/16/99	20	
SXL104	08/23/99	10	K
SXL104	08/30/99	30	
5	05/24/99	**310**	
SXL105	05/26/99	50	Resample
SXL105	06/01/99	30	
SXL105	06/07/99	10	
SXL105	06/14/99	30	
SXL105	06/21/99	40	
SXL105	06/28/99	60	
SXL105	07/06/99	40	
SXL105	07/12/99	10	
SXL105	07/19/99	80	
SXL105	07/26/99	70	
SXL105	08/02/99	10	K
SXL105	08/09/99	20	
SXL105	08/16/99	**450**	
SXL105	08/18/99	30	Resample
SXL105	08/23/99	40	
SXL105	08/30/99	10	
6	05/24/99	**11,000**	
SXL106	05/26/99	**510**	Resample
SXL106	05/26/99	104	Resample
SXL106	05/27/99	**1100**	Resample
SXL106	06/01/99	60	
SXL106	06/07/99	80	
SXL106	06/14/99	30	
SXL106	06/21/99	20	
SXL106	06/28/99	**450**	
SXL106	06/30/99	80	Resample
SXL106	07/06/99	**290**	
SXL106	07/08/99	163	Resample
SXL106	07/09/99	39	Resample

SXL106	07/12/99	10	
SXL106	07/19/99	30	
SXL106	07/26/99	10	K
SXL106	08/02/99	10	
SXL106	08/09/99	10	K
SXL106	08/16/99	60	
SXL106	08/23/99	10	K
SXL106	08/30/99	20	
Happy Valley	05/24/99	90	
SXL108	06/01/99	110	
SXL108	06/07/99	40	
SXL108	06/14/99	20	
SXL108	06/21/99	160	
SXL108	06/28/99	**480**	
SXL108	06/30/99	80	Resample
SXL108	07/06/99	40	
SXL108	07/12/99	**270**	
SXL108	07/19/99	50	
SXL108	07/26/99	20	
SXL108	08/02/99	10	K
SXL108	08/09/99	50	
SXL108	08/16/99	**210**	
SXL108	08/18/99	**490**	Resample
SXL108	08/23/99	40	
Tamarack	05/24/99	50	
SXL111	06/01/99	10	
SXL111	06/07/99	10	K
SXL111	06/14/99	80	
SXL111	06/21/99	90	
SXL111	06/28/99	**400**	
SXL111	06/30/99	50	Resample
SXL111	07/06/99	**330**	
SXL111	07/08/99	14	
SXL111	07/09/99	21	
SXL111	07/12/99	90	
SXL111	07/19/99	**2300**	
SXL111	07/21/99	140	Resample
SXL111	07/26/99	140	
SXL111	08/02/99	10	K
SXL111	08/09/99	10	
SXL111	08/16/99	160	
SXL111	08/23/99	10	K
SXL111	08/30/99	20	
Alpine	05/24/99	110	
SXL112	06/01/99	10	K
SXL112	06/07/99	10	
SXL112	06/14/99	10	

SXL112	06/23/99	10	K
SXL112	06/28/99	160	
SXL112	07/06/99	10	K
SXL112	07/12/99	10	K
SXL112	07/19/99	10	K
SXL112	07/26/99	10	K
SXL112	08/02/99	10	K
SXL112	08/09/99	10	
SXL112	08/16/99	50	
SXL112	08/23/99	10	K
SXL112	08/30/99	80	
Upper	05/24/99	**410**	
SXL113	05/26/99	10	Resample
SXL113	06/01/99	50	
SXL113	06/07/99	20	
SXlL13	06/14/99	20	
SXL113	06/23/99	10	K
SXL113	06/28/99	**400**	
SXL113	06/30/99	10	Resample
SXL113	07/07/99	60	
SXL113	07/12/99	**390**	
SXL113	07/14/99	10	K
SXL113	07/19/99	**580**	
SXL113	07/21/99	180	Resample
SXL113	07/26/99	90	
SXL113	08/02/99	20	
SXL113	08/09/99	10	
SXL113	08/16/99	40	
SXL113	08/23/99	10	K
SXL113	08/30/99	10	K
Lake Mohawk Beach 1	06/26/00	40	
SXL101	07/05/00	110	
SXL101	07/10/00	30	
SXL101	08/07/00	20	
SXL101	08/16/00	50	
SXL101	08/28/00	10	K
Lake Mohawk Beach 2	05/22/00	10	K
SXL102	05/30/00	10	K
SXL102	06/05/00	10	K
SXL102	06/12/00	10	
SXL102	06/19/00	10	
SXL102	06/26/00	10	K
SXL102	07/05/00	10	K
SXL102	07/10/00	60	
SXL102	07/17/00	10	K

SXL102	07/24/00	20	
SXL102	07/31/00	10	
SXL102	08/07/00	10	K
SXL102	08/16/00	60	
SXL102	08/21/00	10	
SXL102	08/28/00	20	
Lake Mohawk Beach 3	05/22/00	10	K
SXL103	05/30/00	10	K
SXL103	06/05/00	10	
SXL103	06/12/00	10	
SXL103	06/19/00	20	
SXL103	06/26/00	10	K
SXL103	07/05/00	10	K
SXL103	07/10/00	170	
SXL103	07/17/00	10	K
SXL103	07/24/00	70	
SXL103	07/31/00	10	K
SXL103	08/07/00	20	
SXL103	08/16/00	10	
SXL103	08/21/00	10	K
SXL103	08/28/00	10	K
Lake Mohawk Beach 4	05/22/00	10	K
SXL104	05/30/00	40	
SXL104	06/05/00	10	
SXL104	06/12/00	40	
SXL104	06/19/00	60	
SXL104	06/26/00	10	K
SXL104	07/05/00	10	
SXL104	07/10/00	40	
SXL104	07/12/00	10	K
SXL104	07/17/00	10	K
SXL104	07/24/00	20	
SXL104	07/31/00	10	K
SXL104	08/07/00	20	
SXL104	08/16/00	40	
SXL104	08/21/00	10	K
SXL104	08/28/00	20	
Lake Mohawk Beach 5	05/22/00	10	K
SXL105	05/30/00	10	K
SXL105	06/05/00	**7800**	
SXL105	06/07/00	10	Resample
SXL105	06/12/00	100	
SXL105	06/19/00	40	
SXL105	06/26/00	10	

SXL105	07/05/00	60	
SXL105	07/10/00	30	
SXL105	07/17/00	150	
SXL105	07/24/00	10	K
SXL105	07/31/00	80	
SXL105	08/07/00	40	
SXL105	08/16/00	20	
SXL105	08/21/00	10	
SXL105	08/28/00	100	
Lake Mohawk Beach 6	05/22/00	50	
SXL106	05/30/00	40	
SXL106	06/05/00	**440**	
SXL106	06/07/00	60	Resample
SXL106	06/12/00	30	
SXL106	06/19/00	10	
SXL106	06/26/00	40	
SXL106	07/05/00	10	
SXL106	07/10/00	50	
SXL106	07/17/00	40	
SXL106	07/24/00	60	
SXL106	07/31/00	30	
SXL106	08/07/00	60	
SXL106	08/16/00	10	K
SXL106	08/21/00	20	
SXL106	08/28/00	10	K
Lake Mohawk Happy Valley Beach	05/22/00	10	
SXL108	05/30/00	10	K
SXL108	06/05/00	10	
SXL108	06/12/00	30	
SXL108	06/19/00	20	
SXL108	06/26/00	50	
SXL108	07/05/00	20	
SXL108	07/10/00	20	
SXL108	07/17/00	10	
SXL108	07/24/00	20	
SXL108	07/31/00	30	
SXL108	08/07/00	20	
SXL108	08/16/00	30	
SXL108	08/21/00	10	K
SXL108	08/28/00	10	K
Lake Mohawk Tamarack Beach	05/22/00	**220**	
SXL111	05/30/00	**70**	

SXL111	06/05/00	**230**	
SXL111	06/07/00	50	Resample
SXL111	06/12/00	90	
SXL111	06/19/00	90	
SXL111	06/26/00	10	K
SXL111	07/05/00	40	
SXL111	07/10/00	30	
SXL111	07/17/00	30	
SXL111	07/24/00	10	K
SXL111	07/31/00	70	
SXL111	08/07/00	10	K
SXL111	08/16/00	40	
SXL111	08/21/00	40	
SXL111	08/28/00	60	
Lake Mohawk Alpine Beach	05/22/00	10	K
SXL112	05/30/00	10	K
SXL112	06/05/00	10	K
SXL112	06/12/00	**290**	
SXL112	06/14/00	20	Resample
SXL112	06/19/00	30	
SXL112	06/26/00	10	
SXL112	07/05/00	10	
SXL112	07/10/00	20	
SXL112	07/17/00	10	K
SXL112	07/24/00	10	K
SXL112	07/31/00	10	
SXL112	08/07/00	10	
SXL112	08/16/00	10	K
SXL112	08/21/00	10	
SXL112	08/28/00	30	
Upper Lake Mohawk	05/22/00	70	
SXL113	05/30/00	20	
SXL113	06/05/00	50	
SXL113	06/12/00	**700**	
SXL113	06/14/00	40	Resample
SXL113	06/19/00	140	
SXL113	06/26/00	10	
SXL113	07/05/00	30	
SXL113	07/10/00	30	
SXL113	07/17/00	50	
SXL113	07/24/00	10	
SXL113	07/31/00	30	
SXL113	08/07/00	40	
SXL113	08/16/00	10	K
SXL113	08/21/00	10	

SXL113	08/28/00	10	K
Beach 1	05/23/01	16	
Beach 1	06/04/01	12	
Beach 1	06/11/01	160	
Beach 1	06/18/01	90	
Beach 1	06/25/01	62	
Beach 1	07/02/01	14	
Beach 1	07/09/01	172	
Beach 1	07/16/01	30	
Beach 1	07/30/01	2	
Beach 1	08/06/01	28	
Beach 1	08/13/01	104	
Beach 1	08/20/01	796	
Beach 1	08/22/01	12	
Beach 1	08/27/01	52	
Beach 2	05/23/01	118	
Beach 2	06/04/01	104	
Beach 2	06/11/01	10	
Beach 2	06/18/01	138	
Beach 2	06/25/01	164	
Beach 2	07/02/01	56	
Beach 2	07/09/01	40	
Beach 2	07/16/01	54	
Beach 2	07/23/01	12	
Beach 2	07/30/01	16	
Beach 2	08/06/01	6	
Beach 2	08/13/01	196	
Beach 2	08/20/01	18	
Beach 2	08/27/01	6	
Beach 3	05/23/01	2	
Beach 3	06/04/01	2	
Beach 3	06/11/01	200	
Beach 3	06/18/01	92	
Beach 3	06/25/01	168	
Beach 3	07/02/01	16	
Beach 3	07/09/01	4	
Beach 3	07/16/01	20	
Beach 3	07/23/01	2	k
Beach 3	08/06/01	2	
Beach 3	08/13/01	6	
Beach 3	08/20/01	2	
Beach 3	08/27/01	2	
Beach 4	05/23/01	40	
Beach 4	06/04/01	40	
Beach 4	06/11/01	200	
Beach 4	06/18/01	136	
Beach 4	06/25/01	96	

Beach 4	07/02/01	62	
Beach 4	07/09/01	26	
Beach 4	07/16/01	2	K
Beach 4	07/23/01	2	K
Beach 4	07/30/01	18	
Beach 4	08/06/01	4	
Beach 4	08/13/01	26	
Beach 4	08/20/01	44	
Beach 4	08/27/01	6	
Beach 5	05/23/01	12	
Beach 5	06/04/01	30	
Beach 5	06/11/01	350	
Beach 5	06/14/01	164	
Beach 5	06/18/01	180	
Beach 5	06/25/01	44	
Beach 5	07/02/01	54	
Beach 5	07/09/01	186	
Beach 5	07/16/01	82	
Beach 5	07/23/01	12	
Beach 5	07/30/01	40	
Beach 5	08/06/01	164	
Beach 5	08/13/01	238	
Beach 5	08/20/01	8	
Beach 5	08/27/01	8	
Beach 6	05/23/01	84	
Beach 6	06/04/01	14	
Beach 6	06/11/01	6	
Beach 6	06/18/01	150	
Beach 6	06/25/01	298	
Beach 6	06/27/01	164	
Beach 6	07/02/01	70	
Beach 6	07/09/01	36	
Beach 6	07/16/01	36	
Beach 6	07/23/01	8	
Beach 6	08/06/01	68	
Beach 6	08/13/01	38	
Beach 6	08/20/01	54	
Beach 6	08/27/01	60	
Alpine	05/23/01	72	
Alpine	06/04/01	6	
Alpine	06/11/01	6	
Alpine	06/18/01	24	
Alpine	06/25/01	34	
Alpine	07/02/01	82	
Alpine	07/09/01	6	
Alpine	07/16/01	2	
Alpine	07/23/01	6	

Alpine	07/30/01	22	
Alpine	08/06/01	32	
Alpine	08/13/01	16	
Alpine	08/20/01	44	
Alpine	08/27/01	122	
Manitou	06/25/01	118	
Manitou	07/09/01	30	
Manitou	07/16/01	36	
Manitou	07/23/01	122	
Manitou	07/30/01	18	
Manitou	08/06/01	104	
Manitou	08/13/01	212	
Manitou	08/15/01	90	
Manitou	08/20/01	350	
Manitou	08/22/01	2	K
Manitou	08/27/01	262	
Manitou	08/30/01	30	
Upper	05/23/01	20	
Upper	06/04/01	52	
Upper	06/11/01	856	
Upper	06/14/01	188	
Upper	06/18/01	230	
Upper	06/20/01	176	
Upper	06/25/01	114	
Upper	07/02/01	98	
Upper	07/09/01	32	
Upper	07/16/01	68	
Upper	07/16/01	172	
Upper	07/23/01	2	K
Upper	07/30/01	2	
Upper	08/06/01	38	
Upper	08/13/01	4	
Upper	08/20/01	30	
Upper	08/27/01	10	
BEACH 1	05/20/02	2	
BEACH 1	05/29/02	50	
BEACH 1	06/03/02	10	
BEACH 1	06/10/02	10	K
BEACH 1	06/17/02	50	
BEACH 1	06/24/02	20	
BEACH 1	07/01/02	30	
BEACH 1	07/08/02	20	
BEACH 1	07/15/02	10	
BEACH 1	07/22/02	10	
BEACH 1	07/29/02	40	
BEACH 1	08/05/02	80	
BEACH 1	08/12/02	20	

BEACH 1	08/19/02	40	
BEACH 1	08/26/02	10	K
BEACH 2	05/20/02	70	
BEACH 2	05/29/02	720	
BEACH 2	05/31/02	91	Resample
BEACH 2	06/03/02	10	
BEACH 2	06/10/02	10	K
BEACH 2	06/17/02	10	
BEACH 2	06/24/02	10	K
BEACH 2	07/01/02	20	
BEACH 2	07/08/02	10	
BEACH 2	07/15/02	10	K
BEACH 2	07/22/02	160	
BEACH 2	07/29/02	40	
BEACH 2	08/05/02	70	
BEACH 2	08/12/02	10	K
BEACH 2	08/19/02	40	
BEACH 2	08/26/02	10	
BEACH 3	05/20/02	10	K
BEACH 3	05/29/02	10	K
BEACH 3	06/03/02	10	K
BEACH 3	06/10/02	10	K
BEACH 3	06/17/02	10	
BEACH 3	06/24/02	30	
BEACH 3	07/01/02	20	
BEACH 3	07/08/02	10	K
BEACH 3	07/15/02	10	K
BEACH 3	07/22/02	30	
BEACH 3	07/29/02	10	K
BEACH 3	08/05/02	10	
BEACH 3	08/12/02	10	K
BEACH 3	08/26/02	40	
BEACH 4	05/20/02	10	K
BEACH 4	05/29/02	200	
BEACH 4	05/31/02	11	Resample
BEACH 4	06/03/02	10	
BEACH 4	06/10/02	10	
BEACH 4	06/17/02	10	
BEACH 4	06/24/02	120	
BEACH 4	07/01/02	20	
BEACH 4	07/08/02	10	K
BEACH 4	07/15/02	30	
BEACH 4	07/22/02	110	
BEACH 4	07/29/02	60	
BEACH 4	08/05/02	10	K
BEACH 4	08/12/02	10	K
BEACH 4	08/19/02	20	

BEACH 4	08/26/02	10	K
BEACH 5	05/20/02	20	
BEACH 5	05/29/02	40	
BEACH 5	06/03/02	10	
BEACH 5	06/10/02	10	K
BEACH 5	06/17/02	10	
BEACH 5	06/24/02	70	
BEACH 5	07/01/02	200	
BEACH 5	07/08/02	180	
BEACH 5	07/15/02	60	
BEACH 5	07/22/02	40	
BEACH 5	07/29/02	40	
BEACH 5	08/05/02	10	
BEACH 5	08/12/02	10	K
BEACH 5	08/19/02	30	
BEACH 5	08/26/02	10	K
BEACH 6	05/20/02	100	
BEACH 6	05/29/02	20	
BEACH 6	06/03/02	20	
BEACH 6	06/10/02	10	
BEACH 6	06/17/02	10	K
BEACH 6	06/24/02	20	
BEACH 6	07/01/02	30	
BEACH 6	07/08/02	20	
BEACH 6	07/15/02	10	K
BEACH 6	07/22/02	50	
BEACH 6	07/29/02	30	
BEACH 6	08/05/02	10	
BEACH 6	08/12/02	30	
BEACH 6	08/19/02	40	
BEACH 6	08/26/02	20	
HAPPY VALLEY	05/20/02	20	
HAPPY VALLEY	05/29/02	130	
HAPPY VALLEY	06/03/02	10	
HAPPY VALLEY	06/10/02	10	K
HAPPY VALLEY	06/17/02	10	
HAPPY VALLEY	06/24/02	10	
HAPPY VALLEY	07/01/02	10	K
HAPPY VALLEY	07/08/02	40	
HAPPY	07/15/02	490	

VALLEY			
HAPPY VALLEY	07/17/02	330	Resample
HAPPY VALLEY	07/18/02	46	Resample
HAPPY VALLEY	07/19/02	163	Resample
HAPPY VALLEY	08/05/02	10	
HAPPY VALLEY	08/12/02	40	
HAPPY VALLEY	08/19/02	10	K
HAPPY VALLEY	08/26/02	30	
MANITOU	05/20/02	40	
MANITOU	05/29/02	10	
MANITOU	06/03/02	10	
MANITOU	06/10/02	30	
MANITOU	06/17/02	10	
MANITOU	06/24/02	180	
MANITOU	07/01/02	60	
MANITOU	07/08/02	40	
MANITOU	07/15/02	130	
MANITOU	07/22/02	90	
MANITOU	07/29/02	200	
MANITOU	08/05/02	10	K
MANITOU	08/12/02	20	
MANITOU	08/19/02	20	
MANITOU	08/26/02	50	
TAMARACK	05/22/02	10	K
TAMARACK	05/29/02	40	
TAMARACK	06/03/02	10	K
TAMARACK	06/10/02	20	
TAMARACK	06/17/02	10	K
TAMARACK	06/24/02	740	
TAMARACK	06/26/02	41	Resample
TAMARACK	07/01/02	40	
TAMARACK	07/08/02	10	
TAMARACK	07/15/02	40	
TAMARACK	07/22/02	40	
TAMARACK	07/29/02	80	
TAMARACK	08/05/02	50	
TAMARACK	08/12/02	30	
TAMARACK	08/19/02	10	
TAMARACK	08/26/02	10	K
ALPINE	05/20/02	20	
ALPINE	05/29/02	10	

ALPINE	06/03/02	20	
ALPINE	06/10/02	10	
ALPINE	06/17/02	10	
ALPINE	06/24/02	40	
ALPINE	07/01/02	10	
ALPINE	07/08/02	10	
ALPINE	07/15/02	30	
ALPINE	07/22/02	10	
ALPINE	07/29/02	10	
ALPINE	08/05/02	10	K
ALPINE	08/12/02	10	K
ALPINE	08/19/02	10	K
ALPINE	08/26/02	20	
	05/20/02	10	
	05/29/02	20	
	06/03/02	20	
	06/10/02	20	
	06/17/02	20	
	06/24/02	10	K
	07/01/02	150	
	07/08/02	20	
	07/15/02	900	
	07/17/02	40	Resample
	07/19/02	18	Resample
	07/22/02	10	
	07/29/02	40	
	08/05/02	10	
	08/12/02	20	
	08/19/02	10	
	08/26/02	10	
LAKE MOHAWK - BEACH 1	05/19/03	10	
	05/28/03	30	
	06/02/03	30	
	06/09/03	10	K
	06/16/03	10	K
	06/23/03	10	
	06/30/03	110	
	07/07/03	10	
	07/14/03	10	
	07/21/03	20	
	07/28/03	10	
	08/04/03	10	
	08/11/03	20	
	08/18/03	10	K
	08/25/03	10	K

LAKE MOHAWK BEACH 2	05/21/03	30	
	05/28/03	240	
	06/02/03	10	Resample
	06/09/03	10	
	06/16/03	20	
	06/23/03	10	K
	06/30/03	40	
	07/07/03	10	
	07/14/03	20	
	07/21/03	110	
	07/28/03	10	K
	08/04/03	20	
	08/11/03	40	
	08/25/03	10	K
LAKE MOHAWK BEACH 3	05/21/03	10	K
	05/28/03	10	
	06/02/03	10	
	06/09/03	10	K
	06/16/03	10	
	06/23/03	20	
	06/30/03	10	K
	07/07/03	10	
	07/14/03	40	
	07/21/03	40	
	07/28/03	10	K
	08/04/03	100	
	08/11/03	10	K
	08/18/03	70	
	08/25/03	10	K
LAKE MOHAWK BEACH 4	05/21/03	230	
	05/28/03	10	K, Resample
	06/02/03	10	K
	06/09/03	20	
	06/16/03	50	
	06/23/03	10	K
	06/30/03	10	K
	07/07/03	10	K
	07/14/03	10	K
	07/21/03	40	
	07/28/03	20	
	08/04/03	80	
	08/11/03	20	

	08/18/03	10	K
	08/25/03	20	
LAKE MOHAWK BEACH 5	05/21/03	40	
	05/28/03	20	
	06/02/03	30	
	06/09/03	10	
	06/16/03	80	
	06/23/03	20	
	06/30/03	60	
	07/07/03	10	
	07/14/03	50	
	07/21/03	140	
	07/28/03	70	
	08/04/03	100	
	08/11/03	20	
	08/18/03	10	
	08/25/03	50	
LAKE MOHAWK BEACH 6	05/21/03	870	
	05/28/03	90	Resample
	06/02/03	40	
	06/09/03	50	
	06/16/03	40	
	06/23/03	60	
	06/30/03	10	K
	07/07/03	10	
	07/14/03	50	
	07/21/03	20	
	07/28/03	10	K
	08/04/03	140	
	08/11/03	40	
	08/18/03	40	
	08/25/03	10	K
LAKE MOHAWK HAPPY VALLEY	05/19/03	10	K
	05/28/03	10	K
	06/02/03	40	
	06/09/03	20	
	06/16/03	210	
	06/18/03	10	K, Resample
	06/23/03	30	
	06/30/03	30	
	07/07/03	10	K

	07/14/03	40	
	07/21/03	10	
	07/28/03	40	
	08/04/03	40	
	08/11/03	80	
	08/18/03	200	
	08/20/03	10	
	08/25/03	10	
LAKE MOHAWK MANITOU	05/19/03	10	K
	05/28/03	1100	
	06/02/03	40	Resample
	06/09/03	10	
	06/16/03	30	
	06/23/03	10	
	06/30/03	130	
	07/07/03	60	
	07/14/03	20	
	07/21/03	50	
	07/28/03	10	
	08/04/03	340	
	08/06/03	20	Resample
	08/06/03	230	Resample
	08/08/03	10	Resample
	08/11/03	60	
	08/18/03	10	
	08/25/03	190	
LAKE MOHAWK TAMARACK	05/19/03	10	K
	05/28/03	10	
	06/02/03	10	
	06/09/03	40	
	06/16/03	100	
	06/23/03	40	
	06/30/03	20	
	07/07/03	20	
	07/14/03	280	
	07/16/03	110	Resample
	07/21/03	90	
	07/28/03	40	
	08/04/03	260	
	08/06/03	360	Resample
	08/06/03	20	Resample
	08/08/03	10	K, Resample
	08/11/03		

	08/18/03	10	
	08/25/03	10	K
LAKE MOHAWK ALPINE	05/21/03	60	
	05/28/03	10	K
	06/02/03	40	
	06/09/03	10	
	06/16/03	30	
	06/23/03	40	
	06/30/03	10	K
	07/07/03	10	
	07/14/03	80	
	07/21/03	30	
	07/28/03	70	
	08/04/03	140	
	08/11/03	180	
	08/18/03	10	K
	08/25/03	20	
LAKE MOHAWK UPPER LAKE	05/21/03	10	
	05/28/03	30	
	06/02/03	50	
	06/09/03	110	
	06/16/03	20	
	06/23/03	50	
	06/30/03	10	K
	07/07/03	10	
	07/14/03	10	K
	07/21/03	20	
	07/28/03	10	K
	08/04/03	70	
	08/11/03	100	
	08/18/03	10	K
	08/25/03	10	K
LAKE MOHAWK BEACH 1	05/24/04	**220**	
	06/02/04	10	Resample
	06/07/04	10	K
	06/14/04	10	
	06/21/04	10	K
	06/28/04	10	K
	07/07/04	10	
	07/15/04	**300**	
	07/21/04	10	K, Resample
	07/26/04	20	

	08/02/04	10	
	08/09/04	150	
	08/16/04	**340**	
	08/18/04	**340**	Resample
	08/23/04	**560**	Resample
	08/25/04	20	Resample
	08/30/04	10	K, Resample
LAKE MOHAWK BEACH 2	05/24/04	10	K
	06/02/04	40	
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	10	
	06/28/04	20	
	07/07/04	10	K
	07/15/04	10	
	07/21/04	10	K
	07/26/04	20	
	08/02/04	30	
	08/09/04	10	
	08/16/04	20	
	08/23/04	40	
	08/30/04	10	K
LAKE MOHAWK BEACH 3	05/24/04	10	K
	06/02/04	10	K
	06/07/04	10	
	06/14/04	10	K
	06/21/04	10	
	06/28/04	20	
	07/07/04	10	K
	07/12/04	10	K
	07/21/04	10	K
	07/26/04	20	
	08/02/04	10	
	08/09/04	10	
	08/16/04	30	
	08/23/04	10	
	08/30/04	10	K
LAKE MOHAWK BEACH 4	05/24/04	40	
	06/02/04	30	
	06/07/04	10	
	06/14/04	30	
	06/21/04	10	

	06/28/04	10	K
	07/07/04	20	
	07/12/04	20	
	07/21/04	10	K
	07/26/04	10	
	08/02/04	10	
	08/09/04	10	
	08/16/04	10	K
	08/23/04	10	K
	08/30/04	10	K
LAKE MOHAWK BEACH 5	05/24/04	180	
	06/02/04	20	
	06/07/04	70	
	06/14/04	10	
	06/21/04	10	K
	06/28/04	10	K
	07/07/04	10	K
	07/12/04	20	
	07/21/04	10	
	07/26/04	60	
	08/02/04	20	
	08/09/04	10	K
	08/16/04	10	K
	08/23/04	30	
	08/30/04	**380**	
	09/02/04	10	K,Resample
LAKE MOHAWK BEACH 6	05/24/04	40	
	06/02/04	10	K
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	10	K
	06/28/04	100	
	07/07/04	80	
	07/12/04	20	
	07/21/04	10	K
	07/26/04	30	
	08/02/04	20	
	08/09/04	10	K
	08/16/04	20	
	08/23/04	50	
	08/30/04	10	K
LAKE MOHAWK HAPPY	05/24/04	**490**	

VALLEY			
	06/02/04	70	Resample
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	20	
	06/28/04	**220**	
	06/30/04	10	K, Resample
	07/07/04	10	K
	07/15/04	10	K
	07/21/04	10	k
	07/26/04	20	
	08/02/04	10	
	08/09/04	**200**	
	08/16/04	10	K
	08/23/04	40	
	08/30/04	**90**	
LAKE MOHAWK MANITOU	05/24/04	160	
	06/02/04	10	
	06/07/04	20	
	06/14/04	30	
	06/21/04	10	K
	06/28/04	190	
	07/07/04	80	
	07/15/04	10	K
	07/21/04	10	K
	07/26/04	60	
	08/02/04	20	
	08/09/04	10	
	08/16/04	40	
	08/23/04	100	
	08/30/04	10	K
LAKE MOHAWK TAMARACK	05/24/04	130	
	06/02/04	10	K
	06/07/04	50	
	06/14/04	90	
	06/21/04	180	
	06/28/04	70	
	07/07/04	10	K
	07/15/04	**6000**	L
	07/20/04	14	Resample
	07/21/04	10	K, Resample
	07/26/04	10	K,
	08/02/04	30	

	08/09/04	10	
	08/16/04	50	
	08/23/04	20	
	08/30/04	10	K
LAKE MOHAWK ALPINE	05/24/04	10	
	06/02/04	10	K
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	10	K
	06/28/04	10	K
	07/07/04	10	K
	07/15/04	10	K
	07/21/04	10	K
	07/26/04	20	
	08/02/04	10	
	08/09/04	10	
	08/16/04	10	K
	08/23/04	40	
	08/30/04	10	K
LAKE MOHAWK UPPER LAKE	05/24/04	20	
	06/02/04	10	K
	06/07/04	10	K
	06/14/04	10	K
	06/21/04	20	
	06/28/04	10	
	07/07/04	10	K
	07/12/04	20	
	07/21/04	50	
	07/26/04	20	
	08/02/04	10	K
	08/09/04	10	K
	08/16/04	30	
	08/23/04	160	
	08/30/04	30	

Sleepy Valley			
count	67	mean+3stdev	1568
median	20	%reduction	91%
Max	2300		
stdev	460	**no data excluded**	
mean	189		
mean+3stdev	1568		

STATION	DATE	VALUE	REMARK
SXL192218	05/28/98	10	K
SXL192218	06/10/98	10	K
SXL192218	06/25/98	10	K
SXL192218	07/10/98	60	
SXL192218	07/22/98	10	K
SXL192218	08/15/98	10	K
SXL192218	08/21/98	10	K
SXL192218	09/02/98	20	
SXL192218	05/24/99	2300	
SXL192218	05/28/99	770	
SXL192218	06/04/99	90	
SXL192218	06/16/99	320	
SXL192218	06/30/99	10	K
SXL192218	07/16/99	30	
SXL192218	07/30/99	10	K
SXL192218	08/11/99	10	K
SXL192218	08/18/99	10	K
SXL192218	08/25/99	10	K
SXL192218	05/22/00	20	BEACH OPENED JULY 1
SXL192218	06/09/00	230	
SXL192218	06/22/00	190	
SXL192218	07/05/00	40	
SXL192218	07/18/00	130	
SXL192218	08/02/00	10	
SXL192218	08/16/00	10	K
SXL192218	08/30/00	10	
	05/30/01	110	
	06/13/01	40	
	06/27/01	140	
	07/11/01	2200	
	07/14/01	520	RESAMPLE
	07/14/01	190	NORTH BRACKET
	07/14/01	400	SOUTH BRACKET
	07/18/01	160	
	07/20/01	50	RESAMPLE
	07/20/01	20	NORTH BRACKET
	07/20/01	90	SOUTH BRACKET
	08/01/01	10	K

	08/15/01	10	K
	08/23/01	10	
	05/24/02	10	
	06/05/02	10	K
	06/19/02	10	
	06/26/02	500	
	06/28/02	180	RESAMPLE
	07/12/02	1	K
	07/26/02	70	
	08/07/02	10	
	08/20/02	80	
Tall Timbers POA	05/19/03	10	K
	06/04/03	250	
	06/10/03	10	RESAMPLE
	06/24/03	20	
	07/09/03	10	K
	07/23/03	420	BEACH CLOSED
	07/31/03	20	RESAMPLE
	08/06/03	560	BEACH CLOSED
	08/13/03	30	RESAMPLE
	08/19/03	10	
Tall Timbers	05/27/04	2000	
	06/08/04	40	
	06/23/04	10	K
	07/07/04	10	K
	07/21/04	10	
	08/03/04	10	
	08/18/04	10	K
	08/23/04	60	

METHYL TERT-BUTYL ETHER (MTBE) AND OTHER VOLATILE ORGANIC COMPOUNDS IN LAKES IN BYRAM TOWNSHIP, SUSSEX COUNTY, NEW JERSEY, SUMMER 1998

by Arthur L. Baehr and Otto S. Zapecza

In cooperation with the Sussex County Health Department

ABSTRACT

Water samples were collected from four lakes in Byram Township, Sussex County, N.J., in the summer of 1998 as part of an investigation of the occurrence of volatile organic compounds (VOCs) in domestic wells of lakeside communities. Cranberry Lake and Lake Lackawanna are surrounded by densely populated communities where the use of gasoline-powered watercraft is prevalent, and water is supplied by lakeside wells. Forest Lake is surrounded by a densely populated community where the use of gasoline-powered watercraft is prohibited. Stag Pond is privately owned, is situated in a sparsely populated area, and is not navigated by gasoline-powered watercraft. Samples were collected from Cranberry Lake in early summer and again in late summer 1998. Concentrations of the gasoline oxygenate methyl tert-butyl ether (MTBE) ranged from 1.6 to 15.0 µg/L (micrograms per liter) on June 24 and decreased with depth. The depth-related concentration gradient is attributed to density stratification caused by the temperature gradient that is present in the lake during the early summer. MTBE concentrations ranged from 7.4 to 29.0 µg/L on September 8 and were uniform with depth, as was water temperature, indicating that the lake was vertically mixed. On the basis of these concentration profiles, the mass of MTBE in Cranberry Lake was estimated to be 15 kilograms on June 24 and 27 kilograms on September 8. These mass estimates are equal to the amount of MTBE in 52 and 95 gallons, respectively, of gasoline that contains 10 percent MTBE by volume. Concentrations of another gasoline oxygenate, tert-amyl-methyl ether (TAME), ranged from 0.07 to 0.43 µg/L on June 24 and from 0.2 to 0.69 µg/L on September 8. The highest concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) were 0.18, 1.2, 0.18, and 0.97 µg/L, respectively, on June 24. All BTEX concentrations in Cranberry Lake on September 8 were less than 0.2 µg/L.

Samples were collected from Lake Lackawanna on September 9. Concentrations of MTBE and TAME ranged from 3.7 to 14.0 µg/L and from 0.17 to 0.38 µg/L, respectively. Like those in Cranberry Lake the previous day, BTEX concentrations were less than 0.2 µg/L, and VOC concentrations and water temperatures were nearly uniform with depth. The mass of MTBE in Lake Lackawanna on September 9 was estimated to be 6 kilograms, which is equal to the amount of MTBE in 21 gallons of gasoline that contains10 percent MTBE by volume. All VOC concentrations were less than 0.2 µg/L in samples collected from Forest Lake on September 8, 1998, and from Stag Pond on the following day.

Oxygenated gasoline is used in watercraft on lakes across northern New Jersey. Many of these lakes are surrounded by communities similar to those at Cranberry Lake and at Lake Lackawanna, which depend largely on wells for water supply. Therefore, a regional assessment of the occurrence of these compounds in lakes and ground water is needed to determine the effect of the use of oxygenated gasoline on water quality in lakeside environments throughout northern New Jersey.

INTRODUCTION

Ground water is the major source of water supply for the residents of Cranberry Lake and Lake Lackawanna in Byram Township, Sussex County, N.J. These lakes are man-made (formed with dams), and the combination of maintained water levels and clustered well withdrawal makes lake/well interaction

likely. Moreover, some residents withdraw water directly from the lakes and treat it before consumption, but the treatment may not be effective for MTBE. Because MTBE is a possible human carcinogen (U.S. Environmental Protection Agency, 1997), the presence of MTBE in the lakes could threaten the quality of the local water supply.

Byram Township is in the southeastern corner of Sussex County in the New Jersey Highlands (New England physiographic province) in northwestern New Jersey, about 50 miles west of New York City. The Highlands province is a northeast-southwest-trending system of folded and faulted Precambrian and Paleozoic rocks that form a terrain characterized by forested, hilly uplands and narrow valleys. The bedrock underlying Byram Township consists of a complex suite of metamorphic and igneous crystalline rocks composed predominantly of hornblende granite, syenite, and gneiss (Volkert and others, 1989). The Township lies just north of the Pleistocene terminal moraine of the Wisconsin glacier. Erosion and deposition associated with the glaciation explain, in part, the presence of many lakes throughout the Highlands and Valley and Ridge provinces of northwestern New Jersey (fig. 1).

Byram Township, referred to as "the Township of Lakes" (Byram Township Environmental Commission, 1994), contains more than two dozen lakes and ponds. Communities surrounding the larger man-made lakes, such as Cranberry Lake, Lake Lackawanna, and Forest Lake, are densely populated because of their picturesque surroundings, bathing beaches, and facilities for boating and water sports. Cranberry Lake was created in the

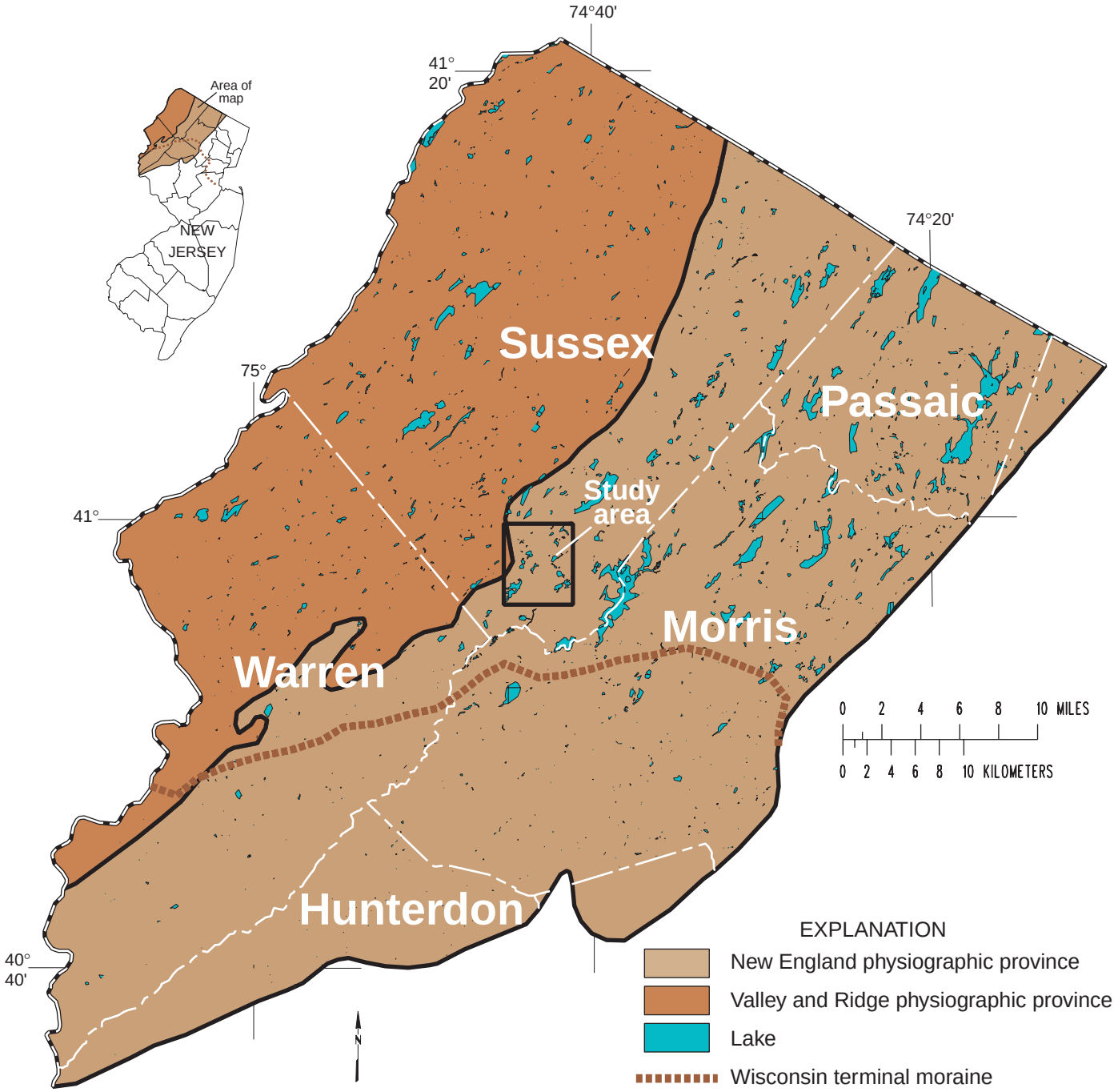


Figure 1. *Location of study area, lakes, and physiographic provinces, northwestern New Jersey.*

1830's. Ground water from fractured crystalline rock is the major source of water supply for approximately 500 residences surrounding Cranberry Lake. About 160 of these residences are served by four small water companies; most of the other residences have individual domestic wells. Lake Lackawanna was created in 1910. Ground water from fractured crystalline rock on its western shore and from stratified glacial drift on its eastern shore is the major source of water for approximately 300 residences surrounding Lake Lackawanna. No water companies serve the Lake Lackawanna community and, therefore, all ground water withdrawn is from domestic wells. Some residences in the Cranberry Lake and Lake Lackawanna communities use water taken directly from the lake after some form of in-house treatment. Forest Lake was created in the 1950's. Ground water is the source of water supply for approximately 400 residences surrounding Forest Lake, which are served by a water company that operates two wells. One well taps stratified glacial drift and the other taps fractured crystalline rock. Stag Pond is a privately owned lake in a sparsely populated area.

The U.S. Geological Survey (USGS) became involved in an investigation, coordinated by the Sussex County Health Department, of methyl tert-butyl ether (MTBE) contamination of water from wells in a neighborhood of Cranberry Lake. As part of this investigation, water samples collected from Cranberry Lake on June 24, 1998, were analyzed for volatile organic compounds (VOCs) to determine whether lake-water quality is related to the ground-water contamination. Concentrations of MTBE in Cranberry Lake were elevated, but lower than concentrations observed in some wells. Additional samples were collected from Cranberry Lake on September 8, 1998. Lake Lackawanna was sampled on September 9, 1998, to determine concentrations of VOCs in another lake in the area in which the use of gasoline-powered watercraft is prevalent. Forest Lake was sampled on September 8, 1998, to determine concentrations of VOCs in a lake surrounded by a densely populated community where gasoline-powered watercraft are prohibited. Stag Pond was sampled on September 9, 1998, to determine VOC concentrations in a lake with minimal exposure to effects of human activities.

USE OF MTBE AND OTHER ETHER OXYGENATES IN GASOLINE

MTBE has been added to gasoline in small quantities since the late 1970's as an octane booster. MTBE use is now (1998) substantially greater because the compound has been blended in gasoline in urban areas throughout the country since the winter of 1992, when requirements associated with amendments made to the Federal Clean Air Act in 1990 went into effect. For example, the Clean Air Act requires that gasoline sold in carbon monoxide nonattainment areas contain at least 2.7 percent oxygen. This oxygen content is achieved by adding 14.8 percent MTBE by volume to gasoline. MTBE is by far the most widely used oxygenate. Tert-amyl-methyl ether (TAME), a less commonly used gasoline oxygenate, also can be associated with MTBE as a by-product. Another ether oxygenate measured in this study is ethyl tert-butyl ether (ETBE).

MTBE is more soluble, less volatile, and less reactive than other constituents of gasoline such as benzene, toluene, ethylbenzene, and xylenes (BTEX)(Zogorski and others, 1997); therefore, when oxygenated gasoline is spilled, MTBE typically is the dominant gasoline constituent of the contaminated water. The use of MTBE in gasoline across the country is a topic of considerable debate (Andrews, 1998) as scientists and regulators evaluate the benefits of improved air quality in relation to the widespread occurrence of MTBE in ground and surface water.

SAMPLING SITES AND PROCEDURES

Cranberry Lake is about 187 acres in size. A bathymetric map produced in 1992 shows that the deepest parts of the lake are about 16 ft (feet) deep and that the average depth is about 7 ft (Coastal Environmental Services, 1992). On June 24, 1998, samples were collected at a depth of 3 ft below the lake surface at 12 locations (fig. 2). Depth measurements at these locations agreed closely with the 1992 bathymetric map. At three locations, where the lake is relatively deep, a second sample was collected at a depth of 10 ft. On September 9, 1998, samples were collected near 9 of the 12 locations at which samples had been collected on June 24 to assess conditions at the end of the summer. At the three sites where two samples had been collected previously, samples were collected at depths of 3, 6, and 10 ft. Depth measurements at the sampling sites indicate that the lake surface was about 1.2 ft lower than on June 24, as a result of the dry summer. Lake Lackawanna is approximately 109 acres in size. A bathymetric map (Perrone, 1989) shows that its maximum depth is about 10 ft and its average depth is about 4 ft. On September 9, 1998, samples were collected at a depth of 3 ft below lake surface at five locations (fig. 2). At two of these locations, a second sample was collected 5 ft below the lake surface. Lubbers Run, the stream that discharges to Lake Lackawanna, was sampled once near the lake inlet.

Forest Lake is about 44 acres in size. On September 8, 1998, its maximum and average depths were estimated to be 15 and 11 ft, respectively. On September 8, 1998, samples were collected from Forest Lake at a depth of 3 ft below the lake surface at four locations (fig. 2). At two of these locations, a second sample was collected 10 ft below the lake surface. Stag Pond is a natural lake with an area of about 33 acres. On September 9, 1998, its maximum and average depths were estimated to be 25 and 16 ft, respectively. On September 9, 1998, samples were collected from Stag Pond at a depth of 3 ft below the lake surface at two locations (fig. 2).

Sites were accessed with a boat equipped with an electric motor. A length of 0.25-inch outside-diameter Teflon tubing was strapped onto a sampling staff and lowered to the desired depth. Back pressure was maintained while the sampling line was being lowered to prevent water above the desired sampling depth from entering the tubing before sampling. No sheens due to spilled oil or gas were observed at any time on any of the lakes. After the sampling line was purged, samples were withdrawn with a peristaltic pump and collected in 40-mL (milliliter) VOC vials. A short length of flexible silicon tubing was fitted around the pump head and spliced into the Teflon sampling line by pushing the Teflon line snugly into the flexible tubing. Because new tubing was used at each sampling site or depth, no decontamination procedures were required. Equipment blanks were collected by sampling VOC-free water with the same apparatus using a 10-ft length of Teflon tubing. At each site, temperature was measured

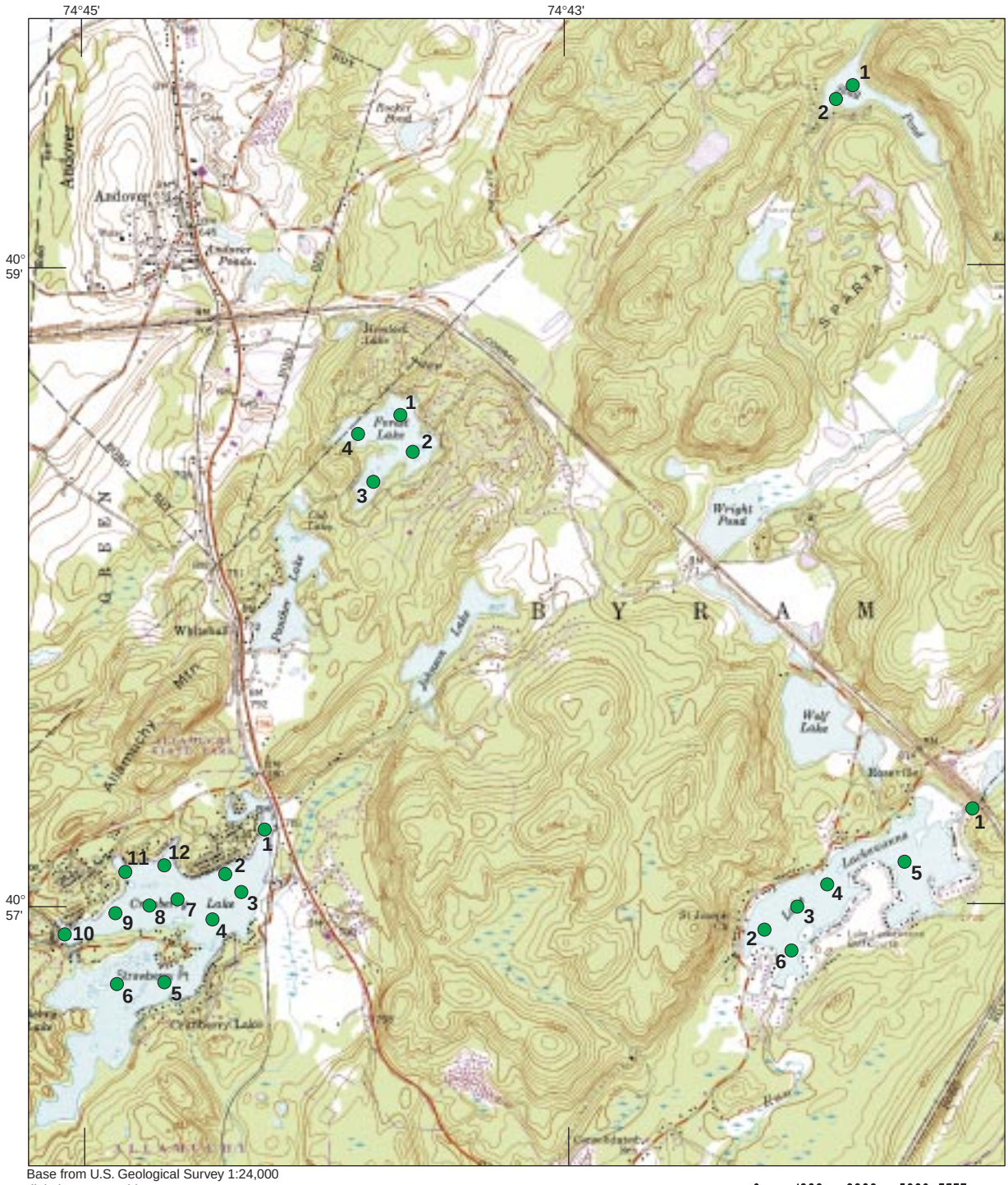


Figure 2. *Lake sampling sites, Sussex County, New Jersey.*

as a function of depth in the lake.

The peristaltic pump applies a pressure to the sample stream that is less than atmospheric, a condition that theoretically could result in VOC mass loss when the sample is transferred to the vial. In lake sampling, however, water is lifted only about 1 ft from the lake surface to near the bottom of the boat, where the vials are filled. This lift corresponds to a pressure differential of less than 3 percent of atmospheric pressure (1 standard atmosphere is equal to 406.38 inches of water); therefore, any VOC loss is negligible.

Samples were preserved with 1:1 hydrochloric acid, immediately stored on ice, and sent overnight to the USGS National Water-Quality Laboratory in Arvada, Colo. Concentrations of VOCs were determined by gas chromatography-mass spectrometry (Connor and others, 1998). In addition to BTEX and the ether gasoline oxygenates MTBE, TAME, and ETBE, the analysis included the following VOCs:

bromodichloromethane	1,1-dichloroethene
bromoform	cis-1,2-dichloroethene
carbon tetrachloride	trans-1,2-dichloroethene
chlorobenzene	1,2-dichloropropane
chloroform	methylene chloride
1,2-dichlorobenzene	styrene
1,3-dichlorobenzene	tetrachloroethene
1,4-dichlorobenzene	1,1,1-trichloroethane
dibromochloromethane	trichloroethene
dichlorodifluoromethane	trichlorofluoromethane
1,1-dichloroethane	trichlorofluoromethane
1,2-dichloroethane	vinyl chloride

CONCENTRATIONS AND MASS ESTIMATES

Concentrations of VOCs and other data obtained during the June 24 and September 8 synoptic sampling of Cranberry Lake are listed in tables 1a and 1b, respectively. Data obtained from Lake Lackawanna on September 9 are summarized in table 2. The only VOCs detected in any of the samples were MTBE, TAME, and BTEX; MTBE and TAME were detected in every sample from Cranberry Lake and Lake Lackawanna. No VOC concentration in any sample from Forest Lake or Stag Pond exceeded 0.2 µg/L.

The concentrations of MTBE in samples collected 3 ft below the surface in Cranberry Lake on June 24 ranged from 10.1 to 15.0 µg/L; therefore, MTBE was evenly distributed across the upper part of the lake (table 1a). MTBE concentrations were lowest (1.6, 3.8, and 4.3 µg/L) in samples from 10 ft below the surface. The difference in concentration with depth is attributed to density stratification caused by the vertical temperature gradient that is present in Cranberry Lake in the early summer. Temperature profiles at the three sites at which samples were collected at multiple depths are shown in figure 3. TAME concentrations were much lower than MTBE concentrations; however, spatial trends for MTBE and TAME concentrations were similar, as evidenced by their high correlation ($r^2 = 0.979$). BTEX concentrations generally are correlated with MTBE and TAME concentrations; however, BTEX was not detected in all samples.

These concentration data do not allow for an accurate

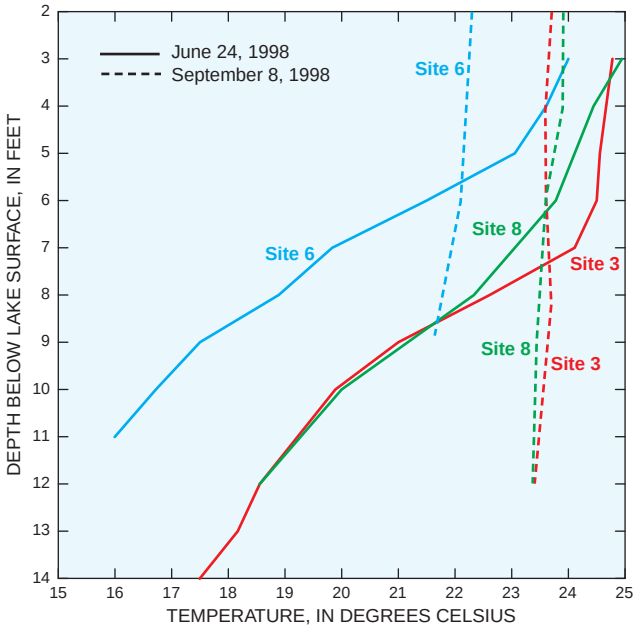


Figure 3. *Temperature as a function of depth at sites at which samples were collected at multiple depths, Cranberry Lake, Sussex County, New Jersey, summer 1998.*

estimate of the VOC mass in Cranberry Lake because the functional dependence of concentration on depth cannot be determined with data from only two sampling depths. Nevertheless, VOC mass estimates, although approximate, can be used to scale the source strength and for comparison with estimates of VOC mass at the end of the summer. Estimates of MTBE and TAME mass in Cranberry Lake on June 24 are 15 and 0.45 kg (kilograms), respectively. Mass estimates were obtained by numerically integrating concentration over the volume of the lake. Concentrations were assumed to be uniform through the upper 3 ft of the lake and to decline exponentially beneath 3 ft to the lake bottom. Values of parameters that define the exponential decline in concentration with depth were obtained by using average concentrations at the 3- and 10-ft depths. The mass of BTEX could not be estimated because most BTEX concentrations at the 10-ft depth were reported as <0.2 µg/L. The estimated MTBE mass of 15 kg in Cranberry Lake on June 24 is equivalent to 52 gal (gallons) of a gasoline that is 10 percent MTBE by volume, an MTBE content representative of gasoline used in the region. If the density of gasoline is assumed to be 0.75 grams per cubic centimeter, 10 percent MTBE by volume corresponds to 281.6 g (grams) of MTBE per gallon of gasoline.

MTBE concentrations in samples collected from Cranberry Lake on September 8 ranged from 7.4 to 29.0 µg/L (table 1b). At the three sites where three samples were collected at different depths, MTBE concentrations and water temperature were nearly uniform (fig. 3), indicating that the lake was vertically mixed. Concentrations were lowest in samples from site 6, which is at the shallow end of Cranberry Lake nearest the inlet stream (fig. 2). TAME concentrations ranged from 0.19 to 0.69 µg/L and are significantly correlated ($r^2 = 0.829$) with MTBE concentrations. BTEX concentrations were less than 0.2 µg/L in all samples, in contrast to the higher MTBE and

Table 1a. Concentrations of volatile organic compounds in samples from Cranberry Lake, Sussex County, N.J., June 24, 1998

[Concentrations are in micrograms per liter; sample depth in feet below lake surface; <, less than]

Site number	Site name	Sample depth (feet)	Concentration					
			MTBE	TAME	Benzene	Toluene	Ethyl-benzene	Xylenes
1	1306N	3	13.6	.38	.12	.65	0.12	.65
2	898WNW	3	13.2	.37	<.20	<.20	<.20	<.20
3	306W	3	13.9	.37	<.20	.21	<.20	.12
3	306W	10	4.3	.16	<.20	.20	<.20	<.20
4	694SW	3	12.5	.36	<.20	<.20	<.20	<.20
5	2041SW	3	12.2	.32	<.20	<.20	<.20	<.20
6	2449SW	3	10.1	.26	<.20	.15	<.20	<.20
6	2449SW	10	1.6	.07	<.20	<.20	<.20	<.20
7	1061W	3	11.0	.38	.11	.39	<.20	.51
8	1633W	3	14.0	.40	.10	.28	<.20	.41
8	1633W	10	3.8	.15	<.20	<.20	<.20	<.20
9	2245WSW	3	13.2	.41	<.20	.17	<.20	.25
10	3061WSW	3	14.2	.40	<.20	<.20	<.20	<.20
11	2000WNW	3	14.2	.40	<.20	<.20	<.20	.17
12	1388NW	3	15.0	.43	.18	1.20	.18	.97
	Blank		<.20	<.20	<.20	<.20	<.20	<.20

Table 1b. Concentrations of volatile organic compounds in samples from Cranberry Lake, Sussex County, N.J., September 8, 1998

[Concentrations are in micrograms per liter; sample depth in feet below lake surface; <, less than; (rep.), replicate sample]

Site number	Site name	Sample depth (feet)	Concentration					
			MTBE	TAME	Benzene	Toluene	Ethyl-benzene	Xylenes
1	1306N	3	27.3	.57	<.40	<.40	<.40	<.40
3	306W	3	22.0	.65	<.20	.14	<.20	<.20
3	306W	6	21.9	.69	<.20	.20	<.20	<.20
3	306W	10	28.1	.59	<.40	<.40	<.40	<.40
3	306W	10 (rep.)	25.8	.63	<.20	<.20	<.20	<.20
4	694SW	3	29.0	.60	<.20	<.20	<.20	<.20
6	2449SW	3	8.0	.19	<.20	<.20	<.20	<.20
6	2449SW	6	8.0	.20	<.20	<.20	<.20	<.20
6	2449SW	9	7.4	.19	<.20	<.20	<.20	<.20
7	1061W	3	19.8	.62	<.20	<.20	<.20	<.20
8	1633W	3	20.1	.63	<.20	<.20	<.20	<.20
8	1633W	6	20.6	.63	<.20	<.20	<.20	<.20
8	1633W	10	20.5	.62	<.20	<.20	<.20	<.20
9	2245WSW	3	20.8	.65	<.20	<.20	<.20	<.20
10	3061WSW	3	18.3	.51	<.20	<.20	<.20	<.20
12	1388NW	3	23.8	.50	<.40	<.40	<.40	<.40
	Blank		<.20	<.20	<.20	<.20	<.20	<.20

Table 2. Concentrations of volatile organic compounds in samples from Lake Lackawanna, Sussex County, N.J., September 9, 1998

[Concentrations are in micrograms per liter; sample depth in feet below lake surface; <, less than; (rep.), replicate sample]

Site number	Site name	Sample depth (feet)	Concentration					
			MTBE	TAME	Benzene	Toluene	Ethyl-benzene	Xylenes
1	Lubbers Run	1.5	<.20	<.20	<.20	<.20	<.20	<.20
2	1085NE	3	12.0	.27	<.20	<.20	<.20	<.20
3	1564N	3	14.0	.27	<.20	<.20	<.20	<.20
3	1564N	5	14.0	.28	<.20	<.20	<.20	<.20
4	2150NE	3	11.0	.38	<.20	<.20	<.20	<.20
4	2150NE	3(rep.)	12.0	.37	<.20	<.20	<.20	<.20
5	3237NE	3	3.7	.17	<.20	<.20	<.20	<.20
6	751NE	3	12.0	.25	<.20	<.20	<.20	<.20
6	751NE	5	12.0	.25	<.20	<.20	<.20	<.20
	Blank		<.20	<.20	<.20	<.20	<.20	<.20

TAME concentrations observed on September 8 than on June 24. These observations are not inconsistent, however, because MTBE and TAME concentrations increase during the summer as a result of the increased operation of gasoline-powered watercraft, whereas summer temperatures increase BTEX volatilization and degradation rates more than those of MTBE and TAME. Also, BTEX concentrations typically were less than 1 µg/L on June 24, and these compounds were further diluted by mixing by September 8. Mass estimates for MTBE and TAME in Cranberry Lake on September 8 are 27 and 0.70 kg, respectively. These estimates were obtained by numerically integrating concentration over the volume of the lake with the assumption that concentrations are constant with depth. The mass of MTBE in Cranberry Lake on September 8 is equivalent to 95 gal of a gasoline that is 10 percent MTBE by volume (281.6 g of MTBE per gallon of gasoline). MTBE and TAME mass estimates for Cranberry Lake on September 8 are approximately 1.8 and 1.6 times those on June 24, as a result of the net accumulation of these ether oxygenates in the lake during the summer season when use of gasoline-powered watercraft is at its peak.

MTBE concentrations in samples collected from Lake Lackawanna on September 9 ranged from 3.7 to 14.0 µg/L (table 2). The concentration was lowest at site 5, which is near the Lubbers Run inlet, in the shallowest part of the lake. Concentrations of all VOCs, including MTBE and TAME, in a sample from Lubbers Run just upstream from Lake Lackawanna were less than 0.2 µg/L. At the two sites where two samples were collected at different depths, MTBE concentrations were unrelated to depth, and water temperature was nearly constant with depth, indicating that the lake was vertically mixed. BTEX concentrations in all samples were less than 0.2 µg/L. Mass estimates for MTBE and TAME in Lake Lackawanna on September 9 are 6.0 and 0.15 kg, respectively. These mass estimates were obtained by numerically integrating concentration over the volume of the lake with the assumption that concentrations were constant with depth. The mass of MTBE in Lake Lackawanna on September 9 is equivalent to 21 gal of a gasoline that is 10 percent MTBE by volume.

SIGNIFICANCE OF FINDINGS

MTBE concentrations in Cranberry Lake and Lake Lackawanna are of immediate concern. The State of New Jersey has set a maximum contaminant level (MCL) of 70 µg/L for MTBE (N.J. Department of Environmental Protection, 1997). This MCL is under review because other regulatory agencies have recently set even more stringent concentration guidelines. The U.S. Environmental Protection Agency has classified MTBE as a possible human carcinogen and has issued a drinking-water advisory for aesthetic concerns of 20 to 40 µg/L (U.S. Environmental Protection Agency, 1997). The State of California has established a draft secondary MCL for MTBE based on taste and odor, of 5 µg/L, and a draft primary MCL for MTBE, of 14 µg/L (California Department of Health Services, 1998). The State of Maine has set a drinking-water standard of 35 µg/L for MTBE (Smith and Kemp, 1998).

The major benefit derived from oxygenated gasoline is in its use in automobiles; however, because gasoline formulation is not specific to use, oxygenated gasoline is used in watercraft across northern New Jersey. Fuel is routinely introduced to water simply by operating gasoline-powered watercraft, which have been associated with MTBE occurrence in lakes in Nevada and California (Boughton and Lico, 1998; Reuter and others, 1998). Spills associated with the handling of gasoline for refueling watercraft can increase the possibility that the underlying aquifer will be contaminated. The occurrence of MTBE and other VOCs in wells surrounding Cranberry Lake and Lake Lackawanna needs to be determined to evaluate the quality of the local water supply. Many lakes in northern New Jersey are surrounded by communities similar to those of Cranberry Lake and Lake Lackawanna, which depend largely on wells for water supply. Therefore, a regional assessment of the occurrence of these compounds in lakes and ground water is needed to determine the effect of the use of oxygenated gasoline on water quality in lakeside environments throughout northern New Jersey.

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Additional information can be obtained from:
District Chief
U.S. Geological Survey
810 Bear Tavern Road, Suite 206
West Trenton, NJ 08628

This report can be accessed on the Internet at the following website: <http://nj.usgs.gov/>

Information on the Toxics Substances Hydrology Program is available at the following website: <http://toxics.usgs.gov/toxics/>

North Shore Water Association

Source Water Assessment Summary

A State Review of Potential Contamination Sources Near Your Drinking Water

The Department of Environmental Protection (DEP) has conducted an assessment of the water sources that supply each public water system in the state, including yours. The goal of this assessment was to measure each system's susceptibility to contamination, not actual (if any) contamination measured in a water supply system.

The assessment of your water system, the *North Shore Water Association*, involved:

- Identifying the area (known as the source water assessment area) that supplies water to your public drinking water system;
- Inventorying any significant potential sources of contamination in the area; and
- Analyzing how susceptible the drinking water source is to the potential sources of contamination.

DEP evaluated the susceptibility of all public water systems to eight categories of contaminants. These contaminant categories are explained, along with a summary of the results for your water system, on page 3. Page 4 contains a map of your water system's source water assessment area.

A public water system's susceptibility rating (L for low, M for medium or H for high) is a combination of two factors. H, M, and L ratings are based on the potential for a contaminant to be at or above 50% of the Drinking Water Standard or MCL (H), between 10 and 50% of the standard (M) and less than 10% of the standard (L).

- How "sensitive" the water supply is to contamination. For example, a shallow well or surface water source, like a reservoir, would be more exposed to contamination from the surface or above ground than a very deep well.
- How frequently a contaminant is used or exists near the source. This is known as "intensity of use." For example, the types of activities (such as industry or agriculture) surrounding the source.

The susceptibility rating does not tell you if the water source is actually contaminated. The Consumer Confidence Report annually issued by your water utility contains important information on the results of your drinking water quality tests, as required by the federal Safe Drinking Water Act.

Where does drinking water come from?

There are two basic sources of drinking water: ground water and surface water.

Ground water is water found beneath the Earth's surface. Ground water comes from rain and snow seeping into rock and soil. Ground water is stored in underground areas called aquifers. Aquifers supply wells and springs. Wells in New Jersey range from about 15 feet to 2,000 feet deep.

Surface water is the water naturally open to the atmosphere, such as rivers, lakes, streams and reservoirs. Precipitation that does not infiltrate the ground or evaporate into the sky runs off into surface water bodies.

Ground water can seep into a stream, river or other surface water body, recharging surface water bodies. Likewise, under some circumstances, surface water can seep into an adjacent aquifer.

A water system obtains its water from 1) wells drilled into the ground that pump out ground water; 2) devices called surface water intakes placed on a river, stream, reservoir; or 3) both.

What factors may affect the quality of your drinking water source?

A variety of conditions and activities may affect the quality of drinking water source. These include geology (rock and soil types); depth of a well or location of a surface water intake; how the land surrounding the source is used (for industry, agriculture or development); the use of pesticides and fertilizers; and the presence of contaminated sites, leaking underground storage tanks, and landfills.

What steps are being taken now to ensure my drinking water quality?

The DEP has numerous programs in place to maintain and protect the quality of our State's water resources. For example, the Safe Drinking Water Program is designed to ensure that water delivered for human consumption meets DEP's stringent health-based drinking water standards. Additionally, DEP has permitting, waste management, and clean up programs in place to avoid and control potential contamination. Key DEP drinking water protection initiatives will be phased-in over time in Source Water Assessment areas to advance existing program protections.

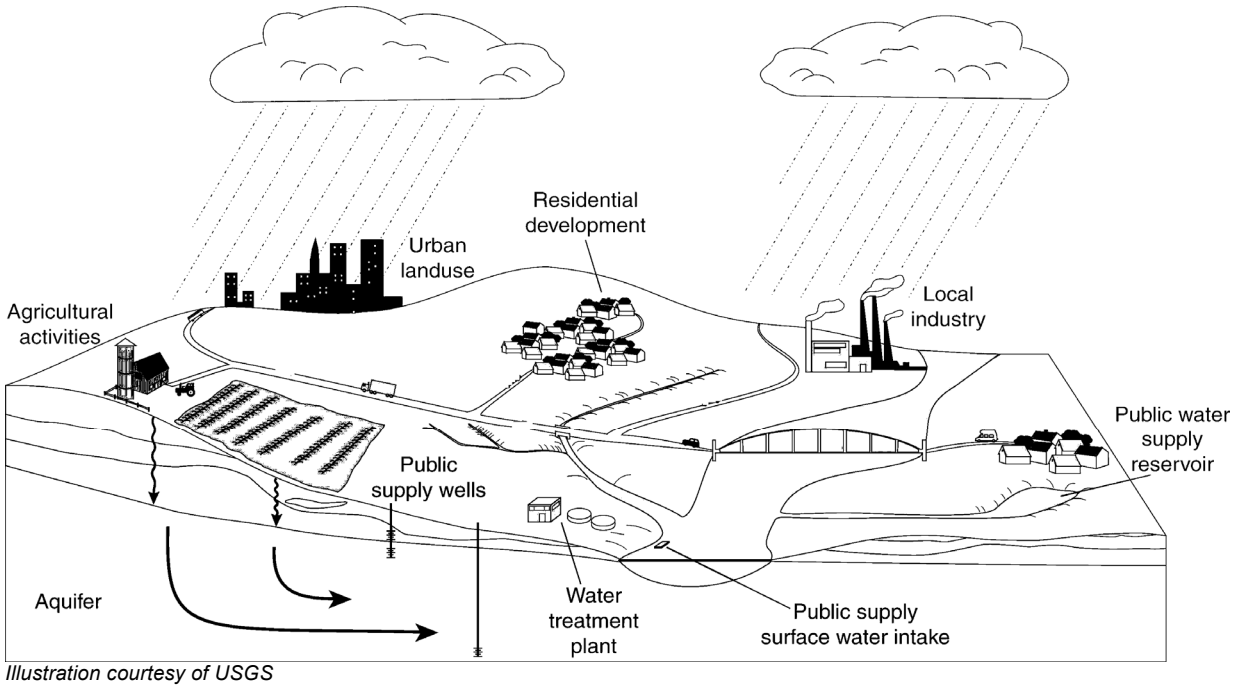


Illustration courtesy of USGS

Among the factors that may affect the quality of drinking water are the type of rock and soil and how the land is used. While some rain and snow evaporates into the sky, most of it runs off into nearby rivers and streams or seeps into the ground. Drinking water comes from underground aquifers or surface water bodies.

What can you and others do to help?

Federal law requires each state to establish and implement a Source Water Assessment Program. While government at the state and local levels can do their part, there are actions that you and your neighbors in homes and businesses can take now to help protect our precious and shared natural resource.

Here's just a few ways you and others can help ensure clean and plentiful water for New Jersey – now and in the future. Join us today for a clean water future.

In your home or business:

- Dispose of waste properly. Some materials such as motor oil, paint, flea collars, and household cleaners have the potential to contaminate source water. Contact your local Department of Public Works for proper household hazardous waste disposal.
- Limit your use of fertilizer, pesticides, and herbicides.

Here are some actions that municipal and county officials/local and county planners can take and you can help encourage and support.

- Manage and work with owners of existing potential contaminant sources to minimize potential contamination.
- Establish regulations prohibiting or restricting certain activities or land uses within the source water assessment area. Take appropriate enforcement action when necessary.
- Update municipal master plans to ensure greater protection.
- Purchase lands or create conservation easements within the source water assessment area.

North Shore Water Association- PWSID # 1904004

North Shore Water Association is a public community water system consisting of 1 well(s), 0 wells under the influence of surface water, 0 surface water intake(s), 0 purchased ground water source(s), and 0 purchased surface water source(s).

This system's source water comes from the following aquifer(s) and/or surface water body(s) (if applicable): igneous and metamorphic rocks

This system purchases water from the following water system(s) (if applicable):

Susceptibility Ratings for North Shore Water Association Sources

The table below illustrates the susceptibility ratings for the seven contaminant categories (and radon) for each source in the system. The table provides the number of wells and intakes that rated high (H), medium (M), or low (L) for each contaminant category. For susceptibility ratings of purchased water, refer to the specific water system's source water assessment report.

The seven contaminant categories are defined at the bottom of this page. DEP considered all surface water highly susceptible to pathogens, therefore all intakes received a high rating for the pathogen category. For the purpose of Source Water Assessment Program, radionuclides are more of a concern for ground water than surface water. As a result, surface water intakes' susceptibility to radionuclides was not determined and they all received a low rating.

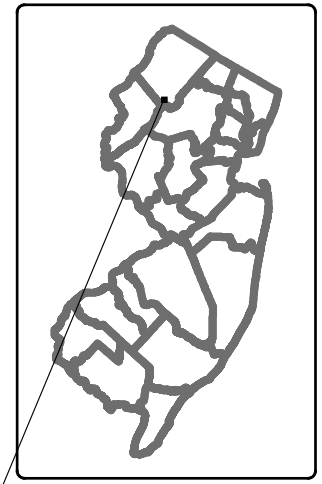
If a system is rated highly susceptible for a contaminant category, it does not mean a customer is or will be consuming contaminated drinking water. The rating reflects the potential for contamination of source water, not the existence of contamination. Public water systems are required to monitor for regulated contaminants and to install treatment if any contaminants are detected at frequencies and concentrations above allowable levels. As a result of the assessments, DEP may customize (change existing) monitoring schedules based on the susceptibility ratings.

	Pathogens			Nutrients			Pesticides			Volatile Organic Compounds			Inorganics			Radio-nuclides			Radon			Disinfection Byproduct Precursors		
Sources	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Wells - 1			**1**	**1**					**1**			**1**			**1**		**1**			**1**			**1**	
GUDI - 0																								
Surface water intakes - 0																								

- **Pathogens:** Disease-causing organisms such as bacteria and viruses. Common sources are animal and human fecal wastes.
- **Nutrients:** Compounds, minerals and elements that aid growth, that are both naturally occurring and man-made. Examples include nitrogen and phosphorus.
- **Volatile Organic Compounds:** Man-made chemicals used as solvents, degreasers, and gasoline components. Examples include benzene, methyl tertiary butyl ether (MTBE), and vinyl chloride.
- **Pesticides**: Man-made chemicals used to control pests, weeds and fungus. Common sources include land application and manufacturing centers of pesticides. Examples include herbicides such as atrazine, and insecticides such as chlordane.
- **Inorganics:** Mineral-based compounds that are both naturally occurring and man-made. Examples include arsenic, asbestos, copper, lead, and nitrate.
- **Radionuclides:** Radioactive substances that are both naturally occurring and man-made. Examples include radium and uranium.
- **Radon:** Colorless, odorless, cancer-causing gas that occurs naturally in the environment. For more information go to http://www.nj.gov/dep/rpp/radon/index.htm or call (800) 648-0394.
- **Disinfection Byproduct Precursors**: A common source is naturally occurring organic matter in surface water. Disinfection byproducts are formed when the disinfectants (usually chlorine) used to kill pathogens react with dissolved organic material (for example leaves) present in surface water.

North Shore Water Association

Source Water Assessment Areas



SUSSEX COUNTY

Legend

- Source Water Areas
- Water Bodies
- Streams
- NJDOT Major Roads
- Municipalities
- Counties

N

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To obtain your water system Source Water Assessment Report, Potential Contaminant Source Inventory, and additional information please go to www.state.nj.us/dep/swap or call (609) 292-5550. August, 2004

Strawberry Point Property Owners Association

Source Water Assessment Summary

A State Review of Potential Contamination Sources Near Your Drinking Water

The Department of Environmental Protection (DEP) has conducted an assessment of the water sources that supply each public water system in the state, including yours. The goal of this assessment was to measure each system's susceptibility to contamination, not actual (if any) contamination measured in a water supply system.

The assessment of your water system, the *Strawberry Point Property Owners Association*, involved:

- Identifying the area (known as the source water assessment area) that supplies water to your public drinking water system;
- Inventorying any significant potential sources of contamination in the area; and
- Analyzing how susceptible the drinking water source is to the potential sources of contamination.

DEP evaluated the susceptibility of all public water systems to eight categories of contaminants. These contaminant categories are explained, along with a summary of the results for your water system, on page 3. Page 4 contains a map of your water system's source water assessment area.

A public water system's susceptibility rating (L for low, M for medium or H for high) is a combination of two factors. H, M, and L ratings are based on the potential for a contaminant to be at or above 50% of the Drinking Water Standard or MCL (H), between 10 and 50% of the standard (M) and less than 10% of the standard (L).

- How "sensitive" the water supply is to contamination. For example, a shallow well or surface water source, like a reservoir, would be more exposed to contamination from the surface or above ground than a very deep well.
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The susceptibility rating does not tell you if the water source is actually contaminated. The Consumer Confidence Report annually issued by your water utility contains important information on the results of your drinking water quality tests, as required by the federal Safe Drinking Water Act.

Where does drinking water come from?

There are two basic sources of drinking water: ground water and surface water.

Ground water is water found beneath the Earth's surface. Ground water comes from rain and snow seeping into rock and soil. Ground water is stored in underground areas called aquifers. Aquifers supply wells and springs. Wells in New Jersey range from about 15 feet to 2,000 feet deep.

Surface water is the water naturally open to the atmosphere, such as rivers, lakes, streams and reservoirs. Precipitation that does not infiltrate the ground or evaporate into the sky runs off into surface water bodies.

Ground water can seep into a stream, river or other surface water body, recharging surface water bodies. Likewise, under some circumstances, surface water can seep into an adjacent aquifer.

A water system obtains its water from 1) wells drilled into the ground that pump out ground water; 2) devices called surface water intakes placed on a river, stream, reservoir; or 3) both.

What factors may affect the quality of your drinking water source?

A variety of conditions and activities may affect the quality of drinking water source. These include geology (rock and soil types); depth of a well or location of a surface water intake; how the land surrounding the source is used (for industry, agriculture or development); the use of pesticides and fertilizers; and the presence of contaminated sites, leaking underground storage tanks, and landfills.

What steps are being taken now to ensure my drinking water quality?

The DEP has numerous programs in place to maintain and protect the quality of our State's water resources. For example, the Safe Drinking Water Program is designed to ensure that water delivered for human consumption meets DEP's stringent health-based drinking water standards. Additionally, DEP has permitting, waste management, and clean up programs in place to avoid and control potential contamination. Key DEP drinking water protection initiatives will be phased-in over time in Source Water Assessment areas to advance existing program protections.

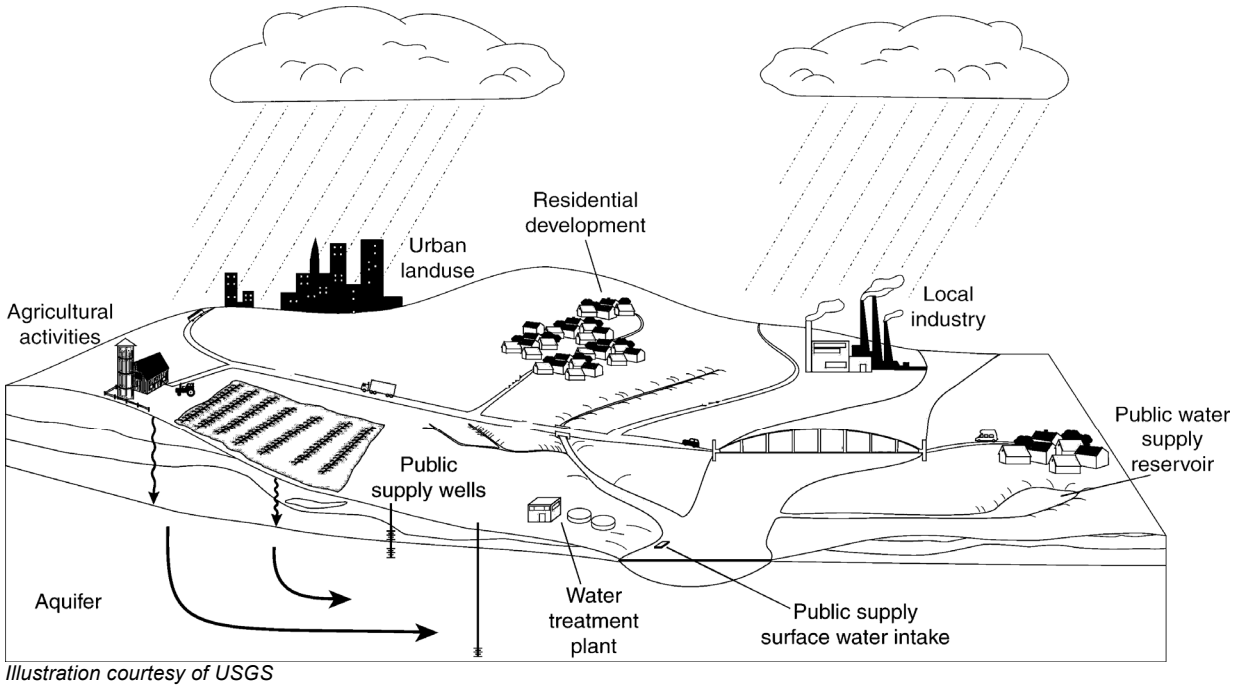

Illustration courtesy of USGS

Among the factors that may affect the quality of drinking water are the type of rock and soil and how the land is used. While some rain and snow evaporates into the sky, most of it runs off into nearby rivers and streams or seeps into the ground. Drinking water comes from underground aquifers or surface water bodies.

What can you and others do to help?

Federal law requires each state to establish and implement a Source Water Assessment Program. While government at the state and local levels can do their part, there are actions that you and your neighbors in homes and businesses can take now to help protect our precious and shared natural resource.

Here's just a few ways you and others can help ensure clean and plentiful water for New Jersey – now and in the future. Join us today for a clean water future.

In your home or business:

- Dispose of waste properly. Some materials such as motor oil, paint, flea collars, and household cleaners have the potential to contaminate source water. Contact your local Department of Public Works for proper household hazardous waste disposal.
- Limit your use of fertilizer, pesticides, and herbicides.

Here are some actions that municipal and county officials/local and county planners can take and you can help encourage and support.

- Manage and work with owners of existing potential contaminant sources to minimize potential contamination.
- Establish regulations prohibiting or restricting certain activities or land uses within the source water assessment area. Take appropriate enforcement action when necessary.
- Update municipal master plans to ensure greater protection.
- Purchase lands or create conservation easements within the source water assessment area.

Strawberry Point Property Owners Association- PWSID # 1904006

Strawberry Point Property Owners Association is a public community water system consisting of 2 well(s), 0 wells under the influence of surface water, 0 surface water intake(s), 0 purchased ground water source(s), and 0 purchased surface water source(s).

This system's source water comes from the following aquifer(s) and/or surface water body(s) (if applicable): igneous and metamorphic rocks

This system purchases water from the following water system(s) (if applicable):

Susceptibility Ratings for Strawberry Point Property Owners Association Sources

The table below illustrates the susceptibility ratings for the seven contaminant categories (and radon) for each source in the system. The table provides the number of wells and intakes that rated high (H), medium (M), or low (L) for each contaminant category. For susceptibility ratings of purchased water, refer to the specific water system's source water assessment report.

The seven contaminant categories are defined at the bottom of this page. DEP considered all surface water highly susceptible to pathogens, therefore all intakes received a high rating for the pathogen category. For the purpose of Source Water Assessment Program, radionuclides are more of a concern for ground water than surface water. As a result, surface water intakes' susceptibility to radionuclides was not determined and they all received a low rating.

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	Pathogens			Nutrients			Pesticides			Volatile Organic Compounds			Inorganics			Radio-nuclides			Radon			Disinfection Byproduct Precursors		
Sources	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Wells - 2		1	1	1	1				2			2			2		2			2			2	
GUDI - 0																								
Surface water intakes - 0																								

- **Pathogens:** Disease-causing organisms such as bacteria and viruses. Common sources are animal and human fecal wastes.
- **Nutrients:** Compounds, minerals and elements that aid growth, that are both naturally occurring and man-made. Examples include nitrogen and phosphorus.
- **Volatile Organic Compounds:** Man-made chemicals used as solvents, degreasers, and gasoline components. Examples include benzene, methyl tertiary butyl ether (MTBE), and vinyl chloride.
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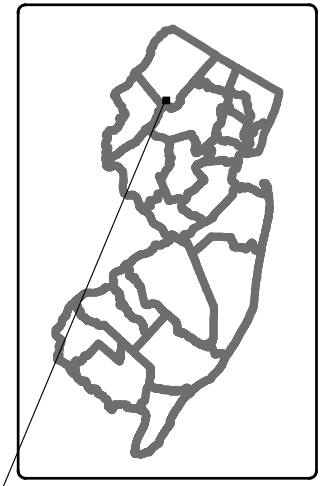
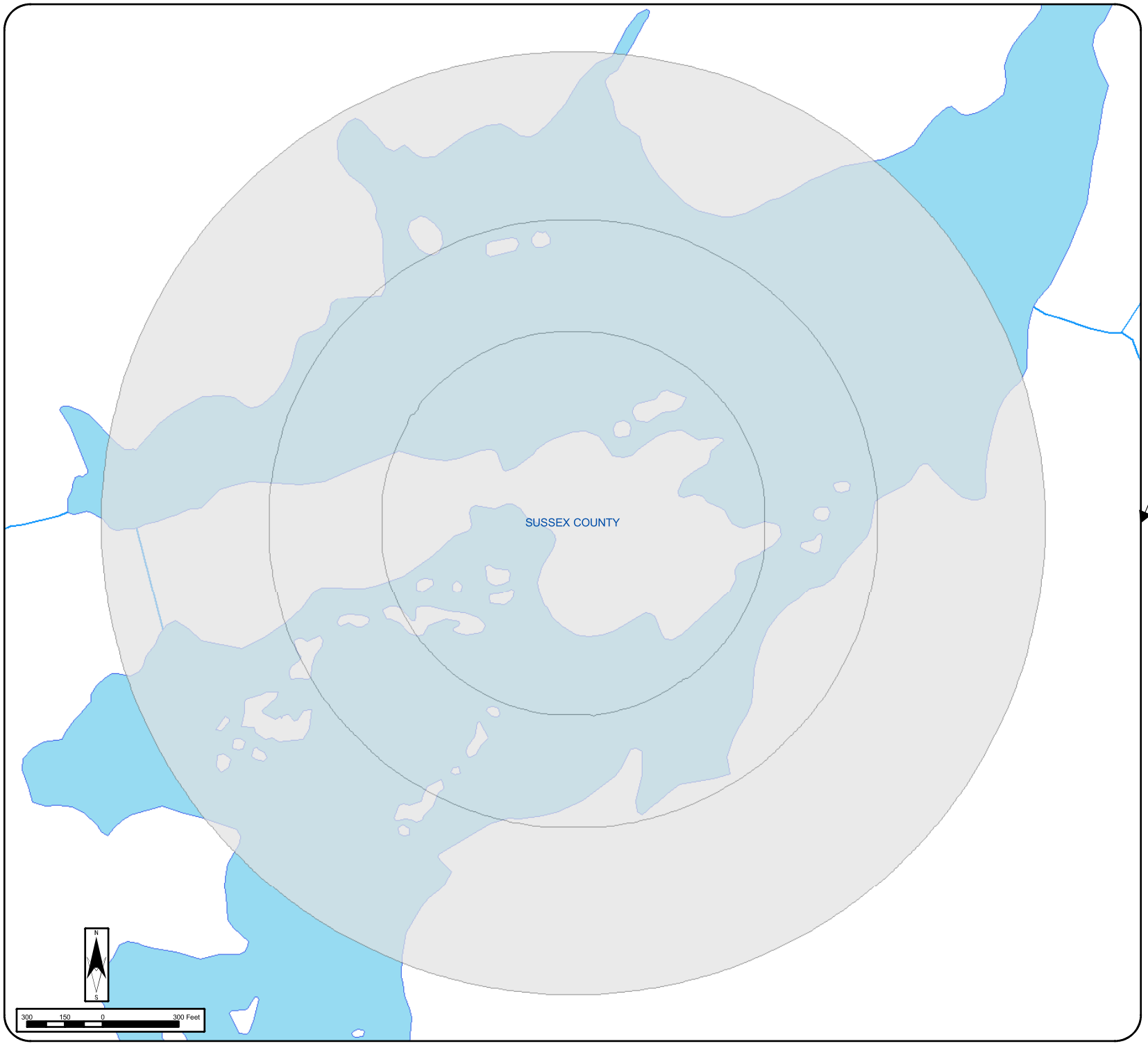
- **Disinfection Byproduct Precursors**: A common source is naturally occurring organic matter in surface water. Disinfection byproducts are formed when the disinfectants (usually chlorine) used to kill pathogens react with dissolved organic material (for example leaves) present in surface water.

Strawberry Point Property Owners Association

Source Water Assessment Areas





Legend

- Source Water Areas
- Water Bodies
- Streams
- NJDOT Major Roads
- Municipalities
- Counties

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Source Water Assessment Report

For

North Shore Water Association

State of New Jersey

Bradley M. Campbell, Commissioner
Department of Environmental Protection

Ernest Hahn, Assistant Commissioner
Land Use Management

Michele Mateo Putnam, Administrator
Water Supply Administration

Barker Hamill, Bureau Chief
Bureau of Safe Drinking Water
401 E. State Street
PO Box 426
Trenton, New Jersey 08625-0426
(609) 292-5550

December 2004

HOW TO USE THIS SOURCE WATER ASSESSMENT REPORT

The following outlines the source water assessment report and directs you to general and/or water system specific information.

Source Water Assessment Executive Summary
A summary of the Source Water Assessment Program and the susceptibility results statewide. This summary also provides the susceptibility ratings for the water system's source(s).

The first three sections of the report contain general information; the remaining four sections are exclusive to the water system and its susceptibility results.

Section I: Background Information on Drinking Water Systems page 1
General information on types of public drinking water systems (community and noncommunity), entry point to the distribution system (EPTDS), and sources of drinking water. The number of public water systems, wells, and surface water intakes in New Jersey is provided.

Section II: Source Water Assessment Program Overview page 7
An introduction to the Source Water Assessment Program and its goals.

Section III: Source Water Assessment Program Steps page 10
A description of the steps the Department of Environmental Protection (DEP) conducted to assess drinking water source(s) susceptibility to potential contamination. The contaminant categories of concern and the potential contaminant sources found to be significant in determining susceptibility (reffered to as explanatory variables) for the Source Water Assessment Program are included in this section. Table 5 provides the percentage of public community water system sources in New Jersey that rated high, medium, and low for each of the contaminant categories.

Section IV: General Description of Water System page 25
General information for the specific water system described in this report such as the system's address, number of entry points to the distribution system, number of wells, number of surface water intakes, and the municipalities and population the system serves. **This is the first section of the report that is specific to the water system.**

Section V: Inventory of Treatment Plants and Drinking Water Sources page 27
An inventory of the specific water system's sources (wells and surface water intakes) and entry points to the distribution system. Additional source information such as source capacity and status is also provided. **The water system data used for the development of the original drinking water source inventory was compiled in the summer of 2003.**

Section VI: Susceptibility Ratings for Drinking Water Source(s) page 29
The susceptibility ratings (high, medium, or low) for each of the specific water system's sources for each contaminant category.

The susceptibility ratings (high, medium, or low) for each of the water system's EPTDS for each contaminant category. The susceptibility ratings were calculated using the susceptibility ratings for the sources. This section explains the process DEP followed to determine the EPTDS's susceptibility ratings.

Appendix A contains additional specific information for the system, immediately follows the report. Appendix A consists of tables and information relating to the susceptibility rating determination for the system's sources. These items include:

Individual Explanatory Variable Inventory

A series of tables show each water source's inventory for each of the explanatory variables for the contaminant categories. For example, agricultural land use in 1995 was found to be one of the significant variables in determining susceptibility to nutrients for a well. The percentage of agricultural land use in 1995 is provided as well as the source's rating for nutrients. The data populating these tables was used to determine susceptibility to the contaminant categories for the drinking water sources.

Specific Potential Contaminant Source Inventory

A table providing a list of potential contaminant sources located within the source water assessment area for each unconfined well and/or intake. This table provides more specific information concerning the source's potential contaminant source inventory. All of the potential contaminant sources are listed individually. The site's name, address, identification number, and county, when available, is provided.

Contaminant Category Scoring System

A series of tables illustrating how the rating score is determined for a source. This document is divided into surface water and ground water sections and provides a table(s) for each of the contaminant categories. Using these rating score tables and the Individual Explanatory Variable Inventory, the numerical susceptibility rating score can be determined. This rating score was then converted into a high, medium, or low susceptibility rating. (The susceptibility rating score conversions are also provided.)

Entry Point to the Distribution System (EPTDS) Rating Calculations

A table illustrating DEP's calculations of the susceptibility ratings for the system's EPTDS. This rating was determined using the susceptibility ratings for the sources and the sources' contributions. The monitoring and treatment takes place at the EPTDS level. Therefore, to assist in developing monitoring strategies, a susceptibility score and rating was developed.

Public Water Treatment

Almost all community water systems in New Jersey treat source water prior to distributing it to their customers. This portion of the appendices contains a list of the treatment processes the water system was using at the time the source water assessment was conducted. This information is important consider when reviewing the susceptibility ratings; treatment may already be operating to remove contaminants associated with systems with high susceptibility ratings.

Source Water Assessment Maps

A collection of maps illustrating the source water assessment areas for the water system's sources (wells and surface water intakes). A separate map has been created for each ground water and surface water susceptibility model. In the case of ground water, there are seven source water assessment maps, one for each of the contaminant categories of concern. These categories include pathogens, nutrients, pesticides, volatile organic compounds, inorganics, radionuclides/radon, and disinfection byproduct precursors. For surface water intakes, five source water assessment area maps were generated: nutrients, pesticides, volatile organic compounds, inorganics, and disinfection byproduct precursors. In addition to illustrating the source water assessment areas, these maps show the potential contaminant sources used in determining susceptibility ratings for the source(s).

Appendix B contains documents that further explain the procedures taken to determine susceptibility of public drinking water sources. These documents contain information addressing the three steps of a source water assessment: develop a source water assessment area, inventory the potential contaminant sources, and determine susceptibility to potential contaminant sources.

Appendix C contains materials to assist in understanding the source water assessment report and contact information for further questions.

SOURCE WATER ASSESSMENT

Executive Summary

North Shore Water Association

As a requirement of the 1996 Amendments to the Safe Drinking Water Act, New Jersey Department of Environmental Protection (DEP) performed a source water assessment of each source of public drinking water and determined each source's susceptibility to contamination. Susceptibility is a measure of the potential exposure of a drinking water source to contamination.

Approximately 85 to 90 percent of New Jersey's population receive their drinking water from public water systems. These public water systems are highly regulated and perform routine monitoring for the presence of contaminants. The remaining population obtains their drinking water from private wells. In 2003, 606 public community water systems consisting of 2237 wells and 64 surface water sources served approximately 7.5 million New Jersey residents.

DEP, in conjunction with the United States Geological Survey (USGS), performed the following steps to determine the drinking water sources' susceptibility.

- Identified the area that supplies water to a public drinking water system well or surface water intake (known as the source water assessment area). For ground water sources, this area is also known as the well head protection area. Approximately 10 percent of New Jersey is contained within a community water system well's source water assessment area. For surface water, approximately 53 percent of the state falls within a source water assessment area.
- Inventoried the significant potential sources of contamination within the source water assessment area.
- Determined how susceptible each drinking water source is to contamination.

Susceptibility to the following categories of contamination was determined:

- Pathogens
- Nutrients (nitrates)
- Pesticides
- Volatile Organic Compounds (VOCs)
- Inorganics
- Radionuclides
- Radon
- Disinfection Byproduct Precursors (DBPs)

To determine susceptibility to these contaminants, the USGS, with DEP assistance, developed statistical models based on extensive analysis of existing well sample data and surface water intake data. The statistical models determined the relationship between environmental factors and the probability for contamination to occur. These models identified factors, such as land use or geology, found to be significantly "linked" to a public water system source's potential to become contaminated by one or more categories of

contaminants. DEP and USGS looked at factors that might affect the quality of drinking water sources and separated them into two categories.

The first category consists of *sensitivity factors*, which includes items related to the construction of a well (such as whether the well is in a confined or unconfined aquifer) and naturally occurring factors (such as the geology of the unit in which a well is drawing water from or over which water flows to the surface water intake).

Significant Sensitivity Factors

- Confinement status: For ground water, the confinement status of the well was by far the most frequently occurring sensitivity factor in predicting susceptibility to contamination and in fact was a factor in all the models. Confined wells are protected from activities at the land surface by relatively thick, laterally extensive units of low permeability (clay layers) and are a sufficient distance from the outcrop area of the geologic unit so that the source water is less likely to be affected by contamination at the land surface. Confined wells were determined to be of low susceptibility to contamination occurring at the land surface. Some confined wells, however, are susceptible to contaminants of natural subsurface origin.
- Depth to the top of the open interval: For unconfined wells, depth to the top of the open interval of the well was the most common sensitivity factor to affect the potential for contamination of a well. Depth to top of open interval was found to be a factor in the following five models: pathogens, nutrients, pesticides, inorganics, and radon. The shorter the distance to the land surface, the more likely for the well to be affected by contamination originating at the surface from point sources and certain land uses.
- Percent soil organic matter: For surface water and ground water, percent soil organic matter was found to be a frequently occurring sensitivity factor. Percent soil organic matter was a factor in the VOC, inorganic, and disinfectant byproduct precursor models for both the surface water and ground water susceptibility models.

The second category of factors affecting a source's potential to become contaminated consists of *intensity of use factors*. This category addresses the susceptibility to contamination resulting from human activities at the land surface. Intensity of use factors include those coming from a specific point source, such as a landfill or leaking underground storage tank, and nonpoint sources of contamination grouped by land-use characteristics, such as agriculture or urban land use.

Significant Intensity of Use Factors

Nonpoint Sources

Overall, the results of the modeling performed by USGS show that of the nonpoint sources, factors related to urban land use and agricultural land use, were most often linked to susceptibility of drinking water sources to contamination.

- Surface water: factors related to urban land use from the 1995 coverage (including percentage of commercial/industrial land use, percentage of developed land, percentage of residential land) were important in predicting a source's susceptibility for four contaminant groups, specifically nutrients, pesticides, VOCs, and inorganics. Agricultural land use was found to be a significant factor in three of the surface water models - nutrients, pesticides, and inorganics.

- Ground water: factors related to urban land use from both 1970 and 1995 were important in predicting the susceptibility of source water for five of the models - nutrients, pesticides, VOCs, inorganics and radionuclides. Agricultural land use in 1970 and 1995 coverages were factors in six of the ground water models: pathogens, nutrients, pesticides, radionuclides, radon, and inorganics.

Point Sources

- Surface water: factors related to New Jersey Pollutant Discharge Elimination System /Discharge to Surface Water (NJPDES/DSW) permits and sewage treatment plant density were found most often to be important factors, specifically for the nutrients, VOCs, and inorganics susceptibility models. NJPDES stormwater permitted locations, compost facilities, sites on DEP's Known Contaminated Site List (KCSL) and solid waste landfills were found to be factors in two of the models: VOCs and inorganics.
- Ground water: point sources were found to be significant only in the models for VOC, inorganics, and disinfection byproduct precursors. No point sources were found to be important in the models for pathogens, nutrients, pesticides, radionuclides, and radon.

The specific sensitivity and intensity of use factors for each drinking water source are provided in the Source Water Assessment Report in Tables 2, 3, and 4.

Using the susceptibility factors, the statistical models provided numerical ratings for each source of drinking water for each contaminant category, which were then converted into high (H), medium (M), or low (L) susceptibility ratings.

The Safe Drinking Water Standards or Maximum Contaminant Levels (MCLs) were used to define the three susceptibility ratings (H, M, and L). These standards are developed based health effects, analytical and treatment factors on either acute or long-term impacts related to drinking water exposure. A low susceptibility rating means a potential contaminant level was predicted to be less than 10 percent of the MCL for that contaminant category. A medium rating was given to drinking water sources where the potential contaminant level was predicted to be equal to or greater than 10 percent and less than 50 percent of the MCL. A high rating was assigned to those sources that were predicted to have potential contaminant levels equal to or greater than 50 percent of the MCL. Sources with high susceptibility ratings are still likely to have contaminant concentrations below the MCL. For the list of New Jersey primary and secondary drinking water standards, containing the MCLs, please refer to http://www.state.nj.us/dep/watersupply/standard.htm.

In some cases, insufficient data for particular supplies were available for all variables used in susceptibility models. In such cases, a default value for missing data was assumed. Use of default values could result in a different susceptibility rating than that which would result if the source-specific data were available.

Statewide Summary

Table E1 illustrates the percentage of community water system sources in New Jersey that rated high, medium, and low for each of the contaminant categories. The table is separated by source type: ground water (confined and unconfined) and surface water.

Table E1: Summary of Statewide Susceptibility Ratings for Community Water System Sources (Percent %)

	Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
Ground Water-Confined[1]								
High	0	0	0	0	0	0	0	27
Medium	0	0	0	0	47	39	19	70
Low	100	100	100	100	53	61	81	3
Ground Water-Unconfined[2]								
High	6	67	0	61	39	50	50	26
Medium	56	30	34	1	33	47	46	74
Low	38	3	66	38	28	3	4	0
Surface Water[3]								
High	100[4]	47	13	5	81	0	0	98
Medium	0	42	34	81	19	0	0	2
Low	0	11	53	14	0	100[4]	100[4]	0

[1] Community water systems confined wells in New Jersey in 2003 = 640
[2] Community water systems unconfined wells in New Jersey in 2003 = 1597
[3] Community water system surface water sources in New Jersey in 2003 = 64
[4] All surface water intakes received high susceptibility ratings for pathogens and low susceptibility rating for radionuclides and radon

For the purpose of the source water assessments, the drinking water derived from all surface water intakes was assumed to be highly susceptible to contamination by pathogens. Therefore, all surface water intakes received a high rating for pathogens (100 percent). Surface water sources are subject to various sources of microbial contamination runoff containing fecal matter. Secondly, radionuclide and radon models for surface water were not developed. Radionuclides are primarily a concern of ground water, therefore, all surface water intakes received a low susceptibility rating for radionuclides and radon (0 percent).

Statewide, 77 percent of the sources rated high for at least one of the contaminant categories. Disinfection byproduct precursors were the contaminant category for which surface water sources most commonly received a high susceptibility rating (excluding pathogens). The factors deemed important for the surface water disinfectant byproduct precursor susceptibility model were average percent soil organic matter and distance to wetlands. To address this important category of contaminants, the United States Environmental Protection Agency (USEPA) and DEP adopted the new Stage 1 Disinfectants and Disinfection Byproduct Rule, that requires all community water systems that add a disinfectant to the drinking water during any part of the treatment process to perform routine monitoring for trihalomethanes and haloacetic acids and meet new MCLs of 80 parts per billion and 60 parts per billion, respectively. For more information on the Stage 1 Disinfectants and Disinfection Byproduct Rule please refer to USEPA's web site at http://www.epa.gov/OGWDW/mdbp/dbp1.html.

In addition, disinfection byproduct precursors were the contaminant category for which confined wells (ground water source) most commonly received a high susceptibility rating. The source water assessments resulted in an unexpected number of medium and high susceptibility ratings for the disinfectant precursor model for ground water. The medium and high ratings were unexpected because the reported levels of disinfection byproduct precursors by ground water systems for compliance in New Jersey are generally low. This model is being reviewed with data collected by DEP and may be further refined in the future.

An important distinction exists between the ground water disinfectant precursor model and the other models. The disinfectant byproduct precursors, for which the model was developed, in combination with the disinfection process, form the actual disinfectant byproducts. The disinfectant byproducts are regulated, not the precursors. The precursors themselves are not considered to have adverse health effects, but instead the chemicals that are formed during the disinfection process have the potential health impacts. The other susceptibility models were developed using the regulated contaminant rather than a constituent that reacts to form the regulated contaminant.

For unconfined wells (ground water sources), nutrients and VOCs, were the contaminant categories in which the most sources received a high susceptibility rating. On the other hand, all confined wells obtained a low susceptibility rating for nutrients and VOCs. Both of these contaminant categories are caused by human activity at the land surface, and confined wells are relatively protected from the activity-related contamination by a layer of less permeable material. (The contaminant categories most related to by human activities are nutrients, pesticides, VOCs, and inorganic compounds.)

Drinking Water System: Summary of Sources for North Shore Water Association
North Shore Water Association consists of 1 wells, 0 wells under the influence of surface water, 0 surface water intake(s), 0 purchased ground water source(s), and 0 purchased surface water source(s) of drinking water. **(The water system data used for the development of the original drinking water source inventory was compiled in the summer of 2003.)**

Table E2 provides a summary of the susceptibility ratings for the North Shore Water Association drinking water source(s). The “sources” column of the table provides the number of ground water and surface water sources and the number of wells under the direct influence of surface water in the system. Ground water under the direct influence of surface water (GUDI) is a well found to be influenced by surrounding surface water bodies, and is classified according to site specific water quality measurements, according to the Surface Water Treatment Rule. The other columns provide the number of each of the source(s) that rated high (H), medium (M), and low (L) for each of the contaminant categories.

Table E2: Summary of Susceptibility Ratings for Drinking Water Source(s) for North Shore Water Association

	Pathogens			Nutrients			Pesticides			VOCs			Inorganics			Radionuclides			Radon			DBPs		
Sources	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Wells - 1			1	1					1			1			1		1			1			1	
GUDI - 0																								
Surface water intakes - 0																								

If a drinking water source's susceptibility is high, it does not necessarily mean the drinking water is contaminated. The rating reflects the potential for contamination of source water, not the existence of contamination.

Under the State's Safe Drinking Water Regulations, all public water systems must routinely monitor for contamination. If MCLs (drinking water standards) are exceeded, the water system must perform additional monitoring and treat the water before it is served to the consumer. The water system is also required to notify its customers when MCL violations occur. The process for notification depends on the severity of the violation, which can include public service announcements and publication in a local newspaper. Information about violations must also be included in the Consumer Confidence Reports that community water systems must mail to all their customers annually.

Drinking Water System: Entry Point to the Distribution System

Each entry point to the distribution system (EPTDS) also received a susceptibility rating by combining the weighted average of all the sources contributing to the EPTDS, after the water has been treated (if the drinking water is treated). The susceptibility rating for each EPTDS is available in the Source Water Assessment Report, Section VII, Table 11.

Since the EPTDS is the point at which monitoring and treatment occurs, the DEP determined the EPTDS susceptibility ratings because the assessment will help determine if the existing monitoring requirements for each public water system need to be revised. The assessment will help determine if the routine monitoring frequencies required of a community water system should be increased or decreased (support monitoring waivers). Secondly, the results of the Source Water Assessments will help DEP protect public health by targeting wells and surface water sources that are highly susceptible to contamination for additional water quality monitoring.

The Source Water Assessment Program was designed to encourage protection of drinking water sources by providing information to state and local regulatory agencies and the public to assist in watershed assessment and planning and to enhance the public's role as "water stewards." The results provide information to allow state and local agencies to determine if increased regulatory controls, including local land use ordinances, are warranted. In addition, the basic data gathered through the Source Water Assessment Program, including the locations of the public water system wells and surface water sources, will be available for

DEP program use in efforts to improve environment regulatory actions, such as cleanup decisions in the hazardous and solid waste programs. For more information on DEP's Source Water Protection Strategy please see the Statewide Summary Document available at www.state.nj/us/dep/swap.

For further information please refer to the detailed information in the Source Water Assessment Report or go to www.state.nj/us/dep/swap.

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SECTION I – BACKGROUND INFORMATION ON DRINKING WATER SYSTEMS

SECTION I – BACKGROUND INFORMATION ON DRINKING WATER SYSTEMS

This background information is provided to describe how public drinking water systems are regulated and the relationship of these water systems with the Source Water Assessment Program. The following section describes sources of drinking water (groundwater and surface water), types of drinking water systems according to the Department of Environmental Protection (DEP) and Environmental Protection Agency (EPA) definitions, and drinking water treatment.

Sources of Drinking Water

1. Ground Water

Ground water infiltrates the ground and is stored in aquifers, soil and rock below the surface. Aquifers typically consist of gravel, sandstone, sand, or fractured rock. An aquifer can be confined or unconfined. A confined aquifer is ground water bounded between impermeable layers, such as clay. An unconfined aquifer is not bounded by impermeable layers and is more directly linked to surface activities and resources.

Ground water is obtained from a spring or by pumping water from an aquifer through a well. A well is a hole or excavation that is drilled, bored, core driven, jetted, dug, driven or otherwise constructed for the purpose of removal of water from the subsurface for potable water supply. Public wells in New Jersey range from 15 to 1,984 feet deep (in 2002).

2. Surface Water

Surface water, is the water at or above the land's surface, which is neither ground water nor contained within the unsaturated zone, including, but not limited to, the ocean and its tributaries, all springs, streams, rivers, lakes, ponds, wetlands, and artificial waterbodies.

An important link exists between ground water and surface water. Surface water can infiltrate the ground and recharge aquifers. Conversely, ground water slowly moves to the surface and discharges into lakes, rivers, or streams and is known as baseflow. New Jersey's natural stream flow, especially during periods of low precipitation, is largely baseflow from ground water.

Figure 1 illustrates the water cycle, ground water and surface water, and potential sources of contamination to drinking water sources.

Figure 1: Hydrologic Cycle and Sources of Drinking Water

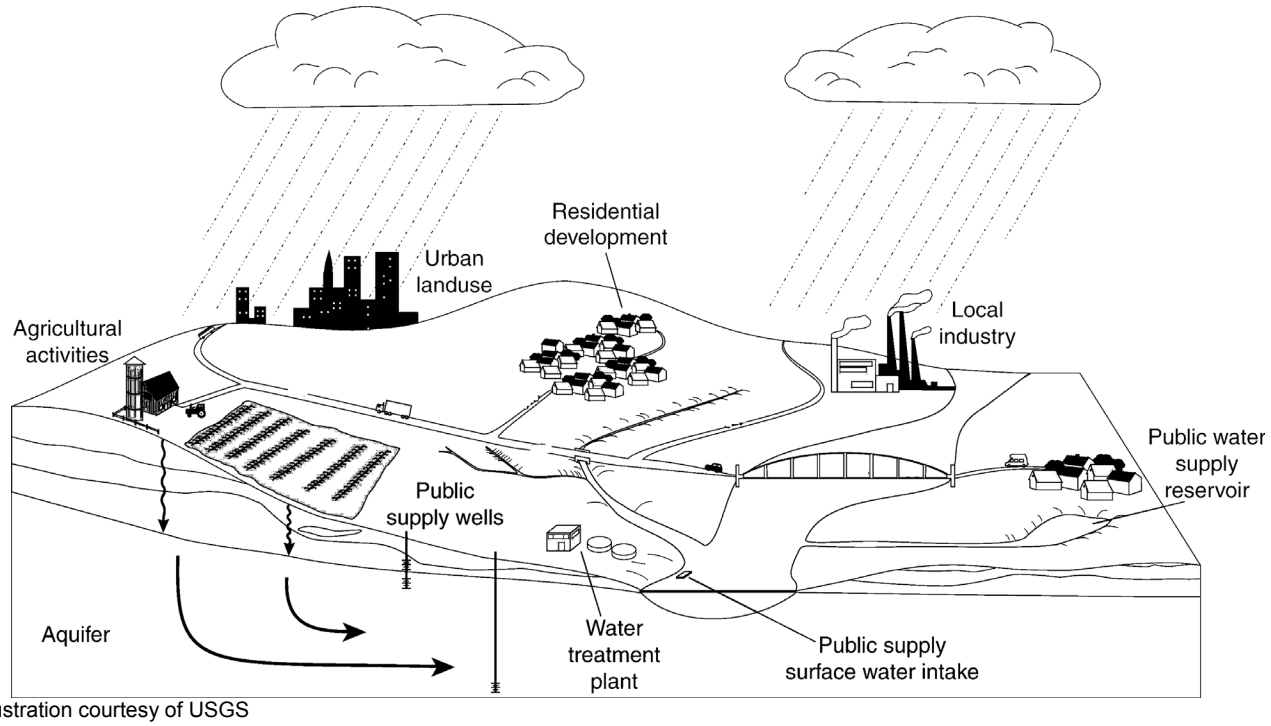


Illustration courtesy of USGS

Types of Public Water Systems

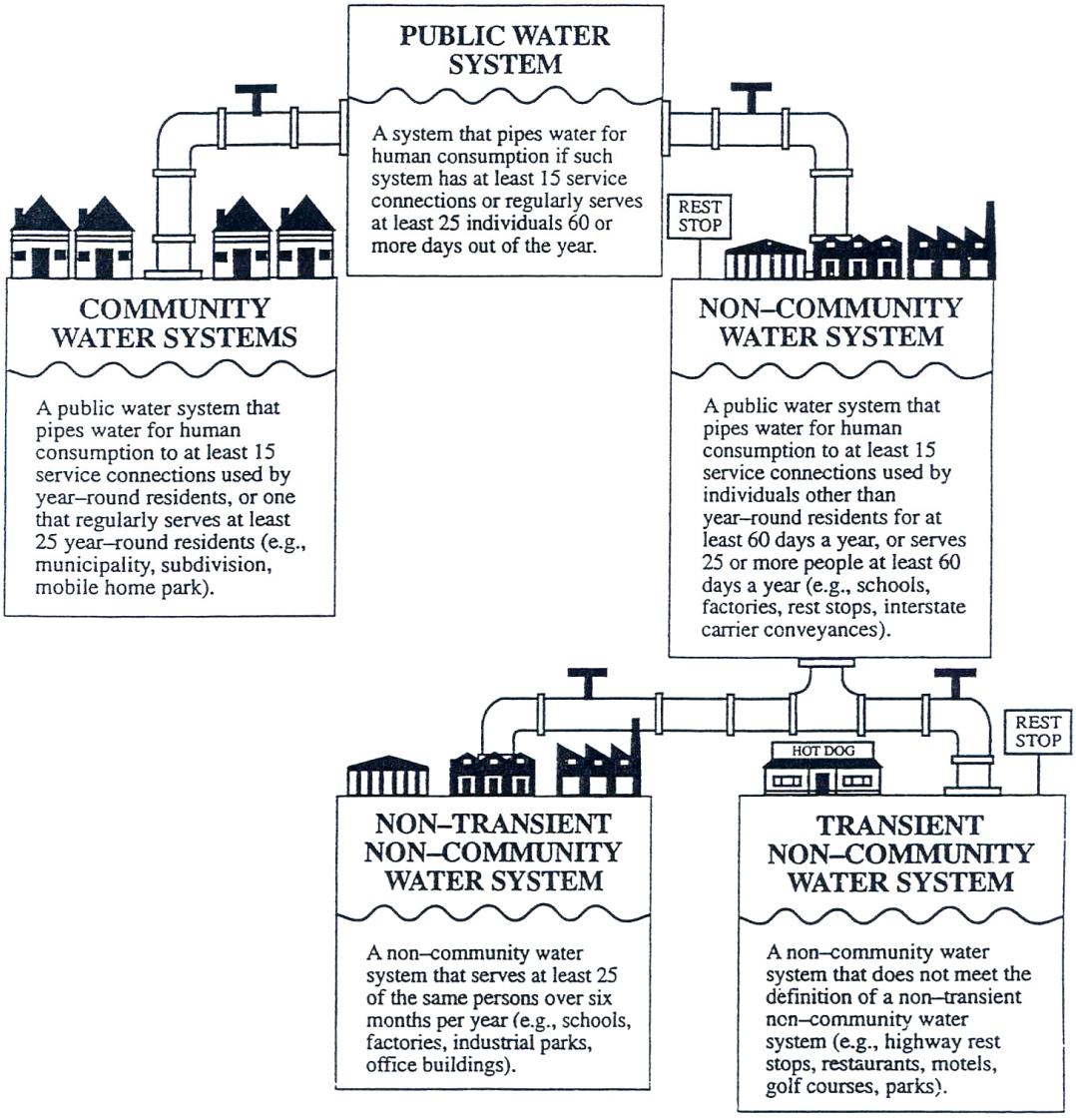
A public water system is defined as a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least 15 service connections or regularly serves at least 25 individuals. Ground water and/or surface water sources can be used for public water systems.

1. **Community Water System**: has at least 15 service connections used by year round residents, or regularly serves at least 25 year round residents. Examples of a community water system are mobile home communities, municipally owned water systems and privately owned water systems that have their own well(s) or surface water intake(s).

2. **Noncommunity Water System**: used by individuals other than year round residents for at least 60 days of the year. A noncommunity water system can be either transient or nontransient. A nontransient noncommunity water system serves at least 25 of the same persons over six months per year, such as schools, factories, and office buildings which have their own well(s) or surface water intake(s). Transient noncommunity water systems are systems that do not fall within the definition of a nontransient water system. Transient noncommunity water systems include rest stop areas, restaurants, and motels that have their own well(s).

A flow chart describing these definitions appears in Figure 2.

Figure 2: Types of Public Water Systems



From: Public Notification Handbook for Public Water Systems, USEPA Office of Water, USEPA Publication 570/9–89–002 September 1989

Approximately 85 to 90 percent of New Jersey's population is served by public water systems. Table 1 summarizes the number of public water systems, wells, and surface water sources in the State of New Jersey in 2003.

Table 1: Public Water Systems in New Jersey in 2003

Type of Public Water System	# of Public Water Systems*	# of Ground Water Sources	# of Surface Water Sources
Community	606	2237	64
Nontransient Noncommunity	876	1083	3
Transient Noncommunity	2654	2779	0
Total	4136	6099	67

* DEP, Bureau of Safe Drinking Water, NJ Public Water System Database.

The remaining New Jersey population is served by private wells (i.e. wells serving individual homes, small businesses, etc.) Private wells are not included in the SWAP. For more information on private wells please visit the Water Supply Administration web site at www.state.nj.us/dep/watersupply or refer to the EPA web site at www.epa.gov/safewater/pwells1.html.

Drinking Water Treatment

A public water system consists of interconnected pipes that lead from the source of drinking water to the consumer. Almost all community water system sources and some noncommunity water system sources are treated to remove microorganisms or dissolved chemicals or minerals. An entry point to the distribution system (EPTDS) is a location in the public water system where treated water from a treatment plant enters into the water distribution system. A public water system may contain one or more EPTDS. If the water is not treated, as some ground water systems are not, then the place where the untreated water source enters the network of pipes is the EPTDS.

Figure 3 illustrates general treatment schemes for both a surface water system and a ground water system. The means of acquiring water (well or surface water intake), the treatment process, and storage are shown. An individual water system may contain only part or even none (do not treat) of these pieces. Individual water treatment may vary according to source water quality.

Figure 3: Example of Drinking Water Treatment

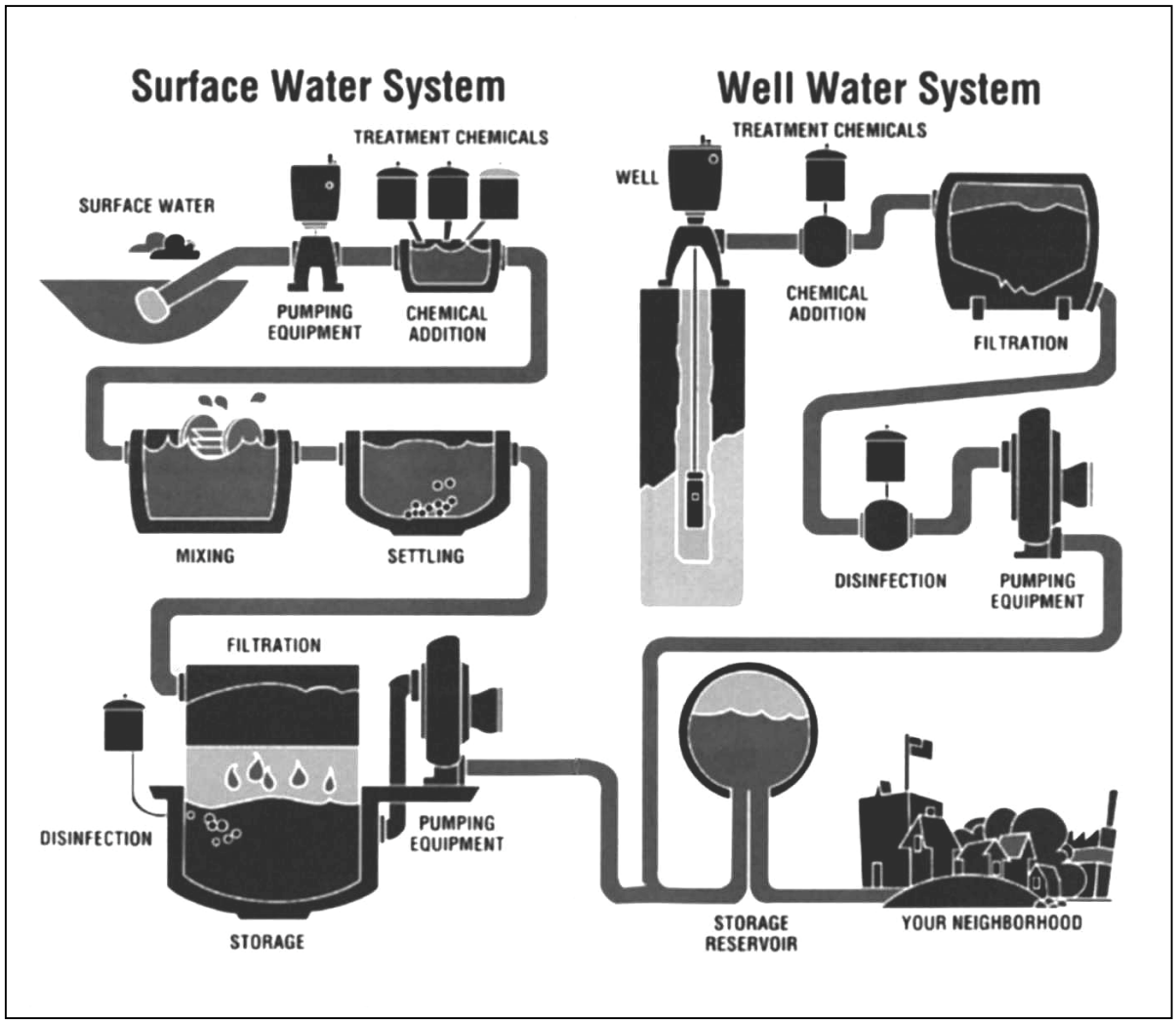


Illustration from “Safeguarding the Quality of Your Drinking Water”, prepared by the Public Information Committee of the New Jersey Section of the American Water Works Association.

SECTION II – SOURCE WATER ASSESSMENT PROGRAM OVERVIEW

SECTION II – SOURCE WATER ASSESSMENT PROGRAM OVERVIEW

Introduction

The 1996 Amendments to the Federal Safe Drinking Water Act place a strong emphasis on public awareness and the information provided to the public concerning the quality of drinking water. As part of the 1996 Amendments, all states were required to establish a Source Water Assessment Program (SWAP).

Through the SWAP, the DEP evaluated the susceptibility of public water systems to several categories of contamination. **If a system rates highly susceptible for a contaminant category, it does not mean a customer is or will be consuming contaminated drinking water.** The rating reflects the potential for contamination of source water, not the existence of contamination. Susceptibility to contamination is a function of several factors, including contaminant use near the water source and the characteristics of the water source.

New Jersey's SWAP Plan, which provides the framework for how DEP performed the assessments, can be found at www.state.nj.us/dep/watersupply/swap1.pdf.

The New Jersey SWAP incorporates four steps:

1. **Delineate the source water assessment area of each public drinking water source.**
2. **Inventory the potential contaminant sources within the source water assessment area.**
3. **Determine the water system's susceptibility to contaminants.**
4. **Incorporate public participation and education.**

Source Water Assessment Program Goals

The information obtained from the completed source water assessments may be used to achieve the goals listed below.

1. Protect sources of drinking water.

The source water assessments provide a susceptibility rating for each source of drinking water, which supplies information on how vulnerable the source is to contamination.

Source water protection focuses on preserving and protecting the public drinking water source. The information obtained from the SWAP will provide communities and decision-makers with the information to protect their drinking water source(s). The source water assessment results can also be used by DEP, purveyors, and local planning officals to lay the groundwork for advancing the State's drinking water protection efforts. Based on the potential of a drinking water source to become contaminated, DEP can initiate a variety of activities to protect the drinking water source through existing DEP programs. For more information regarding DEP's Source Water Protection Strategy please refer to the Source Water Assessment Program Statewide Summary available on the Division of Water Supply's web site at http://www.state.nj.us/dep/watersupply//.

2. Public education of SWAP information.

DEP incorporated public education throughout the development and implementation of the Source Water Assessment Program. During the source water assessment process, DEP

spoke to interested parties, beginning with the development of the SWAP Plan, published articles, wrote two newsletters, and developed a SWAP web site. Upon completion of the source water assessments, DEP generated a source water assessment report and/or summary for each public water system to report the susceptibility ratings.

The goal of the public education efforts is to make the public more aware of the source of their drinking water and the potential contaminants that could impair the water's quality. To continue fulfilling the education requirement, DEP will conduct training sessions following the release of the Source Water Assessment Reports.

3. Establish a customized monitoring schedule for each public water system.
The source water assessments will assist DEP in improving current monitoring requirements for individual public water systems. Currently, the EPA and the DEP have mandatory monitoring schedules that depend on a variety of factors that can include the source of the water (ground water or surface water) and the surrounding land use. These schedules can be customized based on the susceptibility of the sources of drinking water. The SWAP will provide better information for making these determinations.

Source Water Assessment Reports
DEP will issue the following reports to public water systems.

1. **Community Water System Source Water Assessment Report**: primarily intended for the public water system's reference and use, although the report is also available to the public. Individuals, environmental organizations, and municipalities interested in source water protection may also utilize the Community Water System Source Water Assessment Report for protection activities.

2. **Community Water System Source Water Assessment Summary**: a short (4-6 page) informative document created for distribution by the water system to the general public. In addition, DEP will post the summary document on the SWAP web site at http://www.state.nj.us/dep/swap/. The Community Water System Source Water Assessment Summary is a synopsis of the Source Water Assessment Report and provides the source susceptibility ratings for the community water system's sources.

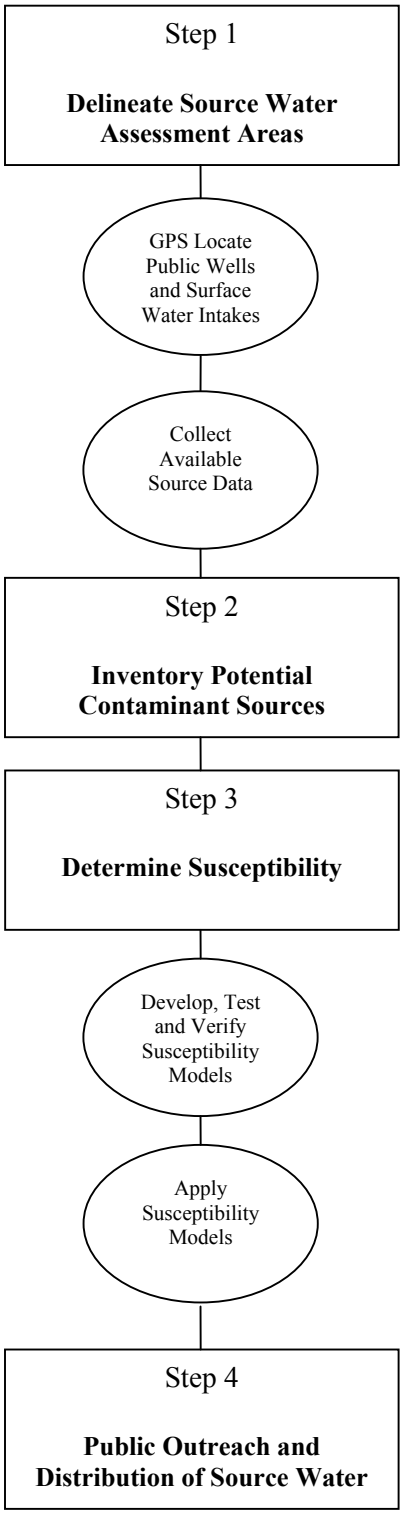
3. **Noncommunity Water System Source Water Assessment Report**: developed for the respective noncommunity water system. The report provides the susceptibility ratings of the system's sources. The general public may request the report from the noncommunity water system or the DEP.

SECTION III – SOURCE WATER ASSESSMENT PROGRAM STEPS

SECTION III – SOURCE WATER ASSESSMENT PROGRAM STEPS

The SWAP consists of four fundamental steps that are illustrated in Figure 4.

Figure 4: Flowchart of Source Water Assessment Program Process



Step 1: Delineation

The first step of the SWAP process is to delineate the source water assessment area for each public water system well and surface water intake. For ground water sources, a source water assessment area in New Jersey is the area from which water is reasonably likely to flow to a well within a 12 year period. This area is also known as a wellhead protection area, or WHPA. For surface water sources, the source water assessment area is the area upstream of a surface water intake, including land that drains to the upstream areas.

Before the source water assessment area was delineated for a public well, attribute data was gathered. Since 1947, a property owner or well driller has been required to obtain a well permit from New Jersey's well permitting program to drill a well in New Jersey. After a licensed well driller drills the well, a well record must be submitted to the Water Supply Administration, DEP. The well record is an "as-built" description of the well construction, and usually contains important attribute data such as well depth, screened interval or length of open hole, and pumping rate/capacity. This information is needed to delineate the source water assessment area around the well. DEP used the well record to determine attribute data. In situations where DEP was unable to obtain attribute data, such as for a well drilled prior to 1947 or when a well record was not available, default values were generated using New Jersey Geological Survey's (NJGS) "Guidelines for Delineation of Well Head Protection Areas in New Jersey," Appendix B- Attachment 1. The guidance document is available on the internet at www.state.nj.us/dep/njgs/whpaguide.pdf, by contacting the DEP, New Jersey Geological Survey at (609) 292-1185, or from the DEP Maps and Publications Sales Office at (609) 777-1038.

For surface water intakes, source water assessment areas were developed based on the location of the intake and the entire drainage area upstream of the intake including headwaters and tributaries. These factors influence the shape and size of the delineations.

Next, the well or intake was located using Global Positioning System (GPS). All wells and intakes were GPS-located according to the "DEP GPS Data Collection Standards for GIS Data Development" available at www.state.nj.us/dep/gis/gpstrim.html. The DEP GPS-located the community water system wells and surface water intakes. The noncommunity water system wells were GPS-located by DEP, County Environmental Health Act (CEHA) Agencies, and the New Jersey Water Association.

After collecting the attribute data and GPS location, the source water assessment areas for wells and intakes were delineated. DEP performed the ground water source water assessment area delineations using the Combined Model/Calculated Fixed Radius Method for all public community water system wells and the Calculated Fixed Radius method for the noncommunity water system wells. For a detailed description of the delineation methods please refer to New Jersey's "Guidelines for Delineation of Well Head Protection Areas in New Jersey," Appendix B- Attachment 1.

For each ground water source, three tiers were calculated and labeled as Tier 1 (two year time of travel), Tier 2 (five year time of travel), and Tier 3 (12 year time of travel). Time of travel was established for determining the risk of contamination to a well. The two year time of travel was developed based on the potential for microbiological contamination. Studies show on average, bacteria can survive in ground water for approximately 170 days and

viruses can survive in ground water for approximately 270 days. The two year time of travel indicates the limits of concern for potential viable microbiological contamination of the water system through the source water.

The five year time of travel was established to address contamination from accidental discharges. This time of travel provides a reasonable amount of time to investigate, monitor, and/or remediate a spill within the source water assessment area. The third time of travel portion of the source water assessment area, 12 year, was designed in consideration of the known contaminant sources. Studies show that 10 to 15 years of time of travel generally covers the full length of a contaminant plume. The 12 year time of travel will permit enough time for responses to be made.

Ground water delineations are available as New Jersey Geological Survey publication DGS02-2, Geographic Information System Coverages of Public Community Water Supply Well Head Protection Areas for New Jersey (1:24,000 scale) at www.state.nj.us/dep/njgs/geodata/dgs02-2.htm.

The DEP delineated the source water assessment areas for surface water intakes using the United States Geological Survey's (USGS) hydrologic unit code 14 (HUC14) as the base data-set for the delineations. Hydrologic unit codes identify drainage basins in a nested group from large to small. The larger the HUC number the smaller the drainage basin. For example a HUC4 will be made up of several smaller HUC8s, and the HUC8s will be made up of several smaller HUC14s. The source water assessment areas for the surface water intakes include the entire drainage area that flows past the intake, including headwaters and tributaries. For more information on the methodology used for surface water delineations, refer to Appendix B- Attachment 2, Surface Water Delineation Methodology.

The DEP has classified approximately 50 wells as "ground water under the direct influence of surface water" (GUDI). GUDI wells are classified according to site specific water quality measurements and provide additional treatment of the source water. For GUDI wells, the DEP performed a conjunctive delineation, an integrated delineation combining the ground water contribution and the surface water contribution to the well. The groundwater and surface water contribution were delineated using the same procedure described above, except the 2 year time of travel for the ground water delineation demarcated the downstream boundary.

A few GUDI wells do not have an obvious surface water body influencing the well. In these instances only the ground water delineated source water assessment area was available. Therefore, the 12 year time of travel boundary for the ground water delineation was used to define the surface water contribution area. An example of this scenario would be the Newton Water and Sewer Utility, Facility number 03, SFID number 010.

The ground water susceptibility models were applied to the GUDI wells ground water contribution area and the surface water susceptibility models were applied to the surface water contribution area. The final susceptibility rating for the GUDI well was determined by taking the higher susceptibility rating of the two (ground water and surface water). Using the pathogen contaminant category as an example, all surface water automatically received a high susceptibility rating for pathogens. Therefore, all GUDI wells received a high susceptibility rating for pathogens. Even if the GUDI well rated low to pathogens for the

ground water contribution area, the high rating for the surface water contribution area was used as the final susceptibility rating (the highest rating of the two).

Step 2: Potential Contaminant Source Inventory

The second step of the SWAP is to identify the potential contaminant sources within the source water assessment area. These potential sources of contamination include point and nonpoint sources. Point source contaminants may be traced to a single source, such as known contaminated sites, industrial and commercial surface and ground water discharges, and sewage treatment discharges. Nonpoint source contaminants may not be traced to one single source because they come from several individual sources within a large area. Land use activities such as salting and runoff from roads and the application of pesticides and herbicides are examples of nonpoint sources. Nonpoint and point sources can have a significant impact on both surface water and ground water quality.

Potential contaminant source inventory information was primarily collected from existing DEP GIS databases. For nonpoint sources, digital GIS land use and land cover data for the years 1970, 1986, and 1995 were used. Several datasets of land coverage were used to account for the changes in land use over the years. The New Jersey Source Water Assessment Program Potential Contaminant Source Inventory (PCSI) Methodology, Appendix B-Attachment 3, describes how the potential contaminant source inventory was developed, the datasets used, the sites and activities included in the inventory, and the preliminary list of explanatory variables used in the susceptibility models.

For the purpose of the SWAP, the DEP, in conjunction with a Source Water Assessment Advisory Committee that met regularly during the development of the SWAP Plan, developed eight conceptual contaminant categories that represent microbiological and chemical contaminants of concern. These categories include pathogens, nutrients, volatile organic compounds, synthetic organic compounds, pesticides, inorganics, radionuclides and disinfection byproduct precursors. This list was further refined during the susceptibility model development process. Tables 2, 3, and 4 contain the final list of contaminant categories and explanatory variables. Each drinking water source was evaluated for susceptibility to each of the following contaminant categories.

Conceptual Contaminant Categories

Pathogens

Disease-causing organisms such as bacteria, protozoa, and viruses. Sources of pathogens include both point and nonpoint activities. An example of a point source of pathogens is a sewer system overflow. An example of a nonpoint source is runoff from areas where livestock are kept.

Nutrients

Common types of nutrients include nitrogen and phosphorous. Nutrients can harm environmental quality, human health, and the efficiency of the drinking water treatment plant by encouraging growth of photosynthetic microorganisms in surface water sources, which alter water characteristics (eutrophic conditions). Sources of nutrients are point and nonpoint sources. Effluents from a sewage treatment plant are a point source of nutrients. Nonpoint sources of nutrients include discharge from septic fields, areas where animal waste is stored, and runoff from agricultural and residential land where fertilizers were used.

Pesticides
Common sources of pesticides include land applications (nonpoint source) and manufacturing/distribution centers of pesticides (point source). Pesticides are manmade chemicals used to control bacteria, fungi, weeds, rodents, and insects. Examples include herbicides such as atrazine and insecticides such as chlordane.

Synthetic Organic Compounds (SOCs)
Sources of SOCs can be point and nonpoint. Common sources include chemical manufacturing plants, pharmaceutical plants, sewage treatment plants, and discharges from contaminated sites. Synthetic organic compounds are manmade.

Volatile Organic Compounds (VOCs)
Common types of VOCs include chemicals that are used as solvents, degreasers, and gasoline components. VOCs are manmade compounds and are the most common organic contaminants in ground water in New Jersey. Sources of VOCs can be point and nonpoint. Examples of VOCs are methyl tertiary butyl ether (MTBE), benzene and vinyl chloride.

Inorganics
Mineral-based compounds that are both naturally occurring and manmade. Sources of inorganics can be point and nonpoint; common sources include discharges from manufacturing plants, releases from contaminated sites, past land uses, and naturally occurring sources. Inorganics include arsenic, cadmium, copper, lead, mercury, and asbestos.

Radionuclides
Sources of radionuclides can be point and nonpoint; common sources include the decay of naturally occurring minerals, leaching of subsurface material (for example rocks and sedimentary materials) into ground water, and improper disposal of radioactive waste. Radionuclides are a category of contaminant that is both naturally occurring and manmade. Radionuclides are radioactive substances such as radium and radon.

Disinfection Byproduct (DBP) Precursors
Disinfection byproducts are formed when the disinfectants used to kill pathogens during treatment react with dissolved organic material present in the water. A common source of DBP precursors is naturally occurring organic material such as leaves in surface water. The amount of organic matter, the type of disinfectant, the concentration of disinfectant, time of contact, pH, and temperature all have an effect on the concentration of disinfection byproducts produced. Chlorine is the most common disinfectant used in New Jersey.

Step 3: Susceptibility Determination
The third step of the SWAP is to determine the public water system's susceptibility to contamination. Susceptibility is a function of source sensitivity (for example soil type and well construction characteristics) and the intensity of surrounding use factors (for example the density of contamination sites or the type of land use).

SUSCEPTIBILITY = Sensitivity + Intensity

DEP contracted with the USGS to develop susceptibility assessment models, with DEP guidance, to determine susceptibility ratings for public supply wells and surface water intakes for the contaminant categories of concern described in Step 2. Some states have determined susceptibility using relatively simple approaches that account for factors such as distance to contaminant sources, but the more thorough modeling approach employed for New Jersey provides a more accurate estimate of susceptibility. The models were based on results from an extensive analysis of ground water and surface water quality data from the DEP-USGS statewide cooperative monitoring networks for a select set of sites in New Jersey. Please refer to the documentation Methods to Determine the Susceptibility of Source Water to Community and Noncommunity Water Supplies in New Jersey to Contamination, Appendix B- Attachment 4 for more information.

USGS developed susceptibility models for seven contaminant categories and radon for both ground water and surface water. DEP had originally intended to develop a susceptibility model for "synthetic organic compounds" (SOCs), but did not do so for two reasons. First, SOCs under the Federal and State Safe Drinking Water Acts consist primarily of pesticides and as part of SWAP, USGS developed a pesticide susceptibility model. Secondly, as USGS investigated whether it could construct a SOCs model, USGS and DEP jointly determined that there was insufficient SOC data that was neither pesticide nor volatile organic compound (VOC) related. (USGS also developed a separate VOC model.) However, it is DEP's experience that the presence of non-pesticide, non-volatile SOCs will typically co-occur with VOCs. Specifically, recent work by DEP and others at community water systems using ground water as a source and known to be contaminated by volatile organic contamination from hazardous waste sites determined that "tentatively identified compounds" (TICs) were present. In this study, although DEP and others were primarily looking for non-volatile organic compounds, TICs were found at some frequency at these sites. As part of the study, a "control" water system with no hazardous waste site nearby and with no volatile contamination was tested and contained no TICs. Qualitative evaluation of the data show systems with the higher levels of volatile organic chemicals and with more than one VOC present contained the highest number of TICs. For these reasons, DEP has determined the SOC rating for a water system would be the same as the public water system's VOC rating, and that a separate SOC susceptibility model was unnecessary.

Separate susceptibility models were developed for radon and other radionuclides for two reasons. First, radon, a gas, is chemically and physically different from other radionuclide constituents. Second, radon most often occurs in areas where other radionuclides are not present. The remedy for radon is different from the remedy for other radionuclides. DEP was concerned that if both radon and other radionuclides were combined, the susceptibility rating would not show the difference in susceptibility of water systems' sources to the different radionuclides.

For the purpose of the source water assessments, all surface water was assumed to be highly susceptible to pathogens, therefore a pathogen model was not developed for surface water. Surface water sources are subject to various sources of microbial contamination runoff containing fecal matter. All surface water intakes received a high rating for pathogens. Secondly, a radionuclide model was not developed for surface water. Radionuclides are primarily a concern of ground water, therefore, all surface water intakes received a low susceptibility rating for radionuclides.

The susceptibility models determined source water susceptibility based on the well or intake's location and explanatory variables. An explanatory variable is a variable that can be used to predict the presence of a contaminant or the potential presence of a contaminant in ground water or surface water. Tables 2, 3, and 4 illustrate the final explanatory variables used in determining sensitivity and intensity ratings for surface water intakes, unconfined wells, and confined wells. These tables also contain the conceptual variables used in the susceptibility rating determinations. A conceptual variable is one that has been shown in a previous scientific investigation to be related to, or is expected to have an effect on, the concentrations of a constituent. Conceptual variables that did not produce significant univariate statistical relations may however, produce a significant relation when used with other variables in multivariate statistical tests.

A list of all contaminant variables reviewed can be found in the documentation Methods to Determine the Susceptibility of Source Water to Community and Noncommunity Water Supplies in New Jersey to Contamination, Appendix B- Attachment 4. For further information, Appendix B- Attachment 5 and 6, Contaminant Group Reports, provide detailed descriptions of the models used for SWAP.

In addition to evaluating the contaminant variables separately, groupings of several point source variables together as a single explanatory variable were investigated to determine if a certain subset of point sources produced meaningful results. USGS determined that although several types of point sources are not statistically significant individually, grouping them as a unit could produce meaningful results. These combinations are known as "Point Source Groupings."

Point Source Grouping 1: consists of sites on the Known Contaminated Site List and on the Solid Waste Landfill Site list. In general, these point sources are existing contamination sources.

Point Source Grouping 2: consists of New Jersey Pollutant Discharge Elimination System for permitted discharges to surface water, New Jersey Pollutant Discharge Elimination System storm water discharges, and Compost Facilities. These point sources are potential surface water contamination problems.

Point Source Grouping 3: consists of New Jersey Pollutant Discharge Elimination System discharges for ground water (NJPDES/DGW), Solid Waste Resource Recovery Facilities (RRF), Solid Waste Transfer Facilities (SWTF), and Class B Recycling Facilities. These point sources are potential ground water contamination problems. The last three activities (RRF, SWTF, and Class B) are designed not to discharge contamination and degrade ground water. They do handle pollutants, and there is a potential to cause contamination. Thus, they are included in the inventory. Facilities that discharge via a NJPDES/DGW permit are given strict permit limits. The discharge standards are typically at or below the ground water quality standards. While these activities are grouped for modeling purposes, the RRF, SWTF, and Class B Recycling Facilities do not appreciably affect the model, based on analysis by USGS.

Point Source Grouping 4: consists of sites regulated by the DEP Discharge Prevention and Countermeasures Plan regulations and Discharge Cleanup and Removal Plan regulations. These facilities store, transfer, process, or use hazardous substances and must specify and

submit information regarding prevention, containment and countermeasure plans and discharge cleanup and removal plans.

Point Source Grouping 5: consists of regulated Underground Storage Tanks (USTs). USTs were treated as a separate point source grouping due to the large number of USTs in New Jersey, relative to the number of other types of potential point sources. There are approximately 19,454 underground storage tank registrations in New Jersey, consisting of active and inactive tanks. USTs were treated separately so that the number of USTs would not obscure possible statistical relations between susceptibility and other potential contaminant sources.

Point Source Grouping 6: consists of the entire Potential Contaminant Source Inventory of point sources.

Several point source groupings were combined to determine whether or not these point source groupings had an effect on a source's susceptibility. If a point source grouping combination was found to be significant it was used as an explanatory variable in the susceptibility models. The explanatory variables can be found in Tables 2, 3, and 4 dependent on the type of drinking water source.

Table 2: Surface Water Explanatory Variables

Illustrates the explanatory variables USGS used in their SWAP surface water modeling.

Constituent/Variable	Pathogens [1]	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides [1]	Radon [1]	DBPs - conceptual [2]
Sensitivity								
% Soil Clay			X					
% Soil Organic Matter				X [2]	X [2]			X [2]
PH of water-quality sample					X			
Physiographic Province					X [2]			
Water Region					X			
Intensity								
% Agricultural Land Use, 1995		X						
% Commercial/Industrial Land Use, 1995					X [2]			
% Developed Land, 1995					X [2]			
% Residential Land Use, 1995			X					
% Urban Land Use, 1995		X		X	X			
Distance to Agricultural Land, 1995			X		X [2]			
Distance to Wetlands, 1995								X [2]
Density of NJPDES SW/Storm, Compost Facilities (Point Source Grouping 2)					X			
Density of KCSL, SWL, NJPDES SW/Storm, Compost Facilities (Point Source Groupings 1,2)				X				
Density of KCSL, SWL, NJPDES GW, SWRRF, SWTF200011, Class B Recycling, DPCC, UST (Point Source Groupings 1, 3, 4, 5)					X			
Sewage Treatment Plant Density		X						
Total Pesticide Application			X					

[1] For the purpose of developing susceptibility models, a pathogen model was not developed because all surface water sources are considered highly susceptible to pathogens; a radionuclide model was not developed because radionuclides are not a concern in surface water.

[2] This conceptual variable shows a graphical relation to water-quality, improves the model, and is supported by scientific investigations.

Table 3: Ground Water Unconfined Explanatory Variables

Illustrates the explanatory variables USGS used in their SWAP ground water unconfined modeling.

Constituent/Variable	Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
Sensitivity								
% Soil Clay					X[4]		X[2]	
% Soil Organic Matter				X	X[2]			X[1]
Conceptual - GWUDI	X[3]							
Depth to Top of Open Interval	X	X[2]	X[2]		X[4]		X	
Depth of Well						X[2]		
Dissolved Oxygen of water-quality sample					X			
Length of Open Interval		X[2]	X[2]					
NJGS Hydrologic Unit (Aquifer)								X[1]
pH of water-quality sample					X	X		
Physiographic Province					X[4]	X	X	
Soil Available Water Capacity	X[1]							
Soil Hydraulic Conductivity					X	X[2]		
Intensity								
% Agricultural Land Use, 1970						X		
% Agricultural Land Use, 1986		X	X					
% Agricultural Land Use, 1995							X	
% Barren Land Use, 1995					X			
% Commercial/Industrial Land Use, 1995				X				
% Urban Land Use, 1970					X			
% Urban Land Use, 1995		X	X[2]					
Area of Urban Land Use, 1995 (square miles)				X				
% Urban Land Use, Tier 1, 1995						X		
% Developed Land, Tier 1, 1995						X		
% Impervious Surface, 1995				X				
Distance to Agricultural Land, 1995	X		X		X	X[1]		
Distance to Golf Course			X[2]					
Distance to DOT Roads					X			
Distance to Sewage Treatment Plant					X			
Distance to Wetlands, 1995							X[2]	
Square Miles of Wetlands, 1995								X[2]
Number of NJPDES SW/GW/Storm, Compost, SWWRF, SWTF200011, Class B Recycling, and DPCC (Point Source Groupings 2, 3, 4)								X

Table 3 continued

Constituent/Variable	Pathogens	Nutrients	Pesticides - conceptual[3]	SOCs[1]	VOCs	Inorganics	Radionuclides	Radon	DBPs
Density of KCSL, SWL, NJPDES GW/SW/Storm, Compost Facility, SWRRF, SWTF200011, Class B Recycling, DPCC, UST (Point Source Groupings 1, 2, 3, 4, 5)						X			
Density of SWL, UST, KCSL (Point Source Groupings 1, 5)					X				
Population Density						X			
Population Density, Tier 1						X			
Septic Tank Density	X[1]								
Septic Tank Density in Piedmont							X		
Sewage Treatment Plant Density						X			
Conceptual - Presence of Streams, Tier 1	X[3]								
Length of Railroads						X			

[1] This conceptual variable shows a graphical relation, improves the model, and is supported by scientific investigations.
[2] This conceptual variable shows a graphical relation to water quality and improves the model.
[3] Statistical tests could not be used because the variable was unavailable for the data set used to develop the model.
[4] This factor is a conceptual variable and an explanatory variable for the contaminant category. As a result of the contaminant category consisting of several inorganics (arsenic, barium, beryllium, fluoride, lead, and mercury), the factor is used as a conceptual and statistically significant variable. Percent soil clay is a conceptual variable (X^2) for lead and mercury, but a statistically significant explanatory variable for beryllium. For depth to top of open interval, the factor is conceptual (X^2) for fluoride and lead, and a statistically significant explanatory variable for beryllium. Thirdly, physiographic province is a conceptual variable (X^3) for mercury and a statistically significant explanatory variable for the arsenic, barium, beryllium, and fluoride models.

Table 4: Ground Water Confined Explanatory Variables

Illustrates the explanatory variables USGS used in their SWAP ground water modeling.

Constituent/Variable	Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
Sensitivity								
% Soil Organic Matter								
NJGS Hydrologic Unit (Aquifer)								X
Geologic Unit					X	X	X	
pH of water-quality sample								X
Intensity [1]								

[1] Confined wells are not susceptible to intensity variables.

Susceptibility is the measurement of potential for a public water system to become contaminated. The susceptibility models developed by the USGS were applied to all community water system sources and resulted in a high, medium, or low susceptibility rating for each source of water.

If a drinking water source's susceptibility is high, it does not mean the water is contaminated. High susceptibility is a vulnerability rating, not a factor determining whether or not the water is or is not safe to drink. The rating reflects the potential for contamination of source water, not the existence of contamination. Public water systems are required to monitor for regulated contaminants and to install treatment if any contaminants are detected at frequencies and concentrations above allowable levels. Customers can refer to the water company's Consumer Confidence Report (CCR) to determine if the drinking water is meeting all of the Safe Drinking Water Act regulatory requirements. The water utility may be contacted for additional water quality information.

DEP calculated the percentage of community water system sources in New Jersey that rated high, medium, and low for each of the contaminant categories. Table 5 summarizes the susceptibility rating information.

Table 5: Summary of Statewide Susceptibility Ratings for Community Water System Sources (Percent %)

	Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
Ground Water[1]								
High	4	48	0	44	27	35	36	22
Medium	40	22	23	0	38	45	38	76
Low	56	31	77	56	35	20	26	2
Surface Water[2]								
High	100	47	13	5	81	0	0	98
Medium	0	42	34	81	19	0	0	2
Low	0	11	53	14	0	100	100	0

[1] Community water systems wells in New Jersey in 2003 = 2237
[2] Community water system surface water sources in New Jersey in 2003 = 64

USGS developed a rating scoring system for each susceptibility model. When each model was applied to a well or intake, a rating score was generated. This score was then converted into a susceptibility rating of high, medium, or low. For further information on the susceptibility rating score scheme please refer to Appendix A- Attachment 3. The Safe Drinking Water Maximum Contaminant Levels (MCLs) were used to guide the division between the three susceptibility ratings. A low susceptibility rating means a potential contaminant level was predicted to be less than 10 percent of the MCL for that contaminant. A medium susceptibility rating was assigned where the potential contaminant level was predicted to be equal to or greater than 10 percent and less than 50 percent of the MCL. A high susceptibility rating was assigned where the potential contaminant level was equal to or greater than 50 percent of the MCL. For the list of New Jersey primary and secondary drinking water standards, containing the MCLs, please refer to http://www.state.nj.us/dep/watersupply/standard.htm.

In many cases, a public water system may have more than one well or intake, or a combination of wells and intakes. In cases of ground water or surface water only systems, the well or intake ratings were grouped together to represent the EPTDS rating. Each EPTDS received a susceptibility rating for radon and each of the seven contaminant categories. The EPTDS rating was determined by weighing each source's rating score according to the rate of withdrawal. Each weighted score was added, the sum was divided by the number of drinking water sources, and the EPTDS score was classified as low, medium or high susceptibility. Appendix A- Attachment 4 provides an explanation of the EPTDS calculation.

Step 4: Public Participation and Outreach

The fourth step, public participation and outreach, is an essential component of the SWAP. The 1996 Amendments to the Federal Safe Drinking Water Act place a strong emphasis on public participation. To ensure the source water assessments are used for source water protection efforts, the public was involved from the beginning of the program.

The DEP used a variety of techniques to include the public in the program.

1. **Created a Source Water Assessment Advisory Committee to provide input on the draft and final SWAP Plan**. The Source Water Assessment Advisory Committee continued to meet with the DEP regularly to discuss the status of the assessments and provide suggestions during the development of the program. In addition, the Source Water Assessment Advisory Committee provided advice concerning the source water assessment summaries and reports.

2. **Developed a SWAP newsletter, the "New Jersey Source Water Assessment News."** Issues of the "New Jersey Source Water Assessment News" may be found at www.state.nj.us/dep/swap. The newsletter was sent to committee members, public water systems, county health agencies, environmental organizations, municipalities, drinking water laboratories, and other interested parties. The New Jersey Source Water Assessment News informed readers of the status of the SWAP, contact information, source water protection issues, and other related topics.

3. **Published SWAP articles in several organizations' newsletters.** For example, articles were published in the New Jersey Section of American Water Works Association newsletter "Pipeline" and the DEP Division of Watershed Management newsletter "Focus."

4. **Provided speakers for numerous SWAP presentations throughout the State.** The presentations were regularly presented to water purveyors at New Jersey Water Association training courses and other interested organizations such as the watershed management area committees.

The DEP will continue its public outreach following the release of the source water assessments. Public outreach activities will include training sessions for water purveyors, published SWAP articles, and correspondence with interested parties such as purveyors, municipalities, planning boards, and environmental commissions.

SECTION IV - GENERAL DESCRIPTION OF YOUR WATER SYSTEM

SECTION IV – DESCRIPTION OF WATER SYSTEM

North Shore Water Association
PWID # 1904004

30 Allamuchy Trail
Andover, NJ 07821
(973)383-6558

North Shore Water Association is a public community water system consisting of

1 Entry Points to the Distribution System (EPTDS)
- 1 wells
- 0 wells under the influence of surface water
- 0 surface water intake(s)
- 0 purchased ground water
- 0 purchased surface water

Table 6 below contains the municipalities and the population within each of these municipalities served by North Shore Water Association.

Table 6: Municipalities and Population Served

Municipality	County	Population Served - 2003
Byram Twp.	Sussex	60

SECTION V - INVENTORY OF TREATMENT PLANTS AND DRINKING WATER SOURCES

SECTION V - SYSTEM INVENTORY FOR: North Shore Water Association

Table 7 provides the North Shore Water Association's treatment plant(s); source(s); the sources' location(s); whether the source(s) are ground water, surface water, or a purchased supply; and the sources' capacity(s). The first column contains the EPTDS ID and sources contributing to the same EPTDS are identified by the same number. An EPTDS is the entry point to the distribution system, and for most community water systems this location is after the water is treated at a treatment plant.

In the case of a ground water source, the well's confinement status and well permit number are provided.

Table 7: Drinking Water Source and EPTDS Inventory

EPTDS ID	Source ID	Source Name	Water System Component *	Source Status *	Source *	Source Capacity (MGD)	Well Permit #	Confinement Status *
01	002	WELL 1 TP	T	P				
01	003	WELL 1/28-A ALLAMUCHY TRAIL	G	P	igneous and metamorphic rocks	0.0251	00-00605	U

*KEY

Water System Component

G = Ground Water, P = Purchased Surface Water, S = Surface Water, T = Treatment Plant (EPTDS), U = Ground Water Under The Direct Influence of Surface Water, W = Purchased Ground Water. For a complete definition of each source of drinking water, please refer to the Glossary at the end of this report.

Confinement Status

C = Confined, U = Unconfined. For a definition of a confined and an unconfined aquifer please refer to the Glossary at the end of this report. K = Unknown, S = Semi-confined. For the purposes of SWAP both K and S were treated as unconfined wells.

Source Status

C = Recharge, E = Emergency, I= Interim, O = Other, P= Permanent, R= Reserve, S= Seasonal, U = Not in Use/Capped, V = Abandoned/Not Capped, W = Not in Use/Unspecified, X = Not in Use/Mechanical, Y = Not in Use/Contaminated. For a complete definition of each well status category, please refer to the Glossary at the end of this report.

Source

For ground water sources, the name of the aquifer is provided. For surface water sources, the name of the surface water body on which the intake is located is given.

The North Shore Water Association contains 1 EPTDS as illustrated in Table 7 (identified by a "T" in the water system component column). Often public water systems treat source water at the EPTDS to ensure the drinking water provided to the public meets Federal and State Drinking Water Standards. Please refer to Appendix A- Attachment 5 for information on the public water system's treatment process.

SECTION VI - SUSCEPTIBILITY RATINGS FOR YOUR DRINKING WATER SOURCE(S)

SECTION VI – SUSCEPTIBILITY RATINGS FOR DRINKING WATER SOURCE(S)

Table 8 provides a summary of the susceptibility ratings for the system's source(s). The source column of the table provides the number of ground water and surface water sources and the number of ground water under the direct influence of surface water (GUDI) wells in the system. The other columns provide the total number of source(s) that rated high (H), medium (M), and low (L) for each of the contaminant categories.

Table 8: Summary of Susceptibility Ratings for Drinking Water Source(s)

	Pathogens			Nutrients			Pesticides			VOCs			Inorganics			Radionuclides			Radon			DBPs		
Sources	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Wells - 1			1	1					1			1			1		1			1			1	
GUDI - 0																								
Surface water intakes - 0																								

To review a summary of how the other public water systems in the State of New Jersey rated, please refer to Table 5, "Summary of Statewide Susceptibility Ratings for Community Water System Sources (Percent %)" in Section III of the Source Water Assessment Report.

If a drinking water source's susceptibility is high, it does not necessarily mean the water is contaminated. High susceptibility is a vulnerability rating, not a factor determining whether or not the water is or is not meeting State and Federal Safe Drinking Water Standards. The rating reflects the potential for contamination of source water, not the existence of contamination. Public water systems are required to monitor for regulated contaminants and to install treatment if any contaminants are detected at frequencies and concentrations above allowable levels. Please refer to the Consumer Confidence Report (CCR) to determine if the drinking water is meeting all of the Safe Drinking Water Act regulatory requirements.

Table 9 illustrates the susceptibility rating for each individual source for each of the contaminant categories.

Table 9: Susceptibility Rating for Drinking Water Source(s)

EPTDS ID	Source ID	Source Name	Contaminant Category							
			Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
			Rating	Rating	Rating	Rating	Rating	Rating		Rating
01	003	WELL 1/28-A ALLAMUCHY TRAIL	L	H	L	L	L	M	M	M

The potential contaminant source inventory and sensitivity variables were used to determine the susceptibility ratings for the sources. For specific information on the water system's potential contaminant source inventory and sensitivity variables, please refer to the Individual Explanatory Variable Inventory and the Specific Potential Contaminant Sources Inventory, Appendix A- Attachment 1 and 2.

SECTION VII - SUSCEPTIBILITY RATINGS FOR YOUR ENTRY POINT TO THE DISTRIBUTION SYSTEM (EPTDS)

SECTION VII – SUSCEPTIBILITY RATINGS FOR ENTRY POINT TO THE DISTRIBUTION SYSTEM (EPTDS)

The North Shore Water Association contains 1 EPTDS. The EPTDS and the susceptibility rating for radon and each of the seven-contaminant categories are provided in Table 11. A susceptibility rating was developed for each EPTDS because this rating represents the water that is treated and delivered to the consumer. A majority of the monitoring regulations are established for the point at which the water exits the water treatment facility, therefore the EPTDS susceptibility rating is important in determining the monitoring requirements.

The EPTDS rating was calculated by the following method. The source contribution resulted from multiplying the pumping rate for each water source by each source's susceptibility score (a point value based on the contaminant category scoring system found in Appendix A – Attachment 3). In cases where the pumping rate was not available, the pumping capacity was used. Next, all source contributions were summed and divided by the total capacity (sum of all the pumping rates and/or capacities) for the EPTDS.

$$\frac{\sum \text{Source Contributions (Source Capacity x Source Susceptibility Score Rating)}}{\text{Total Capacity } (\sum \text{ of all source capacities to the EPTDS})} = \textbf{EPTDS Susceptibility Score}$$

Key

Source Capacity: the source capacity used for determining EPTDS ratings was the same as the pumping rate used by New Jersey Geological Survey to create the source water assessment areas. If the pumping rate was not available, the pumping capacity or a default value was used. The pumping rate selection is described in the New Jersey Geological Survey's "Guidance for Well Head Protection Area Delineations in New Jersey", Appendix B- Attachment 1.

Source Contribution: the value calculated by multiplying the source's pumping rate by the source's susceptibility score rating. The susceptibility score rating is the point value based on the contaminant category scoring system, which can be found in Appendix A – Attachment 3.

Source Susceptibility Score Rating: to obtain a high, medium, or low susceptibility rating, USGS developed a susceptibility scoring system for each contaminant category (pathogens, VOCs, inorganics, nutrients, radionuclides, disinfection byproduct precursors, and pesticides). Each contaminant category has its own point system based on the susceptibility model. For example a susceptibility score range for a contaminant could be 0-5 = low susceptibility, 6-10 = medium susceptibility, and 11-20 = high susceptibility. See Appendices A- Attachment 3 for the susceptibility scoring system USGS used to determine the susceptibility ratings.

Total Capacity: is the full amount of water the sources are contributing to the EPTDS. The pumping rates/capacities are summed to determine the total capacity for the EPTDS.

For groundwater sources, only permanent, seasonal, and interim wells were used in the EPTDS rating calculation. Other wells such as emergency, reserve, and not-in-use, were not included in the source to EPTDS "roll-up", but these wells were rated on a source basis.

For public water systems that consist of a combination of well(s) and intake(s), the EPTDS received a ground water EPTDS rating and a surface water EPTDS rating. Even in circumstances where the surface water is blended with ground water, the EPTDS received two separate susceptibility ratings. A separate ETPDS rating is provided for the ground water and the surface water because separate susceptibility models were developed for ground and surface water. Ground water and surface water susceptibility models differ in susceptibility rating score, therefore, the rating results are not on the same scale.

If a facility has only one well or intake contributing to the EPTDS, that EPTDS received the same rating as the well or intake. DEP used the equation below to determine an EPTDS susceptibility rating.

Table 10 provides an example of how the EPTDS ratings were calculated. To review how the EPTDS ratings were calculated for the North Shore Water Association, please refer to Appendix A- Attachment 4.

Table 10: Example of an EPTDS Susceptibility Rating Calculation

EPTDS 01

Source	Capacity (MGD)	Source Susceptibility Score Rating (0-20, low to high)	Total = Source Contribution
Well 1	1.09	20	(1.09*20) = 21.8
Well 2	1.72	10	17.2
Well 3	0.72	5	3.6
Well 4	1.48	10	14.8
Well 5	0.75	20	15.0
Total Capacity	5.76		72.4
EPTDS Susceptibility Score is 72.4 / 5.76 = 12.6			

For the above example, the sum of the source contributions for EPTDS 01 (72.4) is divided by the total capacity from all sources (5.76) giving a susceptibility score for the EPTDS of 12.6. The original range for rating sources was 0-5 low, 6-10 medium, 11-20 high. EPTDS 01 susceptibility rating was 12.6; therefore the EPTDS would receive a high rating.

Table 11 lists the susceptibility ratings for each EPTDS for the North Shore Water Association.

Table 11: Susceptibility Rating for EPTDS

EPTDS ID	EPTDS Name	Contaminant Category							
		Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
		Rating	Rating	Rating	Rating	Rating	Rating		Rating
01	WELL 1 TP	L	H	L	L	M	M	M	M

Source Water Assessment Report

For

Strawberry Point Property Owners Association

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HOW TO USE THIS SOURCE WATER ASSESSMENT REPORT

The following outlines the source water assessment report and directs you to general and/or water system specific information.

Source Water Assessment Executive Summary
A summary of the Source Water Assessment Program and the susceptibility results statewide. This summary also provides the susceptibility ratings for the water system's source(s).

The first three sections of the report contain general information; the remaining four sections are exclusive to the water system and its susceptibility results.

Section I: Background Information on Drinking Water Systems page 1
General information on types of public drinking water systems (community and noncommunity), entry point to the distribution system (EPTDS), and sources of drinking water. The number of public water systems, wells, and surface water intakes in New Jersey is provided.

Section II: Source Water Assessment Program Overview page 7
An introduction to the Source Water Assessment Program and its goals.

Section III: Source Water Assessment Program Steps page 10
A description of the steps the Department of Environmental Protection (DEP) conducted to assess drinking water source(s) susceptibility to potential contamination. The contaminant categories of concern and the potential contaminant sources found to be significant in determining susceptibility (reffered to as explanatory variables) for the Source Water Assessment Program are included in this section. Table 5 provides the percentage of public community water system sources in New Jersey that rated high, medium, and low for each of the contaminant categories.

Section IV: General Description of Water System page 25
General information for the specific water system described in this report such as the system's address, number of entry points to the distribution system, number of wells, number of surface water intakes, and the municipalities and population the system serves. **This is the first section of the report that is specific to the water system.**

Section V: Inventory of Treatment Plants and Drinking Water Sources page 27
An inventory of the specific water system's sources (wells and surface water intakes) and entry points to the distribution system. Additional source information such as source capacity and status is also provided. **The water system data used for the development of the original drinking water source inventory was compiled in the summer of 2003.**

Section VI: Susceptibility Ratings for Drinking Water Source(s) page 29
The susceptibility ratings (high, medium, or low) for each of the specific water system's sources for each contaminant category.

The susceptibility ratings (high, medium, or low) for each of the water system's EPTDS for each contaminant category. The susceptibility ratings were calculated using the susceptibility ratings for the sources. This section explains the process DEP followed to determine the EPTDS's susceptibility ratings.

Appendix A contains additional specific information for the system, immediately follows the report. Appendix A consists of tables and information relating to the susceptibility rating determination for the system's sources. These items include:

Individual Explanatory Variable Inventory

A series of tables show each water source's inventory for each of the explanatory variables for the contaminant categories. For example, agricultural land use in 1995 was found to be one of the significant variables in determining susceptibility to nutrients for a well. The percentage of agricultural land use in 1995 is provided as well as the source's rating for nutrients. The data populating these tables was used to determine susceptibility to the contaminant categories for the drinking water sources.

Specific Potential Contaminant Source Inventory

A table providing a list of potential contaminant sources located within the source water assessment area for each unconfined well and/or intake. This table provides more specific information concerning the source's potential contaminant source inventory. All of the potential contaminant sources are listed individually. The site's name, address, identification number, and county, when available, is provided.

Contaminant Category Scoring System

A series of tables illustrating how the rating score is determined for a source. This document is divided into surface water and ground water sections and provides a table(s) for each of the contaminant categories. Using these rating score tables and the Individual Explanatory Variable Inventory, the numerical susceptibility rating score can be determined. This rating score was then converted into a high, medium, or low susceptibility rating. (The susceptibility rating score conversions are also provided.)

Entry Point to the Distribution System (EPTDS) Rating Calculations

A table illustrating DEP's calculations of the susceptibility ratings for the system's EPTDS. This rating was determined using the susceptibility ratings for the sources and the sources' contributions. The monitoring and treatment takes place at the EPTDS level. Therefore, to assist in developing monitoring strategies, a susceptibility score and rating was developed.

Public Water Treatment

Almost all community water systems in New Jersey treat source water prior to distributing it to their customers. This portion of the appendices contains a list of the treatment processes the water system was using at the time the source water assessment was conducted. This information is important consider when reviewing the susceptibility ratings; treatment may already be operating to remove contaminants associated with systems with high susceptibility ratings.

Source Water Assessment Maps

A collection of maps illustrating the source water assessment areas for the water system's sources (wells and surface water intakes). A separate map has been created for each ground water and surface water susceptibility model. In the case of ground water, there are seven source water assessment maps, one for each of the contaminant categories of concern. These categories include pathogens, nutrients, pesticides, volatile organic compounds, inorganics, radionuclides/radon, and disinfection byproduct precursors. For surface water intakes, five source water assessment area maps were generated: nutrients, pesticides, volatile organic compounds, inorganics, and disinfection byproduct precursors. In addition to illustrating the source water assessment areas, these maps show the potential contaminant sources used in determining susceptibility ratings for the source(s).

Appendix B contains documents that further explain the procedures taken to determine susceptibility of public drinking water sources. These documents contain information addressing the three steps of a source water assessment: develop a source water assessment area, inventory the potential contaminant sources, and determine susceptibility to potential contaminant sources.

Appendix C contains materials to assist in understanding the source water assessment report and contact information for further questions.

SOURCE WATER ASSESSMENT

Executive Summary

Strawberry Point Property Owners Association

As a requirement of the 1996 Amendments to the Safe Drinking Water Act, New Jersey Department of Environmental Protection (DEP) performed a source water assessment of each source of public drinking water and determined each source's susceptibility to contamination. Susceptibility is a measure of the potential exposure of a drinking water source to contamination.

Approximately 85 to 90 percent of New Jersey's population receive their drinking water from public water systems. These public water systems are highly regulated and perform routine monitoring for the presence of contaminants. The remaining population obtains their drinking water from private wells. In 2003, 606 public community water systems consisting of 2237 wells and 64 surface water sources served approximately 7.5 million New Jersey residents.

DEP, in conjunction with the United States Geological Survey (USGS), performed the following steps to determine the drinking water sources' susceptibility.

- Identified the area that supplies water to a public drinking water system well or surface water intake (known as the source water assessment area). For ground water sources, this area is also known as the well head protection area. Approximately 10 percent of New Jersey is contained within a community water system well's source water assessment area. For surface water, approximately 53 percent of the state falls within a source water assessment area.
- Inventoried the significant potential sources of contamination within the source water assessment area.
- Determined how susceptible each drinking water source is to contamination.

Susceptibility to the following categories of contamination was determined:

- Pathogens
- Nutrients (nitrates)
- Pesticides
- Volatile Organic Compounds (VOCs)
- Inorganics
- Radionuclides
- Radon
- Disinfection Byproduct Precursors (DBPs)

To determine susceptibility to these contaminants, the USGS, with DEP assistance, developed statistical models based on extensive analysis of existing well sample data and surface water intake data. The statistical models determined the relationship between environmental factors and the probability for contamination to occur. These models identified factors, such as land use or geology, found to be significantly "linked" to a public water system source's potential to become contaminated by one or more categories of

contaminants. DEP and USGS looked at factors that might affect the quality of drinking water sources and separated them into two categories.

The first category consists of *sensitivity factors*, which includes items related to the construction of a well (such as whether the well is in a confined or unconfined aquifer) and naturally occurring factors (such as the geology of the unit in which a well is drawing water from or over which water flows to the surface water intake).

Significant Sensitivity Factors

- Confinement status: For ground water, the confinement status of the well was by far the most frequently occurring sensitivity factor in predicting susceptibility to contamination and in fact was a factor in all the models. Confined wells are protected from activities at the land surface by relatively thick, laterally extensive units of low permeability (clay layers) and are a sufficient distance from the outcrop area of the geologic unit so that the source water is less likely to be affected by contamination at the land surface. Confined wells were determined to be of low susceptibility to contamination occurring at the land surface. Some confined wells, however, are susceptible to contaminants of natural subsurface origin.
- Depth to the top of the open interval: For unconfined wells, depth to the top of the open interval of the well was the most common sensitivity factor to affect the potential for contamination of a well. Depth to top of open interval was found to be a factor in the following five models: pathogens, nutrients, pesticides, inorganics, and radon. The shorter the distance to the land surface, the more likely for the well to be affected by contamination originating at the surface from point sources and certain land uses.
- Percent soil organic matter: For surface water and ground water, percent soil organic matter was found to be a frequently occurring sensitivity factor. Percent soil organic matter was a factor in the VOC, inorganic, and disinfectant byproduct precursor models for both the surface water and ground water susceptibility models.

The second category of factors affecting a source's potential to become contaminated consists of *intensity of use factors*. This category addresses the susceptibility to contamination resulting from human activities at the land surface. Intensity of use factors include those coming from a specific point source, such as a landfill or leaking underground storage tank, and nonpoint sources of contamination grouped by land-use characteristics, such as agriculture or urban land use.

Significant Intensity of Use Factors

Nonpoint Sources

Overall, the results of the modeling performed by USGS show that of the nonpoint sources, factors related to urban land use and agricultural land use, were most often linked to susceptibility of drinking water sources to contamination.

- Surface water: factors related to urban land use from the 1995 coverage (including percentage of commercial/industrial land use, percentage of developed land, percentage of residential land) were important in predicting a source's susceptibility for four contaminant groups, specifically nutrients, pesticides, VOCs, and inorganics. Agricultural land use was found to be a significant factor in three of the surface water models - nutrients, pesticides, and inorganics.

- Ground water: factors related to urban land use from both 1970 and 1995 were important in predicting the susceptibility of source water for five of the models - nutrients, pesticides, VOCs, inorganics and radionuclides. Agricultural land use in 1970 and 1995 coverages were factors in six of the ground water models: pathogens, nutrients, pesticides, radionuclides, radon, and inorganics.

Point Sources

- Surface water: factors related to New Jersey Pollutant Discharge Elimination System /Discharge to Surface Water (NJPDES/DSW) permits and sewage treatment plant density were found most often to be important factors, specifically for the nutrients, VOCs, and inorganics susceptibility models. NJPDES stormwater permitted locations, compost facilities, sites on DEP's Known Contaminated Site List (KCSL) and solid waste landfills were found to be factors in two of the models: VOCs and inorganics.
- Ground water: point sources were found to be significant only in the models for VOC, inorganics, and disinfection byproduct precursors. No point sources were found to be important in the models for pathogens, nutrients, pesticides, radionuclides, and radon.

The specific sensitivity and intensity of use factors for each drinking water source are provided in the Source Water Assessment Report in Tables 2, 3, and 4.

Using the susceptibility factors, the statistical models provided numerical ratings for each source of drinking water for each contaminant category, which were then converted into high (H), medium (M), or low (L) susceptibility ratings.

The Safe Drinking Water Standards or Maximum Contaminant Levels (MCLs) were used to define the three susceptibility ratings (H, M, and L). These standards are developed based health effects, analytical and treatment factors on either acute or long-term impacts related to drinking water exposure. A low susceptibility rating means a potential contaminant level was predicted to be less than 10 percent of the MCL for that contaminant category. A medium rating was given to drinking water sources where the potential contaminant level was predicted to be equal to or greater than 10 percent and less than 50 percent of the MCL. A high rating was assigned to those sources that were predicted to have potential contaminant levels equal to or greater than 50 percent of the MCL. Sources with high susceptibility ratings are still likely to have contaminant concentrations below the MCL. For the list of New Jersey primary and secondary drinking water standards, containing the MCLs, please refer to http://www.state.nj.us/dep/watersupply/standard.htm.

In some cases, insufficient data for particular supplies were available for all variables used in susceptibility models. In such cases, a default value for missing data was assumed. Use of default values could result in a different susceptibility rating than that which would result if the source-specific data were available.

Statewide Summary

Table E1 illustrates the percentage of community water system sources in New Jersey that rated high, medium, and low for each of the contaminant categories. The table is separated by source type: ground water (confined and unconfined) and surface water.

Table E1: Summary of Statewide Susceptibility Ratings for Community Water System Sources (Percent %)

	Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
Ground Water-Confined[1]								
High	0	0	0	0	0	0	0	27
Medium	0	0	0	0	47	39	19	70
Low	100	100	100	100	53	61	81	3
Ground Water-Unconfined[2]								
High	6	67	0	61	39	50	50	26
Medium	56	30	34	1	33	47	46	74
Low	38	3	66	38	28	3	4	0
Surface Water[3]								
High	100[4]	47	13	5	81	0	0	98
Medium	0	42	34	81	19	0	0	2
Low	0	11	53	14	0	100[4]	100[4]	0

[1] Community water systems confined wells in New Jersey in 2003 = 640
[2] Community water systems unconfined wells in New Jersey in 2003 = 1597
[3] Community water system surface water sources in New Jersey in 2003 = 64
[4] All surface water intakes received high susceptibility ratings for pathogens and low susceptibility rating for radionuclides and radon

For the purpose of the source water assessments, the drinking water derived from all surface water intakes was assumed to be highly susceptible to contamination by pathogens. Therefore, all surface water intakes received a high rating for pathogens (100 percent). Surface water sources are subject to various sources of microbial contamination runoff containing fecal matter. Secondly, radionuclide and radon models for surface water were not developed. Radionuclides are primarily a concern of ground water, therefore, all surface water intakes received a low susceptibility rating for radionuclides and radon (0 percent).

Statewide, 77 percent of the sources rated high for at least one of the contaminant categories. Disinfection byproduct precursors were the contaminant category for which surface water sources most commonly received a high susceptibility rating (excluding pathogens). The factors deemed important for the surface water disinfectant byproduct precursor susceptibility model were average percent soil organic matter and distance to wetlands. To address this important category of contaminants, the United States Environmental Protection Agency (USEPA) and DEP adopted the new Stage 1 Disinfectants and Disinfection Byproduct Rule, that requires all community water systems that add a disinfectant to the drinking water during any part of the treatment process to perform routine monitoring for trihalomethanes and haloacetic acids and meet new MCLs of 80 parts per billion and 60 parts per billion, respectively. For more information on the Stage 1 Disinfectants and Disinfection Byproduct Rule please refer to USEPA's web site at http://www.epa.gov/OGWDW/mdbp/dbp1.html.

In addition, disinfection byproduct precursors were the contaminant category for which confined wells (ground water source) most commonly received a high susceptibility rating. The source water assessments resulted in an unexpected number of medium and high susceptibility ratings for the disinfectant precursor model for ground water. The medium and high ratings were unexpected because the reported levels of disinfection byproduct precursors by ground water systems for compliance in New Jersey are generally low. This model is being reviewed with data collected by DEP and may be further refined in the future.

An important distinction exists between the ground water disinfectant precursor model and the other models. The disinfectant byproduct precursors, for which the model was developed, in combination with the disinfection process, form the actual disinfectant byproducts. The disinfectant byproducts are regulated, not the precursors. The precursors themselves are not considered to have adverse health effects, but instead the chemicals that are formed during the disinfection process have the potential health impacts. The other susceptibility models were developed using the regulated contaminant rather than a constituent that reacts to form the regulated contaminant.

For unconfined wells (ground water sources), nutrients and VOCs, were the contaminant categories in which the most sources received a high susceptibility rating. On the other hand, all confined wells obtained a low susceptibility rating for nutrients and VOCs. Both of these contaminant categories are caused by human activity at the land surface, and confined wells are relatively protected from the activity-related contamination by a layer of less permeable material. (The contaminant categories most related to by human activities are nutrients, pesticides, VOCs, and inorganic compounds.)

Drinking Water System: Summary of Sources for Strawberry Point Property Owners Association

Strawberry Point Property Owners Association consists of 2 wells, 0 wells under the influence of surface water, 0 surface water intake(s), 0 purchased ground water source(s), and 0 purchased surface water source(s) of drinking water. **(The water system data used for the development of the original drinking water source inventory was compiled in the summer of 2003.)**

Table E2 provides a summary of the susceptibility ratings for the Strawberry Point Property Owners Association drinking water source(s). The “sources” column of the table provides the number of ground water and surface water sources and the number of wells under the direct influence of surface water in the system. Ground water under the direct influence of surface water (GUDI) is a well found to be influenced by surrounding surface water bodies, and is classified according to site specific water quality measurements, according to the Surface Water Treatment Rule. The other columns provide the number of each of the source(s) that rated high (H), medium (M), and low (L) for each of the contaminant categories.

Table E2: Summary of Susceptibility Ratings for Drinking Water Source(s) for Strawberry Point Property Owners Association

	Pathogens			Nutrients			Pesticides			VOCs			Inorganics			Radionuclides			Radon			DBPs		
Sources	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Wells - 2		1	1	1	1				2			2			2		2			2			2	
GUDI - 0																								
Surface water intakes - 0																								

If a drinking water source's susceptibility is high, it does not necessarily mean the drinking water is contaminated. The rating reflects the potential for contamination of source water, not the existence of contamination.

Under the State's Safe Drinking Water Regulations, all public water systems must routinely monitor for contamination. If MCLs (drinking water standards) are exceeded, the water system must perform additional monitoring and treat the water before it is served to the consumer. The water system is also required to notify its customers when MCL violations occur. The process for notification depends on the severity of the violation, which can include public service announcements and publication in a local newspaper. Information about violations must also be included in the Consumer Confidence Reports that community water systems must mail to all their customers annually.

Drinking Water System: Entry Point to the Distribution System

Each entry point to the distribution system (EPTDS) also received a susceptibility rating by combining the weighted average of all the sources contributing to the EPTDS, after the water has been treated (if the drinking water is treated). The susceptibility rating for each EPTDS is available in the Source Water Assessment Report, Section VII, Table 11.

Since the EPTDS is the point at which monitoring and treatment occurs, the DEP determined the EPTDS susceptibility ratings because the assessment will help determine if the existing monitoring requirements for each public water system need to be revised. The assessment will help determine if the routine monitoring frequencies required of a community water system should be increased or decreased (support monitoring waivers). Secondly, the results of the Source Water Assessments will help DEP protect public health by targeting wells and surface water sources that are highly susceptible to contamination for additional water quality monitoring.

The Source Water Assessment Program was designed to encourage protection of drinking water sources by providing information to state and local regulatory agencies and the public to assist in watershed assessment and planning and to enhance the public's role as "water stewards." The results provide information to allow state and local agencies to determine if increased regulatory controls, including local land use ordinances, are warranted. In addition, the basic data gathered through the Source Water Assessment Program, including the locations of the public water system wells and surface water sources, will be available for

DEP program use in efforts to improve environment regulatory actions, such as cleanup decisions in the hazardous and solid waste programs. For more information on DEP's Source Water Protection Strategy please see the Statewide Summary Document available at www.state.nj/us/dep/swap.

For further information please refer to the detailed information in the Source Water Assessment Report or go to www.state.nj/us/dep/swap.

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SECTION I – BACKGROUND INFORMATION ON DRINKING WATER SYSTEMS

SECTION I – BACKGROUND INFORMATION ON DRINKING WATER SYSTEMS

This background information is provided to describe how public drinking water systems are regulated and the relationship of these water systems with the Source Water Assessment Program. The following section describes sources of drinking water (groundwater and surface water), types of drinking water systems according to the Department of Environmental Protection (DEP) and Environmental Protection Agency (EPA) definitions, and drinking water treatment.

Sources of Drinking Water

1. Ground Water

Ground water infiltrates the ground and is stored in aquifers, soil and rock below the surface. Aquifers typically consist of gravel, sandstone, sand, or fractured rock. An aquifer can be confined or unconfined. A confined aquifer is ground water bounded between impermeable layers, such as clay. An unconfined aquifer is not bounded by impermeable layers and is more directly linked to surface activities and resources.

Ground water is obtained from a spring or by pumping water from an aquifer through a well. A well is a hole or excavation that is drilled, bored, core driven, jetted, dug, driven or otherwise constructed for the purpose of removal of water from the subsurface for potable water supply. Public wells in New Jersey range from 15 to 1,984 feet deep (in 2002).

2. Surface Water

Surface water, is the water at or above the land's surface, which is neither ground water nor contained within the unsaturated zone, including, but not limited to, the ocean and its tributaries, all springs, streams, rivers, lakes, ponds, wetlands, and artificial waterbodies.

An important link exists between ground water and surface water. Surface water can infiltrate the ground and recharge aquifers. Conversely, ground water slowly moves to the surface and discharges into lakes, rivers, or streams and is known as baseflow. New Jersey's natural stream flow, especially during periods of low precipitation, is largely baseflow from ground water.

Figure 1 illustrates the water cycle, ground water and surface water, and potential sources of contamination to drinking water sources.

Figure 1: Hydrologic Cycle and Sources of Drinking Water

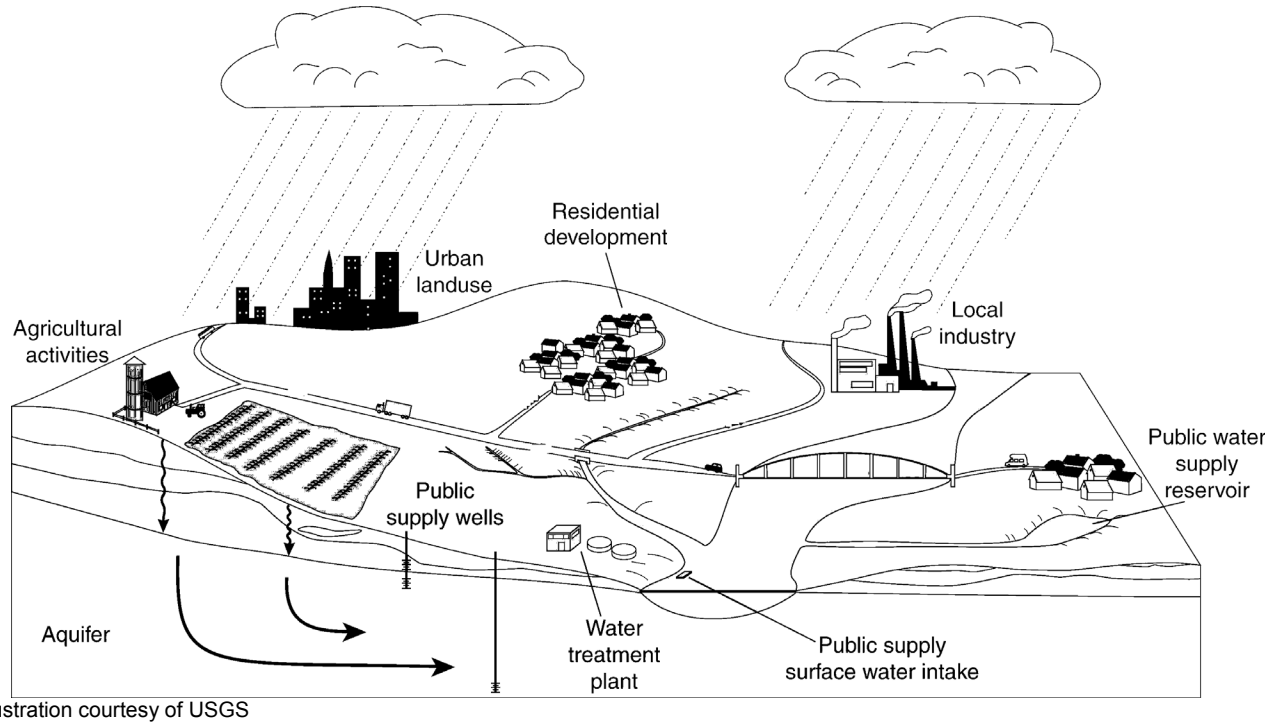


Illustration courtesy of USGS

Types of Public Water Systems

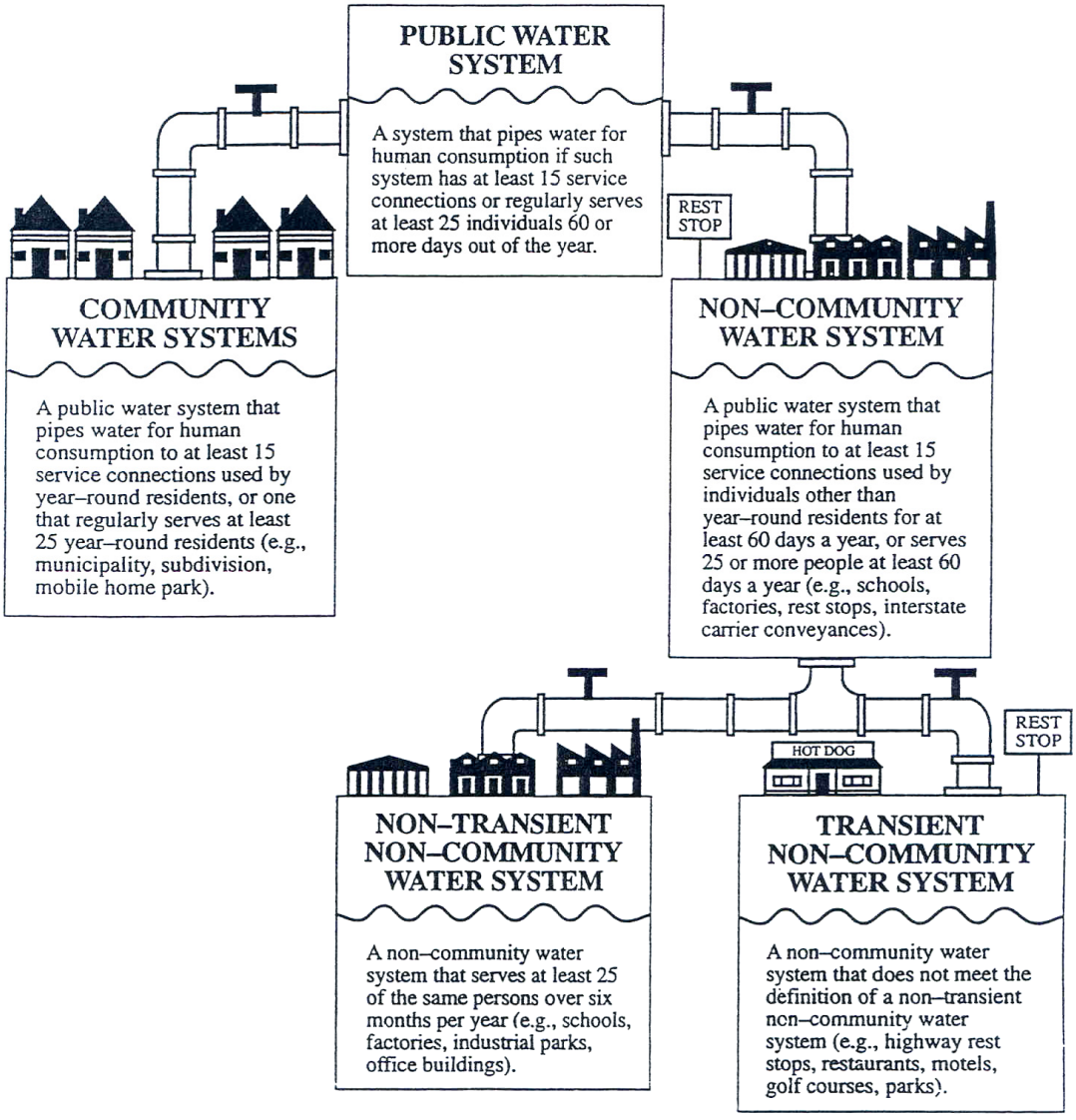
A public water system is defined as a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least 15 service connections or regularly serves at least 25 individuals. Ground water and/or surface water sources can be used for public water systems.

1. **Community Water System**: has at least 15 service connections used by year round residents, or regularly serves at least 25 year round residents. Examples of a community water system are mobile home communities, municipally owned water systems and privately owned water systems that have their own well(s) or surface water intake(s).

2. **Noncommunity Water System**: used by individuals other than year round residents for at least 60 days of the year. A noncommunity water system can be either transient or nontransient. A nontransient noncommunity water system serves at least 25 of the same persons over six months per year, such as schools, factories, and office buildings which have their own well(s) or surface water intake(s). Transient noncommunity water systems are systems that do not fall within the definition of a nontransient water system. Transient noncommunity water systems include rest stop areas, restaurants, and motels that have their own well(s).

A flow chart describing these definitions appears in Figure 2.

Figure 2: Types of Public Water Systems



From: Public Notification Handbook for Public Water Systems, USEPA Office of Water, USEPA Publication 570/9–89–002 September 1989

Approximately 85 to 90 percent of New Jersey's population is served by public water systems. Table 1 summarizes the number of public water systems, wells, and surface water sources in the State of New Jersey in 2003.

Table 1: Public Water Systems in New Jersey in 2003

Type of Public Water System	# of Public Water Systems*	# of Ground Water Sources	# of Surface Water Sources
Community	606	2237	64
Nontransient Noncommunity	876	1083	3
Transient Noncommunity	2654	2779	0
Total	4136	6099	67

* DEP, Bureau of Safe Drinking Water, NJ Public Water System Database.

The remaining New Jersey population is served by private wells (i.e. wells serving individual homes, small businesses, etc.) Private wells are not included in the SWAP. For more information on private wells please visit the Water Supply Administration web site at www.state.nj.us/dep/watersupply or refer to the EPA web site at www.epa.gov/safewater/pwells1.html.

Drinking Water Treatment

A public water system consists of interconnected pipes that lead from the source of drinking water to the consumer. Almost all community water system sources and some noncommunity water system sources are treated to remove microorganisms or dissolved chemicals or minerals. An entry point to the distribution system (EPTDS) is a location in the public water system where treated water from a treatment plant enters into the water distribution system. A public water system may contain one or more EPTDS. If the water is not treated, as some ground water systems are not, then the place where the untreated water source enters the network of pipes is the EPTDS.

Figure 3 illustrates general treatment schemes for both a surface water system and a ground water system. The means of acquiring water (well or surface water intake), the treatment process, and storage are shown. An individual water system may contain only part or even none (do not treat) of these pieces. Individual water treatment may vary according to source water quality.

Figure 3: Example of Drinking Water Treatment

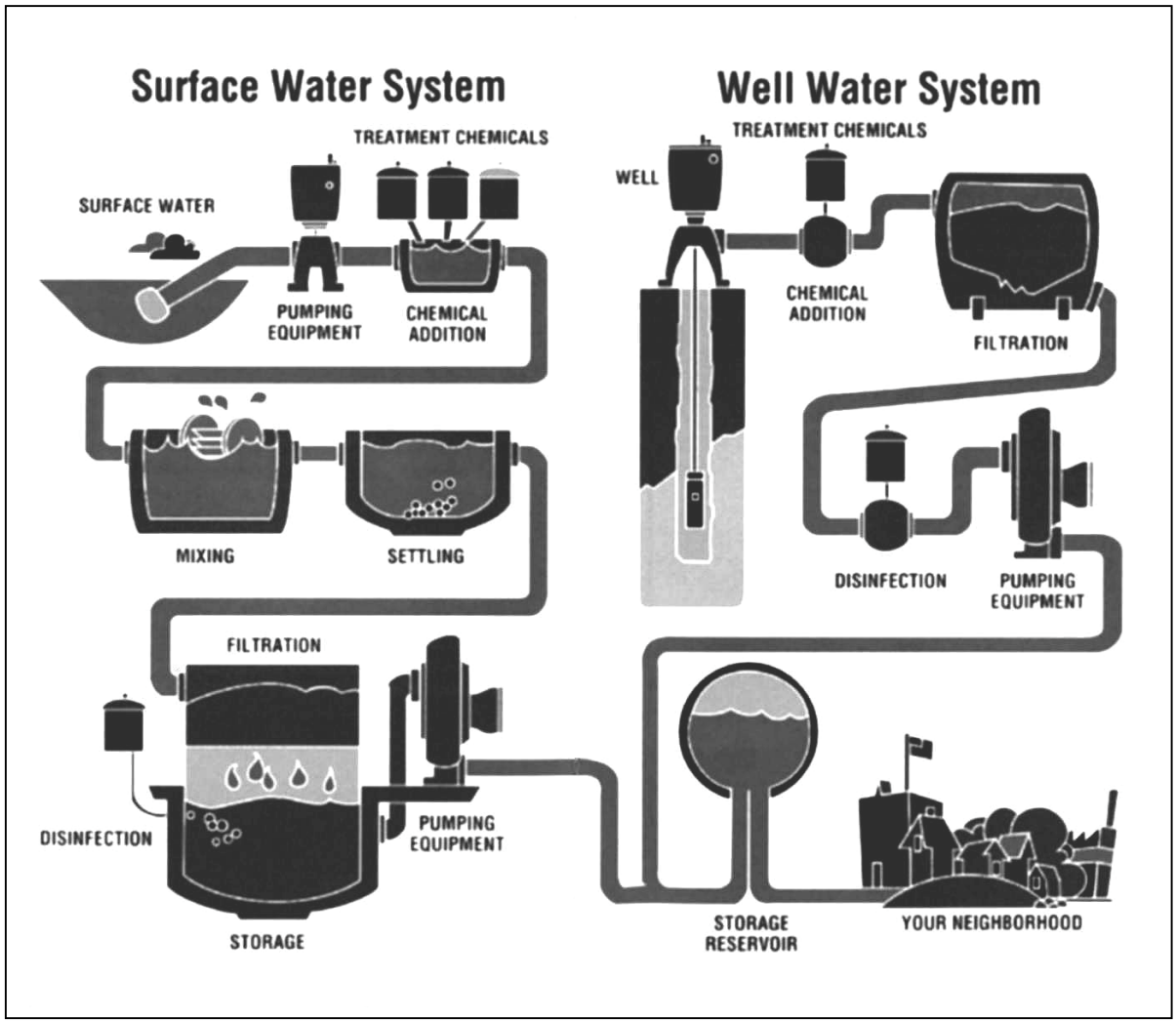


Illustration from “Safeguarding the Quality of Your Drinking Water”, prepared by the Public Information Committee of the New Jersey Section of the American Water Works Association.

SECTION II – SOURCE WATER ASSESSMENT PROGRAM OVERVIEW

SECTION II – SOURCE WATER ASSESSMENT PROGRAM OVERVIEW

Introduction

The 1996 Amendments to the Federal Safe Drinking Water Act place a strong emphasis on public awareness and the information provided to the public concerning the quality of drinking water. As part of the 1996 Amendments, all states were required to establish a Source Water Assessment Program (SWAP).

Through the SWAP, the DEP evaluated the susceptibility of public water systems to several categories of contamination. **If a system rates highly susceptible for a contaminant category, it does not mean a customer is or will be consuming contaminated drinking water.** The rating reflects the potential for contamination of source water, not the existence of contamination. Susceptibility to contamination is a function of several factors, including contaminant use near the water source and the characteristics of the water source.

New Jersey's SWAP Plan, which provides the framework for how DEP performed the assessments, can be found at www.state.nj.us/dep/watersupply/swap1.pdf.

The New Jersey SWAP incorporates four steps:

1. **Delineate the source water assessment area of each public drinking water source.**
2. **Inventory the potential contaminant sources within the source water assessment area.**
3. **Determine the water system's susceptibility to contaminants.**
4. **Incorporate public participation and education.**

Source Water Assessment Program Goals

The information obtained from the completed source water assessments may be used to achieve the goals listed below.

1. Protect sources of drinking water.

The source water assessments provide a susceptibility rating for each source of drinking water, which supplies information on how vulnerable the source is to contamination.

Source water protection focuses on preserving and protecting the public drinking water source. The information obtained from the SWAP will provide communities and decision-makers with the information to protect their drinking water source(s). The source water assessment results can also be used by DEP, purveyors, and local planning officals to lay the groundwork for advancing the State's drinking water protection efforts. Based on the potential of a drinking water source to become contaminated, DEP can initiate a variety of activities to protect the drinking water source through existing DEP programs. For more information regarding DEP's Source Water Protection Strategy please refer to the Source Water Assessment Program Statewide Summary available on the Division of Water Supply's web site at http://www.state.nj.us/dep/watersupply//.

2. Public education of SWAP information.

DEP incorporated public education throughout the development and implementation of the Source Water Assessment Program. During the source water assessment process, DEP

spoke to interested parties, beginning with the development of the SWAP Plan, published articles, wrote two newsletters, and developed a SWAP web site. Upon completion of the source water assessments, DEP generated a source water assessment report and/or summary for each public water system to report the susceptibility ratings.

The goal of the public education efforts is to make the public more aware of the source of their drinking water and the potential contaminants that could impair the water's quality. To continue fulfilling the education requirement, DEP will conduct training sessions following the release of the Source Water Assessment Reports.

3. Establish a customized monitoring schedule for each public water system.
The source water assessments will assist DEP in improving current monitoring requirements for individual public water systems. Currently, the EPA and the DEP have mandatory monitoring schedules that depend on a variety of factors that can include the source of the water (ground water or surface water) and the surrounding land use. These schedules can be customized based on the susceptibility of the sources of drinking water. The SWAP will provide better information for making these determinations.

Source Water Assessment Reports
DEP will issue the following reports to public water systems.

1. **Community Water System Source Water Assessment Report**: primarily intended for the public water system's reference and use, although the report is also available to the public. Individuals, environmental organizations, and municipalities interested in source water protection may also utilize the Community Water System Source Water Assessment Report for protection activities.

2. **Community Water System Source Water Assessment Summary**: a short (4-6 page) informative document created for distribution by the water system to the general public. In addition, DEP will post the summary document on the SWAP web site at http://www.state.nj.us/dep/swap/. The Community Water System Source Water Assessment Summary is a synopsis of the Source Water Assessment Report and provides the source susceptibility ratings for the community water system's sources.

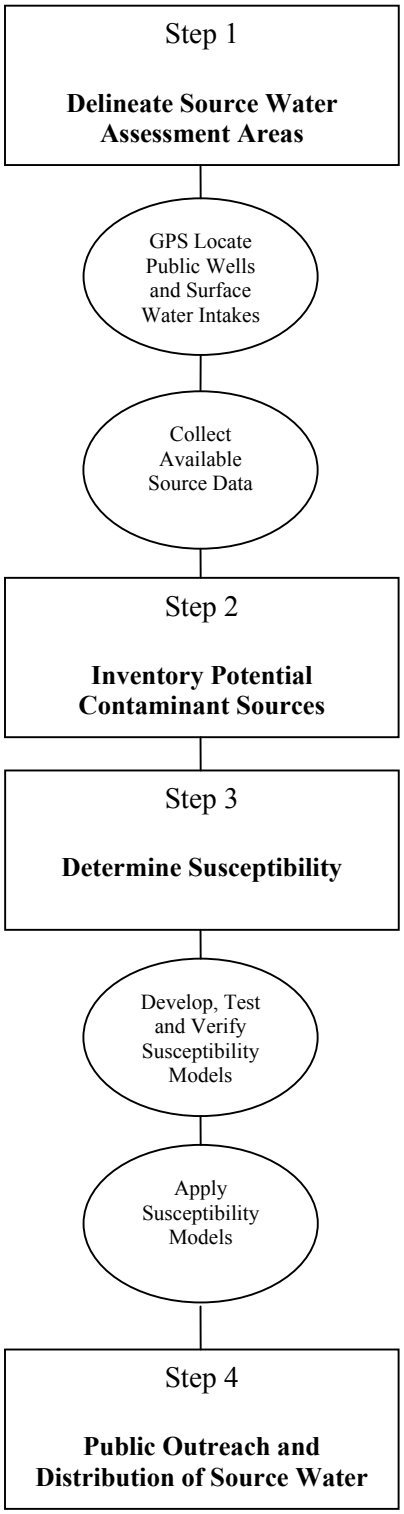
3. **Noncommunity Water System Source Water Assessment Report**: developed for the respective noncommunity water system. The report provides the susceptibility ratings of the system's sources. The general public may request the report from the noncommunity water system or the DEP.

SECTION III – SOURCE WATER ASSESSMENT PROGRAM STEPS

SECTION III – SOURCE WATER ASSESSMENT PROGRAM STEPS

The SWAP consists of four fundamental steps that are illustrated in Figure 4.

Figure 4: Flowchart of Source Water Assessment Program Process



Step 1: Delineation

The first step of the SWAP process is to delineate the source water assessment area for each public water system well and surface water intake. For ground water sources, a source water assessment area in New Jersey is the area from which water is reasonably likely to flow to a well within a 12 year period. This area is also known as a wellhead protection area, or WHPA. For surface water sources, the source water assessment area is the area upstream of a surface water intake, including land that drains to the upstream areas.

Before the source water assessment area was delineated for a public well, attribute data was gathered. Since 1947, a property owner or well driller has been required to obtain a well permit from New Jersey's well permitting program to drill a well in New Jersey. After a licensed well driller drills the well, a well record must be submitted to the Water Supply Administration, DEP. The well record is an "as-built" description of the well construction, and usually contains important attribute data such as well depth, screened interval or length of open hole, and pumping rate/capacity. This information is needed to delineate the source water assessment area around the well. DEP used the well record to determine attribute data. In situations where DEP was unable to obtain attribute data, such as for a well drilled prior to 1947 or when a well record was not available, default values were generated using New Jersey Geological Survey's (NJGS) "Guidelines for Delineation of Well Head Protection Areas in New Jersey," Appendix B- Attachment 1. The guidance document is available on the internet at www.state.nj.us/dep/njgs/whpaguide.pdf, by contacting the DEP, New Jersey Geological Survey at (609) 292-1185, or from the DEP Maps and Publications Sales Office at (609) 777-1038.

For surface water intakes, source water assessment areas were developed based on the location of the intake and the entire drainage area upstream of the intake including headwaters and tributaries. These factors influence the shape and size of the delineations.

Next, the well or intake was located using Global Positioning System (GPS). All wells and intakes were GPS-located according to the "DEP GPS Data Collection Standards for GIS Data Development" available at www.state.nj.us/dep/gis/gpstrim.html. The DEP GPS-located the community water system wells and surface water intakes. The noncommunity water system wells were GPS-located by DEP, County Environmental Health Act (CEHA) Agencies, and the New Jersey Water Association.

After collecting the attribute data and GPS location, the source water assessment areas for wells and intakes were delineated. DEP performed the ground water source water assessment area delineations using the Combined Model/Calculated Fixed Radius Method for all public community water system wells and the Calculated Fixed Radius method for the noncommunity water system wells. For a detailed description of the delineation methods please refer to New Jersey's "Guidelines for Delineation of Well Head Protection Areas in New Jersey," Appendix B- Attachment 1.

For each ground water source, three tiers were calculated and labeled as Tier 1 (two year time of travel), Tier 2 (five year time of travel), and Tier 3 (12 year time of travel). Time of travel was established for determining the risk of contamination to a well. The two year time of travel was developed based on the potential for microbiological contamination. Studies show on average, bacteria can survive in ground water for approximately 170 days and

viruses can survive in ground water for approximately 270 days. The two year time of travel indicates the limits of concern for potential viable microbiological contamination of the water system through the source water.

The five year time of travel was established to address contamination from accidental discharges. This time of travel provides a reasonable amount of time to investigate, monitor, and/or remediate a spill within the source water assessment area. The third time of travel portion of the source water assessment area, 12 year, was designed in consideration of the known contaminant sources. Studies show that 10 to 15 years of time of travel generally covers the full length of a contaminant plume. The 12 year time of travel will permit enough time for responses to be made.

Ground water delineations are available as New Jersey Geological Survey publication DGS02-2, Geographic Information System Coverages of Public Community Water Supply Well Head Protection Areas for New Jersey (1:24,000 scale) at www.state.nj.us/dep/njgs/geodata/dgs02-2.htm.

The DEP delineated the source water assessment areas for surface water intakes using the United States Geological Survey's (USGS) hydrologic unit code 14 (HUC14) as the base data-set for the delineations. Hydrologic unit codes identify drainage basins in a nested group from large to small. The larger the HUC number the smaller the drainage basin. For example a HUC4 will be made up of several smaller HUC8s, and the HUC8s will be made up of several smaller HUC14s. The source water assessment areas for the surface water intakes include the entire drainage area that flows past the intake, including headwaters and tributaries. For more information on the methodology used for surface water delineations, refer to Appendix B- Attachment 2, Surface Water Delineation Methodology.

The DEP has classified approximately 50 wells as "ground water under the direct influence of surface water" (GUDI). GUDI wells are classified according to site specific water quality measurements and provide additional treatment of the source water. For GUDI wells, the DEP performed a conjunctive delineation, an integrated delineation combining the ground water contribution and the surface water contribution to the well. The groundwater and surface water contribution were delineated using the same procedure described above, except the 2 year time of travel for the ground water delineation demarcated the downstream boundary.

A few GUDI wells do not have an obvious surface water body influencing the well. In these instances only the ground water delineated source water assessment area was available. Therefore, the 12 year time of travel boundary for the ground water delineation was used to define the surface water contribution area. An example of this scenario would be the Newton Water and Sewer Utility, Facility number 03, SFID number 010.

The ground water susceptibility models were applied to the GUDI wells ground water contribution area and the surface water susceptibility models were applied to the surface water contribution area. The final susceptibility rating for the GUDI well was determined by taking the higher susceptibility rating of the two (ground water and surface water). Using the pathogen contaminant category as an example, all surface water automatically received a high susceptibility rating for pathogens. Therefore, all GUDI wells received a high susceptibility rating for pathogens. Even if the GUDI well rated low to pathogens for the

ground water contribution area, the high rating for the surface water contribution area was used as the final susceptibility rating (the highest rating of the two).

Step 2: Potential Contaminant Source Inventory

The second step of the SWAP is to identify the potential contaminant sources within the source water assessment area. These potential sources of contamination include point and nonpoint sources. Point source contaminants may be traced to a single source, such as known contaminated sites, industrial and commercial surface and ground water discharges, and sewage treatment discharges. Nonpoint source contaminants may not be traced to one single source because they come from several individual sources within a large area. Land use activities such as salting and runoff from roads and the application of pesticides and herbicides are examples of nonpoint sources. Nonpoint and point sources can have a significant impact on both surface water and ground water quality.

Potential contaminant source inventory information was primarily collected from existing DEP GIS databases. For nonpoint sources, digital GIS land use and land cover data for the years 1970, 1986, and 1995 were used. Several datasets of land coverage were used to account for the changes in land use over the years. The New Jersey Source Water Assessment Program Potential Contaminant Source Inventory (PCSI) Methodology, Appendix B-Attachment 3, describes how the potential contaminant source inventory was developed, the datasets used, the sites and activities included in the inventory, and the preliminary list of explanatory variables used in the susceptibility models.

For the purpose of the SWAP, the DEP, in conjunction with a Source Water Assessment Advisory Committee that met regularly during the development of the SWAP Plan, developed eight conceptual contaminant categories that represent microbiological and chemical contaminants of concern. These categories include pathogens, nutrients, volatile organic compounds, synthetic organic compounds, pesticides, inorganics, radionuclides and disinfection byproduct precursors. This list was further refined during the susceptibility model development process. Tables 2, 3, and 4 contain the final list of contaminant categories and explanatory variables. Each drinking water source was evaluated for susceptibility to each of the following contaminant categories.

Conceptual Contaminant Categories

Pathogens

Disease-causing organisms such as bacteria, protozoa, and viruses. Sources of pathogens include both point and nonpoint activities. An example of a point source of pathogens is a sewer system overflow. An example of a nonpoint source is runoff from areas where livestock are kept.

Nutrients

Common types of nutrients include nitrogen and phosphorous. Nutrients can harm environmental quality, human health, and the efficiency of the drinking water treatment plant by encouraging growth of photosynthetic microorganisms in surface water sources, which alter water characteristics (eutrophic conditions). Sources of nutrients are point and nonpoint sources. Effluents from a sewage treatment plant are a point source of nutrients. Nonpoint sources of nutrients include discharge from septic fields, areas where animal waste is stored, and runoff from agricultural and residential land where fertilizers were used.

Pesticides
Common sources of pesticides include land applications (nonpoint source) and manufacturing/distribution centers of pesticides (point source). Pesticides are manmade chemicals used to control bacteria, fungi, weeds, rodents, and insects. Examples include herbicides such as atrazine and insecticides such as chlordane.

Synthetic Organic Compounds (SOCs)
Sources of SOCs can be point and nonpoint. Common sources include chemical manufacturing plants, pharmaceutical plants, sewage treatment plants, and discharges from contaminated sites. Synthetic organic compounds are manmade.

Volatile Organic Compounds (VOCs)
Common types of VOCs include chemicals that are used as solvents, degreasers, and gasoline components. VOCs are manmade compounds and are the most common organic contaminants in ground water in New Jersey. Sources of VOCs can be point and nonpoint. Examples of VOCs are methyl tertiary butyl ether (MTBE), benzene and vinyl chloride.

Inorganics
Mineral-based compounds that are both naturally occurring and manmade. Sources of inorganics can be point and nonpoint; common sources include discharges from manufacturing plants, releases from contaminated sites, past land uses, and naturally occurring sources. Inorganics include arsenic, cadmium, copper, lead, mercury, and asbestos.

Radionuclides
Sources of radionuclides can be point and nonpoint; common sources include the decay of naturally occurring minerals, leaching of subsurface material (for example rocks and sedimentary materials) into ground water, and improper disposal of radioactive waste. Radionuclides are a category of contaminant that is both naturally occurring and manmade. Radionuclides are radioactive substances such as radium and radon.

Disinfection Byproduct (DBP) Precursors
Disinfection byproducts are formed when the disinfectants used to kill pathogens during treatment react with dissolved organic material present in the water. A common source of DBP precursors is naturally occurring organic material such as leaves in surface water. The amount of organic matter, the type of disinfectant, the concentration of disinfectant, time of contact, pH, and temperature all have an effect on the concentration of disinfection byproducts produced. Chlorine is the most common disinfectant used in New Jersey.

Step 3: Susceptibility Determination
The third step of the SWAP is to determine the public water system's susceptibility to contamination. Susceptibility is a function of source sensitivity (for example soil type and well construction characteristics) and the intensity of surrounding use factors (for example the density of contamination sites or the type of land use).

SUSCEPTIBILITY = Sensitivity + Intensity

DEP contracted with the USGS to develop susceptibility assessment models, with DEP guidance, to determine susceptibility ratings for public supply wells and surface water intakes for the contaminant categories of concern described in Step 2. Some states have determined susceptibility using relatively simple approaches that account for factors such as distance to contaminant sources, but the more thorough modeling approach employed for New Jersey provides a more accurate estimate of susceptibility. The models were based on results from an extensive analysis of ground water and surface water quality data from the DEP-USGS statewide cooperative monitoring networks for a select set of sites in New Jersey. Please refer to the documentation Methods to Determine the Susceptibility of Source Water to Community and Noncommunity Water Supplies in New Jersey to Contamination, Appendix B- Attachment 4 for more information.

USGS developed susceptibility models for seven contaminant categories and radon for both ground water and surface water. DEP had originally intended to develop a susceptibility model for "synthetic organic compounds" (SOCs), but did not do so for two reasons. First, SOCs under the Federal and State Safe Drinking Water Acts consist primarily of pesticides and as part of SWAP, USGS developed a pesticide susceptibility model. Secondly, as USGS investigated whether it could construct a SOCs model, USGS and DEP jointly determined that there was insufficient SOC data that was neither pesticide nor volatile organic compound (VOC) related. (USGS also developed a separate VOC model.) However, it is DEP's experience that the presence of non-pesticide, non-volatile SOCs will typically co-occur with VOCs. Specifically, recent work by DEP and others at community water systems using ground water as a source and known to be contaminated by volatile organic contamination from hazardous waste sites determined that "tentatively identified compounds" (TICs) were present. In this study, although DEP and others were primarily looking for non-volatile organic compounds, TICs were found at some frequency at these sites. As part of the study, a "control" water system with no hazardous waste site nearby and with no volatile contamination was tested and contained no TICs. Qualitative evaluation of the data show systems with the higher levels of volatile organic chemicals and with more than one VOC present contained the highest number of TICs. For these reasons, DEP has determined the SOC rating for a water system would be the same as the public water system's VOC rating, and that a separate SOC susceptibility model was unnecessary.

Separate susceptibility models were developed for radon and other radionuclides for two reasons. First, radon, a gas, is chemically and physically different from other radionuclide constituents. Second, radon most often occurs in areas where other radionuclides are not present. The remedy for radon is different from the remedy for other radionuclides. DEP was concerned that if both radon and other radionuclides were combined, the susceptibility rating would not show the difference in susceptibility of water systems' sources to the different radionuclides.

For the purpose of the source water assessments, all surface water was assumed to be highly susceptible to pathogens, therefore a pathogen model was not developed for surface water. Surface water sources are subject to various sources of microbial contamination runoff containing fecal matter. All surface water intakes received a high rating for pathogens. Secondly, a radionuclide model was not developed for surface water. Radionuclides are primarily a concern of ground water, therefore, all surface water intakes received a low susceptibility rating for radionuclides.

The susceptibility models determined source water susceptibility based on the well or intake's location and explanatory variables. An explanatory variable is a variable that can be used to predict the presence of a contaminant or the potential presence of a contaminant in ground water or surface water. Tables 2, 3, and 4 illustrate the final explanatory variables used in determining sensitivity and intensity ratings for surface water intakes, unconfined wells, and confined wells. These tables also contain the conceptual variables used in the susceptibility rating determinations. A conceptual variable is one that has been shown in a previous scientific investigation to be related to, or is expected to have an effect on, the concentrations of a constituent. Conceptual variables that did not produce significant univariate statistical relations may however, produce a significant relation when used with other variables in multivariate statistical tests.

A list of all contaminant variables reviewed can be found in the documentation Methods to Determine the Susceptibility of Source Water to Community and Noncommunity Water Supplies in New Jersey to Contamination, Appendix B- Attachment 4. For further information, Appendix B- Attachment 5 and 6, Contaminant Group Reports, provide detailed descriptions of the models used for SWAP.

In addition to evaluating the contaminant variables separately, groupings of several point source variables together as a single explanatory variable were investigated to determine if a certain subset of point sources produced meaningful results. USGS determined that although several types of point sources are not statistically significant individually, grouping them as a unit could produce meaningful results. These combinations are known as "Point Source Groupings."

Point Source Grouping 1: consists of sites on the Known Contaminated Site List and on the Solid Waste Landfill Site list. In general, these point sources are existing contamination sources.

Point Source Grouping 2: consists of New Jersey Pollutant Discharge Elimination System for permitted discharges to surface water, New Jersey Pollutant Discharge Elimination System storm water discharges, and Compost Facilities. These point sources are potential surface water contamination problems.

Point Source Grouping 3: consists of New Jersey Pollutant Discharge Elimination System discharges for ground water (NJPDES/DGW), Solid Waste Resource Recovery Facilities (RRF), Solid Waste Transfer Facilities (SWTF), and Class B Recycling Facilities. These point sources are potential ground water contamination problems. The last three activities (RRF, SWTF, and Class B) are designed not to discharge contamination and degrade ground water. They do handle pollutants, and there is a potential to cause contamination. Thus, they are included in the inventory. Facilities that discharge via a NJPDES/DGW permit are given strict permit limits. The discharge standards are typically at or below the ground water quality standards. While these activities are grouped for modeling purposes, the RRF, SWTF, and Class B Recycling Facilities do not appreciably affect the model, based on analysis by USGS.

Point Source Grouping 4: consists of sites regulated by the DEP Discharge Prevention and Countermeasures Plan regulations and Discharge Cleanup and Removal Plan regulations. These facilities store, transfer, process, or use hazardous substances and must specify and

submit information regarding prevention, containment and countermeasure plans and discharge cleanup and removal plans.

Point Source Grouping 5: consists of regulated Underground Storage Tanks (USTs). USTs were treated as a separate point source grouping due to the large number of USTs in New Jersey, relative to the number of other types of potential point sources. There are approximately 19,454 underground storage tank registrations in New Jersey, consisting of active and inactive tanks. USTs were treated separately so that the number of USTs would not obscure possible statistical relations between susceptibility and other potential contaminant sources.

Point Source Grouping 6: consists of the entire Potential Contaminant Source Inventory of point sources.

Several point source groupings were combined to determine whether or not these point source groupings had an effect on a source's susceptibility. If a point source grouping combination was found to be significant it was used as an explanatory variable in the susceptibility models. The explanatory variables can be found in Tables 2, 3, and 4 dependent on the type of drinking water source.

Table 2: Surface Water Explanatory Variables

Illustrates the explanatory variables USGS used in their SWAP surface water modeling.

Constituent/Variable	Pathogens [1]	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides [1]	Radon [1]	DBPs - conceptual [2]
Sensitivity								
% Soil Clay			X					
% Soil Organic Matter				X [2]	X [2]			X [2]
PH of water-quality sample					X			
Physiographic Province					X [2]			
Water Region					X			
Intensity								
% Agricultural Land Use, 1995		X						
% Commercial/Industrial Land Use, 1995					X [2]			
% Developed Land, 1995					X [2]			
% Residential Land Use, 1995			X					
% Urban Land Use, 1995		X		X	X			
Distance to Agricultural Land, 1995			X		X [2]			
Distance to Wetlands, 1995								X [2]
Density of NJPDES SW/Storm, Compost Facilities (Point Source Grouping 2)					X			
Density of KCSL, SWL, NJPDES SW/Storm, Compost Facilities (Point Source Groupings 1,2)				X				
Density of KCSL, SWL, NJPDES GW, SWRRF, SWTF200011, Class B Recycling, DPCC, UST (Point Source Groupings 1, 3, 4, 5)					X			
Sewage Treatment Plant Density		X						
Total Pesticide Application			X					

[1] For the purpose of developing susceptibility models, a pathogen model was not developed because all surface water sources are considered highly susceptible to pathogens; a radionuclide model was not developed because radionuclides are not a concern in surface water.

[2] This conceptual variable shows a graphical relation to water-quality, improves the model, and is supported by scientific investigations.

Table 3: Ground Water Unconfined Explanatory Variables

Illustrates the explanatory variables USGS used in their SWAP ground water unconfined modeling.

Constituent/Variable	Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
Sensitivity								
% Soil Clay					X[4]		X[2]	
% Soil Organic Matter				X	X[2]			X[1]
Conceptual - GWUDI	X[3]							
Depth to Top of Open Interval	X	X[2]	X[2]		X[4]		X	
Depth of Well						X[2]		
Dissolved Oxygen of water-quality sample					X			
Length of Open Interval		X[2]	X[2]					
NJGS Hydrologic Unit (Aquifer)								X[1]
pH of water-quality sample					X	X		
Physiographic Province					X[4]	X	X	
Soil Available Water Capacity	X[1]							
Soil Hydraulic Conductivity					X	X[2]		
Intensity								
% Agricultural Land Use, 1970						X		
% Agricultural Land Use, 1986		X	X					
% Agricultural Land Use, 1995							X	
% Barren Land Use, 1995					X			
% Commercial/Industrial Land Use, 1995				X				
% Urban Land Use, 1970					X			
% Urban Land Use, 1995		X	X[2]					
Area of Urban Land Use, 1995 (square miles)				X				
% Urban Land Use, Tier 1, 1995						X		
% Developed Land, Tier 1, 1995						X		
% Impervious Surface, 1995				X				
Distance to Agricultural Land, 1995	X		X		X	X[1]		
Distance to Golf Course			X[2]					
Distance to DOT Roads					X			
Distance to Sewage Treatment Plant					X			
Distance to Wetlands, 1995							X[2]	
Square Miles of Wetlands, 1995								X[2]
Number of NJPDES SW/GW/Storm, Compost, SWWRF, SWTF200011, Class B Recycling, and DPCC (Point Source Groupings 2, 3, 4)								X

Table 3 continued

Constituent/Variable	Pathogens	Nutrients	Pesticides - conceptual[3]	SOCs [1]	VOCs	Inorganics	Radionuclides	Radon	DBPs
Density of KCSL, SWL, NJPDES GW/SW/Storm, Compost Facility, SWRRF, SWTF200011, Class B Recycling, DPCC, UST (Point Source Groupings 1, 2, 3, 4, 5)						X			
Density of SWL, UST, KCSL (Point Source Groupings 1, 5)					X				
Population Density						X			
Population Density, Tier 1						X			
Septic Tank Density	X[1]								
Septic Tank Density in Piedmont							X		
Sewage Treatment Plant Density						X			
Conceptual - Presence of Streams, Tier 1	X[3]								
Length of Railroads						X			

[1] This conceptual variable shows a graphical relation, improves the model, and is supported by scientific investigations.
[2] This conceptual variable shows a graphical relation to water quality and improves the model.
[3] Statistical tests could not be used because the variable was unavailable for the data set used to develop the model.
[4] This factor is a conceptual variable and an explanatory variable for the contaminant category. As a result of the contaminant category consisting of several inorganics (arsenic, barium, beryllium, fluoride, lead, and mercury), the factor is used as a conceptual and statistically significant variable. Percent soil clay is a conceptual variable (X^2) for lead and mercury, but a statistically significant explanatory variable for beryllium. For depth to top of open interval, the factor is conceptual (X^2) for fluoride and lead, and a statistically significant explanatory variable for beryllium. Thirdly, physiographic province is a conceptual variable (X^3) for mercury and a statistically significant explanatory variable for the arsenic, barium, beryllium, and fluoride models.

Table 4: Ground Water Confined Explanatory Variables

Illustrates the explanatory variables USGS used in their SWAP ground water modeling.

Constituent/Variable	Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
Sensitivity								
% Soil Organic Matter								
NJGS Hydrologic Unit (Aquifer)								X
Geologic Unit					X	X	X	
pH of water-quality sample								X
Intensity [1]								

[1] Confined wells are not susceptible to intensity variables.

Susceptibility is the measurement of potential for a public water system to become contaminated. The susceptibility models developed by the USGS were applied to all community water system sources and resulted in a high, medium, or low susceptibility rating for each source of water.

If a drinking water source's susceptibility is high, it does not mean the water is contaminated. High susceptibility is a vulnerability rating, not a factor determining whether or not the water is or is not safe to drink. The rating reflects the potential for contamination of source water, not the existence of contamination. Public water systems are required to monitor for regulated contaminants and to install treatment if any contaminants are detected at frequencies and concentrations above allowable levels. Customers can refer to the water company's Consumer Confidence Report (CCR) to determine if the drinking water is meeting all of the Safe Drinking Water Act regulatory requirements. The water utility may be contacted for additional water quality information.

DEP calculated the percentage of community water system sources in New Jersey that rated high, medium, and low for each of the contaminant categories. Table 5 summarizes the susceptibility rating information.

Table 5: Summary of Statewide Susceptibility Ratings for Community Water System Sources (Percent %)

	Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
Ground Water[1]								
High	4	48	0	44	27	35	36	22
Medium	40	22	23	0	38	45	38	76
Low	56	31	77	56	35	20	26	2
Surface Water[2]								
High	100	47	13	5	81	0	0	98
Medium	0	42	34	81	19	0	0	2
Low	0	11	53	14	0	100	100	0

[1] Community water systems wells in New Jersey in 2003 = 2237
[2] Community water system surface water sources in New Jersey in 2003 = 64

USGS developed a rating scoring system for each susceptibility model. When each model was applied to a well or intake, a rating score was generated. This score was then converted into a susceptibility rating of high, medium, or low. For further information on the susceptibility rating score scheme please refer to Appendix A- Attachment 3. The Safe Drinking Water Maximum Contaminant Levels (MCLs) were used to guide the division between the three susceptibility ratings. A low susceptibility rating means a potential contaminant level was predicted to be less than 10 percent of the MCL for that contaminant. A medium susceptibility rating was assigned where the potential contaminant level was predicted to be equal to or greater than 10 percent and less than 50 percent of the MCL. A high susceptibility rating was assigned where the potential contaminant level was equal to or greater than 50 percent of the MCL. For the list of New Jersey primary and secondary drinking water standards, containing the MCLs, please refer to http://www.state.nj.us/dep/watersupply/standard.htm.

In many cases, a public water system may have more than one well or intake, or a combination of wells and intakes. In cases of ground water or surface water only systems, the well or intake ratings were grouped together to represent the EPTDS rating. Each EPTDS received a susceptibility rating for radon and each of the seven contaminant categories. The EPTDS rating was determined by weighing each source's rating score according to the rate of withdrawal. Each weighted score was added, the sum was divided by the number of drinking water sources, and the EPTDS score was classified as low, medium or high susceptibility. Appendix A- Attachment 4 provides an explanation of the EPTDS calculation.

Step 4: Public Participation and Outreach

The fourth step, public participation and outreach, is an essential component of the SWAP. The 1996 Amendments to the Federal Safe Drinking Water Act place a strong emphasis on public participation. To ensure the source water assessments are used for source water protection efforts, the public was involved from the beginning of the program.

The DEP used a variety of techniques to include the public in the program.

1. **Created a Source Water Assessment Advisory Committee to provide input on the draft and final SWAP Plan**. The Source Water Assessment Advisory Committee continued to meet with the DEP regularly to discuss the status of the assessments and provide suggestions during the development of the program. In addition, the Source Water Assessment Advisory Committee provided advice concerning the source water assessment summaries and reports.

2. **Developed a SWAP newsletter, the "New Jersey Source Water Assessment News."** Issues of the "New Jersey Source Water Assessment News" may be found at www.state.nj.us/dep/swap. The newsletter was sent to committee members, public water systems, county health agencies, environmental organizations, municipalities, drinking water laboratories, and other interested parties. The New Jersey Source Water Assessment News informed readers of the status of the SWAP, contact information, source water protection issues, and other related topics.

3. **Published SWAP articles in several organizations' newsletters.** For example, articles were published in the New Jersey Section of American Water Works Association newsletter "Pipeline" and the DEP Division of Watershed Management newsletter "Focus."

4. **Provided speakers for numerous SWAP presentations throughout the State.** The presentations were regularly presented to water purveyors at New Jersey Water Association training courses and other interested organizations such as the watershed management area committees.

The DEP will continue its public outreach following the release of the source water assessments. Public outreach activities will include training sessions for water purveyors, published SWAP articles, and correspondence with interested parties such as purveyors, municipalities, planning boards, and environmental commissions.

SECTION IV - GENERAL DESCRIPTION OF YOUR WATER SYSTEM

SECTION IV – DESCRIPTION OF WATER SYSTEM

Strawberry Point Property Owners Association
PWID # 1904006

200 North Shore Road
Andover, NJ 07821
(973)347-8677

Strawberry Point Property Owners Association is a public community water system consisting of

1 Entry Points to the Distribution System (EPTDS)
- 2 wells
- 0 wells under the influence of surface water
- 0 surface water intake(s)
- 0 purchased ground water
- 0 purchased surface water

Table 6 below contains the municipalities and the population within each of these municipalities served by Strawberry Point Property Owners Association.

Table 6: Municipalities and Population Served

Municipality	County	Population Served - 2003
Byram Twp.	Sussex	90

SECTION V - INVENTORY OF TREATMENT PLANTS AND DRINKING WATER SOURCES

SECTION V - SYSTEM INVENTORY FOR: Strawberry Point Property Owners Association

Table 7 provides the Strawberry Point Property Owners Association's treatment plant(s); source(s); the sources' location(s); whether the source(s) are ground water, surface water, or a purchased supply; and the sources' capacity(s). The first column contains the EPTDS ID and sources contributing to the same EPTDS are identified by the same number. An EPTDS is the entry point to the distribution system, and for most community water systems this location is after the water is treated at a treatment plant.

In the case of a ground water source, the well's confinement status and well permit number are provided.

Table 7: Drinking Water Source and EPTDS Inventory

EPTDS ID	Source ID	Source Name	Water System Component *	Source Status *	Source *	Source Capacity (MGD)	Well Permit #	Confinement Status *
01	002	WELL 1 & 2 TP/NORTH SHORE RD &	T	P				
01	003	WELL 1/STRAWBERRY PATCH	G	P	igneous and metamorphic rocks	0.042	00-00626	U
01	004	WELL #2 INTERSECTION OF N. SHO	G	P	igneous and metamorphic rocks	0.0144		U

*KEY

Water System Component

G = Ground Water, P = Purchased Surface Water, S = Surface Water, T = Treatment Plant (EPTDS), U = Ground Water Under The Direct Influence of Surface Water, W = Purchased Ground Water. For a complete definition of each source of drinking water, please refer to the Glossary at the end of this report.

Confinement Status

C = Confined, U = Unconfined. For a definition of a confined and an unconfined aquifer please refer to the Glossary at the end of this report. K = Unknown, S = Semi-confined. For the purposes of SWAP both K and S were treated as unconfined wells.

Source Status

C = Recharge, E = Emergency, I= Interim, O = Other, P= Permanent, R= Reserve, S= Seasonal, U = Not in Use/Capped, V = Abandoned/Not Capped, W = Not in Use/Unspecified, X = Not in Use/Mechanical, Y = Not in Use/Contaminated. For a complete definition of each well status category, please refer to the Glossary at the end of this report.

Source

For ground water sources, the name of the aquifer is provided. For surface water sources, the name of the surface water body on which the intake is located is given.

The Strawberry Point Property Owners Association contains 1 EPTDS as illustrated in Table 7 (identified by a "T" in the water system component column). Often public water systems treat source water at the EPTDS to ensure the drinking water provided to the public meets Federal and State Drinking Water Standards. Please refer to Appendix A- Attachment 5 for information on the public water system's treatment process.

SECTION VI - SUSCEPTIBILITY RATINGS FOR YOUR DRINKING WATER SOURCE(S)

SECTION VI – SUSCEPTIBILITY RATINGS FOR DRINKING WATER SOURCE(S)

Table 8 provides a summary of the susceptibility ratings for the system's source(s). The source column of the table provides the number of ground water and surface water sources and the number of ground water under the direct influence of surface water (GUDI) wells in the system. The other columns provide the total number of source(s) that rated high (H), medium (M), and low (L) for each of the contaminant categories.

Table 8: Summary of Susceptibility Ratings for Drinking Water Source(s)

	Pathogens			Nutrients			Pesticides			VOCs			Inorganics			Radionuclides			Radon			DBPs		
Sources	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Wells - 2		1	1	1	1				2			2			2		2			2			2	
GUDI - 0																								
Surface water intakes - 0																								

To review a summary of how the other public water systems in the State of New Jersey rated, please refer to Table 5, "Summary of Statewide Susceptibility Ratings for Community Water System Sources (Percent %)" in Section III of the Source Water Assessment Report.

If a drinking water source's susceptibility is high, it does not necessarily mean the water is contaminated. High susceptibility is a vulnerability rating, not a factor determining whether or not the water is or is not meeting State and Federal Safe Drinking Water Standards. The rating reflects the potential for contamination of source water, not the existence of contamination. Public water systems are required to monitor for regulated contaminants and to install treatment if any contaminants are detected at frequencies and concentrations above allowable levels. Please refer to the Consumer Confidence Report (CCR) to determine if the drinking water is meeting all of the Safe Drinking Water Act regulatory requirements.

Table 9 illustrates the susceptibility rating for each individual source for each of the contaminant categories.

Table 9: Susceptibility Rating for Drinking Water Source(s)

EPTDS ID	Source ID	Source Name	Contaminant Category							
			Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
			Rating	Rating	Rating	Rating	Rating	Rating		Rating
01	003	WELL 1/STRAWBERRY PATCH	M	H	L	L	L	M	M	M
01	004	WELL #2 INTERSECTION OF N. SHO	L	M	L	L	L	M	M	M

The potential contaminant source inventory and sensitivity variables were used to determine the susceptibility ratings for the sources. For specific information on the water system's potential contaminant source inventory and sensitivity variables, please refer to the Individual Explanatory Variable Inventory and the Specific Potential Contaminant Sources Inventory, Appendix A- Attachment 1 and 2.

SECTION VII - SUSCEPTIBILITY RATINGS FOR YOUR ENTRY POINT TO THE DISTRIBUTION SYSTEM (EPTDS)

SECTION VII – SUSCEPTIBILITY RATINGS FOR ENTRY POINT TO THE DISTRIBUTION SYSTEM (EPTDS)

The Strawberry Point Property Owners Association contains 1 EPTDS. The EPTDS and the susceptibility rating for radon and each of the seven-contaminant categories are provided in Table 11. A susceptibility rating was developed for each EPTDS because this rating represents the water that is treated and delivered to the consumer. A majority of the monitoring regulations are established for the point at which the water exits the water treatment facility, therefore the EPTDS susceptibility rating is important in determining the monitoring requirements.

The EPTDS rating was calculated by the following method. The source contribution resulted from multiplying the pumping rate for each water source by each source's susceptibility score (a point value based on the contaminant category scoring system found in Appendix A – Attachment 3). In cases where the pumping rate was not available, the pumping capacity was used. Next, all source contributions were summed and divided by the total capacity (sum of all the pumping rates and/or capacities) for the EPTDS.

$$\frac{\sum \text{Source Contributions (Source Capacity x Source Susceptibility Score Rating)}}{\text{Total Capacity } (\sum \text{ of all source capacities to the EPTDS})} = \textbf{EPTDS Susceptibility Score}$$

Key

Source Capacity: the source capacity used for determining EPTDS ratings was the same as the pumping rate used by New Jersey Geological Survey to create the source water assessment areas. If the pumping rate was not available, the pumping capacity or a default value was used. The pumping rate selection is described in the New Jersey Geological Survey's "Guidance for Well Head Protection Area Delineations in New Jersey", Appendix B- Attachment 1.

Source Contribution: the value calculated by multiplying the source's pumping rate by the source's susceptibility score rating. The susceptibility score rating is the point value based on the contaminant category scoring system, which can be found in Appendix A – Attachment 3.

Source Susceptibility Score Rating: to obtain a high, medium, or low susceptibility rating, USGS developed a susceptibility scoring system for each contaminant category (pathogens, VOCs, inorganics, nutrients, radionuclides, disinfection byproduct precursors, and pesticides). Each contaminant category has its own point system based on the susceptibility model. For example a susceptibility score range for a contaminant could be 0-5 = low susceptibility, 6-10 = medium susceptibility, and 11-20 = high susceptibility. See Appendices A- Attachment 3 for the susceptibility scoring system USGS used to determine the susceptibility ratings.

Total Capacity: is the full amount of water the sources are contributing to the EPTDS. The pumping rates/capacities are summed to determine the total capacity for the EPTDS.

For groundwater sources, only permanent, seasonal, and interim wells were used in the EPTDS rating calculation. Other wells such as emergency, reserve, and not-in-use, were not included in the source to EPTDS "roll-up", but these wells were rated on a source basis.

For public water systems that consist of a combination of well(s) and intake(s), the EPTDS received a ground water EPTDS rating and a surface water EPTDS rating. Even in circumstances where the surface water is blended with ground water, the EPTDS received two separate susceptibility ratings. A separate ETPDS rating is provided for the ground water and the surface water because separate susceptibility models were developed for ground and surface water. Ground water and surface water susceptibility models differ in susceptibility rating score, therefore, the rating results are not on the same scale.

If a facility has only one well or intake contributing to the EPTDS, that EPTDS received the same rating as the well or intake. DEP used the equation below to determine an EPTDS susceptibility rating.

Table 10 provides an example of how the EPTDS ratings were calculated. To review how the EPTDS ratings were calculated for the Strawberry Point Property Owners Association, please refer to Appendix A- Attachment 4.

Table 10: Example of an EPTDS Susceptibility Rating Calculation

EPTDS 01

Source	Capacity (MGD)	Source Susceptibility Score Rating (0-20, low to high)	Total = Source Contribution
Well 1	1.09	20	(1.09*20) = 21.8
Well 2	1.72	10	17.2
Well 3	0.72	5	3.6
Well 4	1.48	10	14.8
Well 5	0.75	20	15.0
Total Capacity	5.76		72.4
EPTDS Susceptibility Score is 72.4 / 5.76 = 12.6			

For the above example, the sum of the source contributions for EPTDS 01 (72.4) is divided by the total capacity from all sources (5.76) giving a susceptibility score for the EPTDS of 12.6. The original range for rating sources was 0-5 low, 6-10 medium, 11-20 high. EPTDS 01 susceptibility rating was 12.6; therefore the EPTDS would receive a high rating.

Table 11 lists the susceptibility ratings for each EPTDS for the Strawberry Point Property Owners Association.

Table 11: Susceptibility Rating for EPTDS

EPTDS ID	EPTDS Name	Contaminant Category							
		Pathogens	Nutrients	Pesticides	VOCs	Inorganics	Radionuclides	Radon	DBPs
		Rating	Rating	Rating	Rating	Rating	Rating		Rating
01	WELL 1 & 2 TP/NORTH SHORE RD &	L	H	L	L	L	M	M	M

Amendment to the Atlantic, Cape May, Lower Delaware, Lower Raritan-Middlesex, Mercer, Monmouth, Northeast, Ocean, Sussex, Tri-County, Upper Delaware and Upper Raritan Water Quality Management Plans

Total Maximum Daily Load for Mercury Impairments Based on Concentration in Fish Tissue Caused Mainly by Air Deposition to Address 122 HUC 14s Statewide

Proposed: June 15, 2009
Established: September 10, 2009
Approved: September 25, 2009
Adopted: June 10, 2010

New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418

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Executive Summary

In accordance with Section 305(b) and 303(d) of the Federal Clean Water Act (CWA), the State of New Jersey, Department of Environmental Protection (Department or NJDEP) published the *2008 Integrated Water Quality Monitoring and Assessment Report*, which provides information on water quality conditions and trends, and various management strategies and actions being employed to protect and improve water quality. The report includes the List of Water Quality Limited Waters, also known as the 303(d) List, which identifies waters that do not attain an applicable designated use because of a known pollutant and for which a TMDL must be established. On March 3, 2008, the Department proposed the *2008 List of Water Quality Limited Waters* (40NJR4835(c)) as an amendment to the Statewide Water Quality Management Plan, pursuant to the Water Quality Planning Act at N.J.S.A.58:11A-7 in accordance with the Water Quality Management Planning rules at N.J.A.C. 7:15-6.4(a). The Environmental Protection Agency has approved this list. The *2008 List of Water Quality Limited Waters* identifies 256 waters as impaired with respect to mercury, as indicated by the presence of mercury concentrations in fish tissue in excess of New Jersey fish consumption advisories and/or not complying with the Surface Water Quality Standards (SWQS) for mercury at N.J.A.C. 7:9B.

A TMDL has been developed to address mercury impairment in 122 waters identified in Table 1 below. These are waters whose main source of contamination is air deposition. Waters that are tidal, where there are other significant sources of mercury or where cooperative efforts have been or are expected to be undertaken are not addressed in this TMDL pending additional study.

Table 1. Assessment Units Covered by this TMDL

Watershed Management Area (WMA)	Assessment Unit ID	Waterbody Name	2006 Integrated list	2008 Integrated list
01	02040104090020	Clove Brook (Delaware R)	Sublist 5	Sublist 5
01	02040104130010	Little Flat Brook (Beerskill and above)	Sublist 5	Sublist 5
01	02040104140010	Big Flat Brook (above Forked Brook)	Sublist 5	Sublist 5
01	02040105030020	Swartswood Lake and tribs	Sublist 5	Sublist 5
01	02040105030030	Trout Brook	Sublist 5	Sublist 5
01	02040105050040	Yards Creek	Sublist 3	Sublist 3*
01	02040105090040	Mountain Lake Brook	Sublist 5	Sublist 5
01	02040105140040	Merrill Creek	Sublist 5	Sublist 5
01	02040105140060	Pohatcong Ck (Springtown to Merrill Ck)	Sublist 3	Sublist 3*
01	02040105150020	Lake Hopatcong	Sublist 5	Sublist 5
01	02040105150060	Cranberry Lake / Jefferson Lake & tribs	Sublist 5	Sublist 5
02	02020007040040	Highland Lake/Wawayanda Lake	Sublist 5	Sublist 5
03	02030103050020	Pacock Brook	Sublist 5	Sublist 5
03	02030103050030	Pequannock R (above OakRidge Res outlet)	Sublist 5	Sublist 5
03	02030103050040	Clinton Reservior/Mossmans Brook	Sublist 5	Sublist 5

03	02030103050060	Pequannock R(Macopin gage to Charl'brg)	Sublist 5	Sublist 5
03	02030103050080	Pequannock R (below Macopin gage)	Sublist 5	Sublist 5
03	02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	Sublist 5	Sublist 5
03	02030103070050	Wanaque Reservior (below Monks gage)	Sublist 5	Sublist 5
03	02030103110020	Pompton River	Sublist 5	Sublist 5
06	02030103010170	Passaic R Upr (Rockaway to Hanover RR)	Sublist 5	Sublist 5
06	02030103020040	Whippany R(Lk Pocahontas to Wash Val Rd)	Sublist 5	Sublist 5
06	02030103020080	Troy Brook (above Reynolds Ave)	Sublist 5	Sublist 5
06	02030103030030	Rockaway R (above Longwood Lake outlet)	Sublist 5	Sublist 5
06	02030103030040	Rockaway R (Stephens Bk to Longwood Lk)	Sublist 5	Sublist 5
06	02030103030070	Rockaway R (74d 33m 30s to Stephens Bk)	Sublist 5	Sublist 5
06	02030103030090	Rockaway R (BM 534 brdg to 74d 33m 30s)	Sublist 5	Sublist 5
06	02030103030110	Beaver Brook (Morris County)	Sublist 5	Sublist 5
06	02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	Sublist 5	Sublist 5
06	02030103030150	Rockaway R (Boonton dam to Stony Brook)	Sublist 5	Sublist 5
06	02030103030170	Rockaway R (Passaic R to Boonton dam)	Sublist 5	Sublist 5
08	02030105010030	Raritan River SB(above Rt 46)	Sublist 5	Sublist 5
08	02030105010040	Raritan River SB(74d 44m 15s to Rt 46)	Sublist 3	Sublist 3*
08	02030105010050	Raritan R SB(LongValley br to 74d44m15s)	Sublist 3	Sublist 3*
08	02030105010060	Raritan R SB(Califon br to Long Valley)	Sublist 3	Sublist 3*
08	02030105020040	Spruce Run Reservior / Willoughby Brook	Sublist 5	Sublist 5
08	02030105020090	Prescott Brook / Round Valley Reservior	Sublist 5	Sublist 5
08	02030105020100	Raritan R SB(Three Bridges-Prescott Bk)	Sublist 3	Sublist 3*
08	02030105040010	Raritan R SB(Pleasant Run-Three Bridges)	Sublist 3	Sublist 3*
08	02030105040040	Raritan R SB(NB to Pleasant Run)	Sublist 3	Sublist 3*
09	02030105080020	Raritan R Lwr (Rt 206 to NB / SB)	Sublist 3	Sublist 3*
09	02030105080030	Raritan R Lwr (Millstone to Rt 206)	Sublist 3	Sublist 3*
09	02030105120080	South Fork of Bound Brook	Sublist 3	Sublist 3*
09	02030105120100	Bound Brook (below fork at 74d 25m 15s)	Sublist 3	Sublist 3*
09	02030105120140	Raritan R Lwr(I-287 Piscatway-Millstone)	Sublist 5	Sublist 5
09	02030105130050	Lawrence Bk (Church Lane to Deans Pond)	Sublist 3	Sublist 3*
09	02030105130060	Lawrence Bk (Milltown to Church Lane)	Sublist 3	Sublist 3*

09	02030105140020	Manalapan Bk(incl LkManlpn to 40d16m15s)	Sublist 3	Sublist 3*
09	02030105140030	Manalapan Brook (below Lake Manalapan)	Sublist 5	Sublist 5
09	02030105160030	Duhernal Lake / Iresick Brook	Sublist 3	Sublist 3*
10	02030105090050	Stony Bk(Province Line Rd to 74d46m dam)	Sublist 3	Sublist 3*
10	02030105100130	Bear Brook (below Trenton Road)	Sublist 3	Sublist 5
10	02030105110020	Millstone R (HeathcoteBk to Harrison St)	Sublist 3	Sublist 5
10	02030105110110	Millstone R (BlackwellsMills to BedenBk)	Sublist 3	Sublist 3*
10	02030105110140	Millstone R(AmwellRd to BlackwellsMills)	Sublist 3	Sublist 3*
10	02030105110170	Millstone River (below Amwell Rd)	Sublist 3	Sublist 3*
12	02030104060020	Matawan Creek (above Ravine Drive)	Sublist 3	Sublist 3*
12	02030104060030	Matawan Creek (below Ravine Drive)	Sublist 5	Sublist 5
12	02030104070070	Swimming River Reservior / Slope Bk	Sublist 3	Sublist 3*
12	02030104070090	Nut Swamp Brook	Sublist 3	Sublist 5
12	02030104090030	Deal Lake	Sublist 3	Sublist 3*
12	02030104090080	Wreck Pond Brook (below Rt 35)	Sublist 3	Sublist 5
12	02030104100050	Manasquan R (gage to West Farms Rd)	Sublist 5	Sublist 5
13	02040301030040	Metedeconk R SB (Rt 9 to Bennetts Pond)	Sublist 5	Sublist 5
13	02040301060050	Dove Mill Branch (Toms River)	Sublist 5	Sublist 5
13	02040301070010	Shannae Brook	Sublist 5	Sublist 5
13	02040301070030	Ridgeway Br (Hope Chapel Rd to HarrisBr)	Sublist 5	Sublist 5
13	02040301070040	Ridgeway Br (below Hope Chapel Rd)	Sublist 5	Sublist 5
13	02040301070080	Manapaqua Brook	Sublist 3	Sublist 5
13	02040301070090	Union Branch (below Blacks Br 74d22m05s)	Sublist 5	Sublist 5
13	02040301080030	Davenport Branch (above Pinewald Road)	Sublist 3	Sublist 5
13	02040301090050	Cedar Creek (GS Parkway to 74d16m38s)	Sublist 5	Sublist 5
13	02040301130030	Mill Ck (below GS Parkway)/Manahawkin Ck	Sublist 3	Sublist 3*
13	02040301130050	Westecunk Creek (above GS Parkway)	Sublist 5	Sublist 5
13	02040301140020	Mill Branch (below GS Parkway)	Sublist 3	Sublist 3*
13	02040301140030	Tuckerton Creek (below Mill Branch)	Sublist 3	Sublist 3*
14	02040301150080	Batsto R (Batsto gage to Quaker Bridge)	Sublist 5	Sublist 5
14	02040301160030	Mullica River (Rt 206 to Jackson Road)	Sublist 5	Sublist 5
14	02040301160140	Mullica River (39d40m30s to Rt 206)	Sublist 5	Sublist 5
14	02040301160150	Mullica R (Pleasant Mills to 39d40m30s)	Sublist 5	Sublist 5
14	02040301180060	Oswego R (Andrews Rd to Sim Place Resv)	Sublist 3	Sublist 3*
14	02040301180070	Oswego River (below Andrews Road)	Sublist 5	Sublist 5

14	02040301190050	Wading River WB (Jenkins Rd to Rt 563)	Sublist 5	Sublist 5
14	02040301200010	Beaver Branch (Wading River)	Sublist 5	Sublist 5
14	02040301200050	Bass River EB	Sublist 3	Sublist 3*
15	02040302030020	GEHR (AC Expressway to New Freedom Rd)	Sublist 5	Sublist 5
15	02040302040050	Collings Lakes trib (Hospitality Branch)	Sublist 5	Sublist 5
15	02040302040130	GEHR (Lake Lenape to Mare Run)	Sublist 5	Sublist 5
15	02040302050120	Middle River / Peters Creek	Sublist 3	Sublist 3*
16	02040206210050	Savages Run (above East Creek Pond)	Sublist 5	Sublist 5
16	02040206210060	East Creek	Sublist 5	Sublist 5
17	02040206030010	Salem River (above Woodstown gage)	Sublist 5	Sublist 5
17	02040206070030	Canton Drain (above Maskell Mill)	Sublist 5	Sublist 5
17	02040206080050	Cohansey R (incl CornwellRun - BeebeRun)	Sublist 3	Sublist 5
17	02040206090030	Cohansey R (Rocaps Run to Cornwell Run)	Sublist 5	Sublist 5
17	02040206100060	Nantuxent Creek (above Newport Landing)	Sublist 3	Sublist 3*
17	02040206130010	Scotland Run (above Fries Mill)	Sublist 5	Sublist 5
17	02040206130040	Scotland Run (below Delsea Drive)	Sublist 5	Sublist 5
17	02040206140010	MauriceR(BlkwtrBr to/incl WillowGroveLk)	Sublist 5	Sublist 5
17	02040206150050	Muddy Run (incl ParvinLk to Palatine Lk)	Sublist 3	Sublist 3*
17	02040206180050	Menantico Creek (below Rt 552)	Sublist 3	Sublist 3*
18	02040202100020	Pennsauken Ck NB (incl StrwbrdgLk-NJTPK)	Sublist 3	Sublist 5
18	02040202110030	Cooper River (above Evesham Road)	Sublist 5	Sublist 5
18	02040202110040	Cooper R (Wallworth gage to Evesham Rd)	Sublist 5	Sublist 5
18	02040202110050	Cooper River (Rt 130 to Wallworth gage)	Sublist 5	Sublist 5
18	02040202120010	Big Timber Creek NB (above Laurel Rd)	Sublist 5	Sublist 5
18	02040202120020	Big Timber Creek NB (below Laurel Rd)	Sublist 5	Sublist 5
18	02040202120030	Big Timber Creek SB (above Lakeland Rd)	Sublist 5	Sublist 5
18	02040202120040	Big T Ck SB(incl Bull Run to LakelandRd)	Sublist 5	Sublist 5
18	02040202120050	Big Timber Creek SB (below Bull Run)	Sublist 5	Sublist 5
18	02040202120060	Almonesson Creek	Sublist 5	Sublist 5
18	02040202120090	Newton Creek (LDRV-Kaighn Ave to LT Ck)	Sublist 5	Sublist 5
18	02040202120100	Woodbury Creek (above Rt 45)	Sublist 5	Sublist 5
18	02040202130030	Chestnut Branch (above Sewell)	Sublist 5	Sublist 5
18	02040202150020	Raccoon Ck (Rt 45 to/incl Clems Run)	Sublist 3	Sublist 3*
18	02040202150040	Raccoon Ck (Russell Mill Rd to Rt 45)	Sublist 5	Sublist 5
19	02040202030050	Bucks Cove Run / Cranberry Branch	Sublist 5	Sublist 5
19	02040202050050	Friendship Ck (below/incl Burrs Mill Bk)	Sublist 3	Sublist 3*

19	02040202050060	Rancocas Creek SB(above Friendship Ck)	Sublist 3	Sublist 3*
19	02040202050080	Rancocas Ck SB (Vincentown-FriendshipCk)	Sublist 3	Sublist 3*
19	02040202050090	Rancocas Ck SB (BobbysRun to Vincentown)	Sublist 3	Sublist 3*
20	02040201090030	LDRV tribs (Assiscunk Ck to Blacks Ck)	Sublist 5	Sublist 5

* Data became available in these assessment units after the 2008 list was approved indicating fish tissue levels that would result in listing of these waters in accordance with the current listing methodology; therefore, these assessment units will also be addressed in this TMDL.

The target for the TMDL is a concentration of 0.18 µg/g in fish tissue, which is the concentration at which the recommended rate of fish consumption for the high risk population is not more than 1 meal per week of top trophic level fish. At this concentration unlimited consumption is appropriate for the general population. An overall reduction of 84.3% in existing mercury loads is required to achieve the target. In its *New Jersey Mercury Reduction Plan*, the Department outlines measures needed to achieve these reductions.

The TMDLs in this report were proposed on June 15, 2009 and, having completed the public participation process, shall be adopted by the Department as amendments to the Atlantic, Cape May, Lower Delaware, Lower Raritan-Middlesex, Mercer, Monmouth, Northeast, Ocean, Sussex, Tri-County, Upper Delaware and Upper Raritan Water Quality Management Plans in accordance with N.J.A.C. 7:15-6.4. This TMDL report was developed consistent with the United States Environmental Protection Agency's (USEPA or EPA) May 20, 2002 guidance document entitled, "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992" (Sutfin, 2002), which describes the general statutory and regulatory requirements for approvable TMDLs, as well as EPA's more specific guidance memo for the subject type of TMDL, dated September 29, 2008 and entitled "Elements of Mercury TMDLs Where Mercury Loadings are Predominantly from Air Deposition" (Hooks, 2008).

1.0. Introduction

Mercury is a persistent, bio-accumulative toxin that can be found in solid, liquid, or vapor form. Mercury can cause a variety of harmful health effects including damage to the brain, central nervous system, and kidneys and is particularly harmful to children and pregnant and nursing women. Mercury comes from various natural and anthropogenic sources, including volcanic activity, burning of some forms of coal, use in dental procedures and manufacturing, use and disposal of products containing mercury. Most often, mercury enters the environment in gas or particulate form and is deposited on surfaces, often through precipitation, which washes deposited mercury into waterways. There it undergoes a natural chemical process and is converted to a more toxic form – methyl mercury. The methyl mercury builds up in the tissues of fish and animals, increasing its concentration as it moves up through the food chain, which results in high levels of mercury in some of the foods we eat. At certain levels, fish consumption advisories are triggered.

Mercury contamination in the environment is ubiquitous, not only in New Jersey, but worldwide. Mercury contamination is a global issue because the overwhelming source of mercury is air deposition. Consequently, mercury pollution will not be abated on a state by state basis alone, but must be controlled by regional, national and international efforts. In recognition of this, the New England Interstate Water Pollution Control Commission (NEIWPCC) established the *Northeast Regional Mercury Total Maximum Daily Load* dated October 24, 2007 (Northeast Regional TMDL), a regional TMDL for the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont which addressed impairments due to mercury contamination of waterbodies where the main source of mercury contamination is air deposition. It was approved by EPA on December 20, 2007. As EPA has approved establishment of regional TMDLs for mercury impairments where the primary source is air deposition using the NEIWPCC approach, the Department has determined that it is appropriate for New Jersey to develop a similar TMDL for comparable impairments in New Jersey, not only to recommend a course of action to reduce mercury contamination in New Jersey, but to further emphasize that substantial source reductions from outside New Jersey will be needed to achieve water quality objectives. Therefore, New Jersey has developed a statewide TMDL that will complement the Northeast Regional TMDL developed for the northeast states.

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required biennially to prepare and submit to the USEPA a report that identifies waters that do not meet or are not expected to meet Surface Water Quality Standards (SWQS) after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the State of New Jersey is also required biennially to prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report. The Department combines these reports into the Integrated Water Quality Monitoring and Assessment Report and assigns each designated use within the assessment unit to one of five sublists. An assessment unit is listed as Sublist 1 if all designated uses are assessed and attained. (The Department does not include the fish consumption use for this sublist.) If some but not all uses are attained, an assessment unit is placed on Sublist 2 for attained uses. If the Department

did not have data to assess a use, the assessment unit is placed on Sublist 3 for that use. If a use is not attained, the assessment unit will be placed on Sublist 5, or Sublist 4 if there is an approved TMDL, there are other enforceable management measures in effect or the impairment is due to pollution, not a pollutant. Sublist 5 constitutes the list of waters for which a TMDL may be required, also known as the 303(d) list. In accordance with the *2008 Integrated Water Quality Monitoring and Assessment Methods*, although there is a State-wide fish consumption advisory for mercury, only waters with actual fish tissue monitoring data that exceed the threshold which results in a consumption restriction (greater than 0.07 mg/kg) are placed on Sublist 5. All other assessment units are listed on Sublist 3 for this use. Based on the TMDL analysis, which demonstrates that reduction of natural sources of mercury would be needed in order to achieve the level necessary to allow unlimited consumption for high risk populations, the Department intends to revise its Assessment Method when developing future Integrated Water Quality Monitoring and Assessment Reports to allow that a limit of 1 meal per week for the high risk population would be considered as attaining the use with respect to mercury-based fish consumption (listing threshold would be results greater than 0.18 μg/g).

The *2008 List of Water Quality Limited Waters* currently identifies 256 Assessment Units as impaired due to mercury in surface water and/or fish tissue. This report establishes 122 TMDLs for mercury contamination based on fish tissue concentration whose source is largely air deposition. Waters where there are other significant sources of mercury in a waterbody, as indicated by a water column concentration in excess of the Surface Water Quality Standards, documentation of high levels of mercury in ground water or the presence of hazardous waste sites where mercury is a contaminant of concern, are deferred at this time, pending additional study. Tidal waters are also excluded because the approach used in this TMDL is intended for waters not affected by tidal dynamics. In addition, areas that are included in the spatial extent of the on-going interstate effort to address mercury impairments in the New York/New Jersey Harbor are excluded from this TMDL. A similar interstate effort is an appropriate means of addressing mercury impairments in the shared waters of the Atlantic Ocean and the Delaware River and Estuary, and these waters are deferred as well.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point and nonpoint sources in the form of waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and a margin of safety (MOS).

EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. EPA has also issued guidance for the development of TMDLs for mercury impairments that are due primarily to air deposition (Hooks, 2008).

2.0. Pollutant of Concern, Applicable Surface Water Quality Standards, and Area of Interest

2.1 Pollutant of Concern

The pollutant of concern for these TMDLs is mercury. According to the current assessment methodology, an assessment unit is listed as impaired for mercury if the data show water column concentrations in excess of the Surface Water Quality Standards (SWQS) or fish tissue concentrations that would result in any limitations on fish consumption. These advisories are not SWQS, but they do indicate a limitation on the use of the waters. As previously discussed, this TMDL is limited to assessment units where impairment is attributed to fish tissue in excess of advisory thresholds, where the mercury is primarily from air deposition. The assessment units addressed are identified in Table 1. These listings have a medium priority ranking in the *2008 List of Water Quality Limited Waters* (40NJR4835(c)).

2.2 Applicable Surface Water Quality Standards and Fish Consumption Advisory Criteria

Most of the waters addressed in this report are classified in the Surface Water Quality Standards (SWQS) at N.J.A.C. 7:9B as Fresh Water 2 (FW2), either Non-Trout (NT), Trout Maintenance (TM) or Trout Production (TP). Some waters are classified as Pinelands (PL) or Freshwater 1 (FW1). A few Assessment Units include waters classified as FW2-NT/SE1 or FW2-NT/SE2. If the measured salinity is less than 3.5 parts per thousand at mean high tide, the FW2-NT classification applies. The TMDL does not apply to fresh or saline tidal waters. If the majority of the waters in the HUC 14 subwatershed are fresh and non-tidal, that assessment unit was included in this TMDL. Therefore, even though portions of some assessment units are noted as including the SE (Saline Estuarine) designation, these designations are not affected and are not discussed below. Table 2 below lists the surface water classifications for the assessment units addressed in this document and Table 3 provides the numeric criteria for mercury.

Table 2. Surface Water Classifications for the Assessment Units Addressed Under this TMDL

WMA	Assessment Unit ID	Waterbody Name	Surface Water Classifications
01	2040104090020	Clove Brook (Delaware River)	FW1, FW1-TP, FW2-TPC1, FW2-TPMC1
01	2040104130010	Little Flat Brook (Beerskill And Above)	FW1, FW2-TP, FW2-TPC1, FW2-NTC1
01	2040104140010	Big Flat Brook (Above Forked Brook)	FW1, FW2-NTC1
01	2040105030020	Swartswood Lake And Tributaries	FW2-TM, FW2-TMC1, FW2-NT, FW2-NTC1
01	2040105030030	Trout Brook	FW2-TPC1, FW2-NT
01	2040105050040	Yards Creek	FW2-TPC1, FW2-NT
01	2040105090040	Mountain Lake Brook	FW2-TM, FW2-NT

01	2040105140040	Merrill Creek	FW2-TPC1, FW2-TM
01	2040105140060	Pohatcong Creek (Springtown To Merrill Creek)	FW2-TPC1, FW2-TMC1
01	2040105150020	Lake Hopatcong	FW2-TM, FW2-NT
01	2040105150060	Cranberry Lake / Jefferson Lake & Tributaries	FW2-TMC1, FW2-NT, FW2-NTC1
02	2020007040040	Highland Lake/Wawayanda Lake	FW2-NT, FW2-NTC1
03	2030103050020	Pacock Brook	FW1, FW1-TP, FW2-NTC1
03	2030103050030	Pequannock River (Above Oak Ridge Reservoir Outlet)	FW1-TP, FW1-TM, FW2-TP, FW2-TPC1, FW2-TMC1, FW2-NT
03	2030103050040	Clinton Reservior/Mossmans Brook	FW1, FW2-TPC1, FW2-TP, FW2-TMC1, FW2-NTC1
03	2030103050060	Pequannock River (Macopin Gage To Charl'brg)	FW1-TM, FW2-TPC1, FW2-TP, FW2-TM, FW2-TMC1, FW2-NT
03	2030103050080	Pequannock River (Below Macopin Gage)	FW2-TPC1, FW2-TP, FW2-NTC1, FW2-TM, FW2-NT
03	2030103070030	Wanaque River /Greenwood Lake (Above Monks Gage)	FW2-TPC1, FW2-TM, FW2-TMC1, FW2-NT, FW2-NTC1
03	2030103070050	Wanaque Reservoir (Below Monks Gage)	FW2-TPC1, FW2-TMC1, FW2-NTC1
03	2030103110020	Pompton River	FW2-NT
06	2030103010170	Passaic River Upper (Rockaway To Hanover Rr)	FW2-NT
06	2030103020040	Whippany River(Lake Pocahontas To Washington Valley Rd)	FW2-TM, FW2-NT
06	2030103020080	Troy Brook (Above Reynolds Ave)	FW2-NT
06	2030103030030	Rockaway River (Above Longwood Lake Outlet)	FW2-NTC1
06	2030103030040	Rockaway River (Stephens Brook To Longwood Lake)	FW2-NTC1
06	2030103030070	Rockaway RIVER (74d 33m 30s To Stephens Brook)	FW1, FW2-NTC1, FW2-TPC1, FW2-TMC1
06	2030103030090	Rockaway River (BM 534 Bridge To 74d 33m 30s)	FW2-NTC1, FW2-NT
06	2030103030110	Beaver Brook (Morris County)	FW2-TPC1, FW2-TMC1, FW2-NTC1
06	2030103030140	Rockaway River (Stony Brook To BM 534 Bridge)	FW2-NTC1
06	2030103030150	Rockaway River (Boonton Dam To Stony Brook)	FW2-TMC1, FW2-NTC1, FW2-NT
06	2030103030170	Rockaway River (Passaic River To Boonton Dam)	FW2-NT
08	2030105010030	Raritan River South Branch (Above Route 46)	FW2-NT, FW2-TM, FW2-NTC1
08	2030105010040	Raritan River South Branch(74d 44m 15s To Route 46)	FW2-NTC1, FW2-TPC1, FW2-NT, FW2-TMC1

08	2030105010050	Raritan River South BRANCH(Longvalley Brook To 74d44m15s)	FW2-TPC1, FW2-NT
08	2030105010060	Raritan River South Branch(Califon Brook To Long Valley)	FW2-TPC1, FW2-NT
08	2030105020040	Spruce Run Reservior / Willoughby Brook	FW2-TPC1, FW2-TMC1, FW2-TM, FW2-NT
08	2030105020090	Prescott Brook / Round Valley Reservoir	FW2-TPC1, FW2-TM, FW2-NT
08	2030105020100	Raritan River South Branch(Three Bridges-Prescott Brook)	FW2-TM, FW2-NT
08	2030105040010	Raritan River South Branch(Pleasant Run-Three Bridges)	FW2-NT
08	2030105040040	Raritan River South Branch(North Branch To Pleasant Run)	FW2-NT
09	2030105080020	Raritan River Lower (Route 206 To North Branch / South Branch)	FW2-NT
09	2030105080030	Raritan River Lower (Millstone To Route 206)	FW2-NT
09	2030105120080	South Fork Of Bound Brook	FW2-NT
09	2030105120100	Bound Brook (Below Fork At 74d 25m 15s)	FW2-NT
09	2030105120140	Raritan River Lwr(I-287 Piscatway-Millstone)	FW2-NT
09	2030105130050	Lawrence Brook (Church Lane To Deans Pond)	FW2-NT
09	2030105130060	Lawrence Brook (Milltown To Church Lane)	FW2-NT
09	2030105140020	Manalapan Brook(Incl Lakemanlpn To 40d16m15s)	FW2-NT
09	2030105140030	Manalapan Brook (Below Lake Manalapan)	FW2-NT
09	2030105160030	Duhernal Lake / Iresick Brook	FW2-NT
10	2030105090050	Stony Brook(Province Line Rd To 74d46m Dam)	FW2-NT
10	2030105100130	Bear Brook (Below Trenton Road)	FW2-NT
10	2030105110020	Millstone River (Heathcotebk To Harrison St)	FW2-NT
10	2030105110110	Millstone River (Blackwellsmills To Beden Brook)	FW2-NT
10	2030105110140	Millstone River(Amwellrd To Blackwellsmills)	FW2-NT
10	2030105110170	Millstone River (Below Amwell Rd)	FW2-NT
12	2030104060020	Matawan Creek (Above Ravine Drive)	FW2-NT/SE1
12	2030104060030	Matawan Creek (Below Ravine Drive)	FW2-NT/SE1
12	2030104070070	Swimming River Reservoir / Slope Brook	FW2-NTC1
12	2030104070090	Nut Swamp Brook	FW2-NT/SE1
12	2030104090030	Deal Lake	FW2-NT/SE1
12	2030104090080	Wreck Pond Brook (Below Route 35)	FW2-NT, FW2-NT/SE1
12	2030104100050	Manasquan River (Gage To West Farms Road)	FW2-TMC1, FW2-NTC1

13	2040301030040	Metedeconk River South Branch (Rt 9 To Bennetts Pond)	FW2-TMC1, FW2-NTC1
13	2040301060050	Dove Mill Branch (Toms River)	FW2-NTC1, PL
13	2040301070010	Shannae Brook	FW2-NT, PL
13	2040301070030	Ridgeway Brook (Hope Chapel Rd To Harrisbrook)	PL
13	2040301070040	Ridgeway Brook (Below Hope Chapel Rd)	PL, FW2-NT/SE1
13	2040301070080	Manapaqua Brook	PL, FW2-NT/SE1
13	2040301070090	Union Branch (Below Blacks Brook 74d22m05s)	PL, FW2-NT/SE1
13	2040301080030	Davenport Branch (Above Pinewald Road)	PL
13	2040301090050	Cedar Creek (GS Parkway To 74d16m38s)	PL
13	2040301130030	Mill Creek (Below Gs Parkway)/Manahawkin Creek	PL, FW2-NT, FW2-NTC1/SE1
13	2040301130050	Westecunk Creek (Above Garden State Parkway)	PL
13	2040301140020	Mill Branch (Below Garden State Parkway)	FW2-NT/SE1
13	2040301140030	Tuckerton Creek (Below Mill Branch)	PL, FW2-NTC1/SE1, FW2-NT/SE1
14	2040301150080	Batsto River (Batsto Gage To Quaker Bridge)	FW1, PL
14	2040301160030	Mullica River (Route 206 To Jackson Road)	PL
14	2040301160140	Mullica River (39d40m30s To Rt 206)	PL
14	2040301160150	Mullica RIVER (Pleasant Mills To 39d40m30s)	PL
14	2040301180060	Oswego River (Andrews Rd To Sim Place Reservoir)	PL
14	2040301180070	Oswego River (Below Andrews Road)	PL
14	2040301190050	Wading River West Branch (Jenkins Road To Route 563)	PL
14	2040301200010	Beaver Branch (Wading River)	PL
14	2040301200050	Bass River East Branch	PL, FW1
15	2040302030020	Great Egg Harbor (Atlantic City Expressway To New Freedom Road)	PL, FW2-NT
15	2040302040050	Collings Lakes Tributary (Hospitality Branch)	PL
15	2040302040130	Great Egg Harbor (Lake Lenape To Mare Run)	PL
15	2040302050120	Middle River / Peters Creek	FW1, /SE1 C1, FW2-NTC1/SE1
16	2040206210050	Savages Run (Above East Creek Pond)	FW1, PL,
16	2040206210060	East Creek	FW1, PL, FW2-NTC1/SE1, FW2-NT/SE1
17	2040206030010	Salem River (Above Woodstown Gage)	FW2-NTC1, FW2-NT
17	2040206070030	Canton Drain (Above Maskell Mill)	FW2-NT/SE1

17	2040206080050	Cohansey River (Including Cornwell Run – Beebe Run)	FW2-NT/SE1
17	2040206090030	Cohansey R (Rocaps Run To Cornwell Run)	FW2-NT/SE1
17	2040206100060	Nantuxent Creek (Above Newport Landing)	FW1, FW2-NTC1/SE1, FW2-NT/SE1
17	2040206130010	Scotland Run (Above Fries Mill)	FW2-NT
17	2040206130040	Scotland Run (Below Delsea Drive)	FW2-NT
17	2040206140010	Mauriceriver(Blackwater Book To Include Willow Grovelake)	FW2-NT, FW2-NTC1
17	2040206150050	Muddy Run (Including Parvin Lake To Palatine Lake)	FW2-NT, FW2-NTC1
17	2040206180050	Menantico Creek (Below Route 552)	FW2-NT, FW2-NTC1
18	2040202100020	Pennsauken Creek North Branch (Including Strawbridge Lake-Njtpk)	FW2-NT
18	2040202110030	Cooper River (Above Evesham Road)	FW2-NT
18	2040202110040	Cooper River (Wallworth Gage To Evesham Road)	FW2-NT
18	2040202110050	Cooper River (Route 130 To Wallworth Gage)	FW2-NT
18	2040202120010	Big Timber Creek North Branch (Above Laurel Road)	FW2-NT
18	2040202120020	Big Timber Creek North Branch (Below Laurel Road)	FW2-TPC1, FW2-NT
18	2040202120030	Big Timber Creek South Branch (Above Lakeland Road)	FW2-NT
18	2040202120040	Big Timber Creek South Branch(Including Bull Run To Lakeland Road)	FW2-NT
18	2040202120050	Big Timber Creek South Branch (Below Bull Run)	FW2-NT
18	2040202120060	Almonesson Creek	FW2-NT
18	2040202120090	Newton Creek (Ldrv-Kaighn Ave To Lt Creek)	FW2-NT
18	2040202120100	Woodbury Creek (Above Rt 45)	FW2-NT/SE2
18	2040202130030	Chestnut Branch (Above Sewell)	FW2-NT/SE2
18	2040202150020	Raccoon Creek (Rt 45 To/Include Clems Run)	FW2-NT/SE2
18	2040202150040	Raccoon Creek (Russell Mill Road To Route 45)	FW2-NT/SE2
19	2040202030050	Bucks Cove Run / Cranberry Branch	PL
19	2040202050050	Friendship Creek (Below/Including Burrs Mill Brook)	PL
19	2040202050060	Rancocas Creek South Branch(Above Friendship Creek)	PL
19	2040202050080	Rancocas Creek South Branch (Vincentown-Friendship Creek)	PL, FW2-NT
19	2040202050090	Rancocas Creek South Branch (Bobbys Run To Vincentown)	FW2-NT
20	2040201090030	Lower Delaware River Tributaries (Assiscunk Creek To Blacks Creek)	FW2-NT

C1 refers to Category One, a specific category of water relevant with respect to the antidegradation policies in the SWQS.

In all FW1 waters, the designated uses are (NJAC 7:9B-1.12):

1. Set aside for posterity to represent the natural aquatic environment and its associated biota;
2. Primary and secondary contact recreation;
3. Maintenance, migration and propagation of the natural and established aquatic biota; and
4. Any other reasonable uses.

In all FW2 waters, the designated uses are (NJAC 7:9B-1.12):

1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

In all PL waters, the designated uses are (NJAC 7:9B-1.12):

1. Cranberry bog water supply and other agricultural uses;
2. Maintenance, migration and propagation of the natural and established biota indigenous to this unique ecological system;
3. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation, and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection;
4. Primary and secondary contact recreation; and
5. Any other reasonable uses.

Table 3. Mercury Water Column Criteria (µg/l)

Toxic substance	Fresh Water (FW2) Criteria		
	Aquatic		Human Health
	Acute	Chronic	
Mercury	1.4(d) (s)	0.77(d) (s)	0.05(h)(T)

d = criterion expressed as a function of the water effects ratio
T = total
h = noncarcinogenic effect-based human health criteria
s = dissolved

Surface water quality criteria for FW1 waters are that they shall be maintained as to quality in their natural state. PL waters shall be maintained as to quality in their existing state or that quality necessary to attain or protect the designated uses, whichever is more stringent.

In addition N.J.A.C. 7:9B-1.5(a) 4 includes the requirement that "Toxic substances in water shall not be at levels that are toxic to humans or the aquatic biota so as to render them unfit for human consumption."

Fish consumption advisories are jointly issued by the New Jersey Department of Environmental Protection and the New Jersey Department of Health and Senior Services. They provide advice to the general population and high-risk individuals (for example, women of childbearing age and children) concerning the number of meals that represent safe levels of consumption of recreational fish from New Jersey waters. Fish consumption advisories for mercury include information on how to limit risk by providing guidance on the types and sizes of fish and the number of meals to eat. They are not promulgated standards, but they are used for determining whether the fish consumption use is met. Where fish tissue levels exceed the advisory thresholds, a waterbody is listed on the 303(d) list. The New Jersey fish consumption advisories are as follows:

Table 4. New Jersey Fish Consumption Advisory Thresholds (from Toxics in Biota Committee 1994)

Advisories for the high risk population*	
Mercury (TR) Concentration in Fish Tissue	**Advisory**
Greater than 0.54 µg/g (ppm)	Do not eat
Between 0.19 and 0.54 µg/g (ppm)	One meal per month
Between 0.08 and 0.18 µg/g (ppm)	One meal per week
0.07 µg/g (ppm) or less	Unlimited consumption
Advisories for the general population	
Mercury (TR) Concentration in Fish Tissue	**Advisory**
Greater than 2.81 µg/g (ppm)	Do not eat
Between 0.94 and 2.81 µg/g (ppm)	One meal per month
Between 0.35 and 0.93 µg/g (ppm)	One meal per week
0.34 µg/g (ppm) or less	Unlimited consumption

TR – Total Recoverable Mercury

***** The high risk population consists of women of childbearing years, pregnant and nursing mothers and children.

Under the current assessment methodology, an assessment unit was listed as not attaining the fish consumption use if fish tissue data indicated that any restriction of consumption would be necessary, in other words if the fish tissue concentration was above 0.07 µg/g. However, based on this TMDL analysis, this level in fish tissue can be caused solely by natural sources of mercury in some waters (see Section 5 *TMDL Calculations* below). Therefore, the Department intends to revise the assessment methodology in the development of future lists (2010) to reflect a minimal level of consumption advisory for the high risk population. It is expected that the

future assessment method will use a tissue concentration of greater than 0.18 µg/g as the listing threshold, which would allow consumption by the high risk population of one meal per week. Therefore, the target for this TMDL is 0.18 µg/g total mercury fish tissue concentration. Big Timber Creek would not have been listed using this listing threshold, however, because it is listed on the 2008 303(d) list, it will be included in this TMDL document. All other waters included in this TMDL exceed the 0.18 ug/g fish tissue target.

Because fish consumption advisories are not SWQS and a TMDL must demonstrate attainment of the applicable SWQS, it is necessary to demonstrate that using this fish tissue target will also attain the applicable SWQS for mercury. This is done using bioaccumulation factors (BAFs), to convert the levels found in the fish tissue to a water column value so there can be a direct comparison with the State's current water quality criterion of 0.050 µg/L as total mercury. There is no numerical standard for waters classified as PL or FW1. The 0.18 ug/g fish tissue target is a human health endpoint which is protective of all waters, regardless of a waterbody's designation. NJAC 7:9B-1.5(a) 4's narrative standard regarding toxic substances is applicable to all waters. Absent a numeric standard for FW1 and PL waters, the narrative standard was applied and implemented using the 0.18 ug/g mercury fish tissue target. In addition the target of 0.18 µg/L requires the reduction of mercury to near natural background levels (see TMDL calculations in section 5 below) and as such is protective of waters with PL and FW1 designations.

New Jersey is engaged in an ongoing effort to develop regional BAFs. As this work is not complete, the EPA national default values will be used for this TMDL. A BAF of 1,690,000 L/kg was selected, which is based on the averaging of EPA national default values for trophic level 3 and trophic level 4 fish of 2,700,000 and 680,000 L/kg, respectively. Averaging the two values assumes a diet of 50% of these higher trophic level fish. This BAF is for methyl mercury. A further conversion to a corresponding total mercury concentration in the water column can be calculated by using the ratio of dissolved methyl mercury to total mercury. Data available from the various regions of New Jersey show that the ratios range from 0.059 to 0.005 (pers. comm. G. A. Buchanan, NJDEP, May 5, 2009). A ratio of 0.055 can be calculated from national data (EPA, 1997). The water column mercury concentration, 0.021 ug/L, expressed as total mercury using the selected BAF and the most conservative conversion factor (0.005) is lower than the mercury surface water criterion of 0.050 ug/L. Therefore, the use of a fish tissue criterion as a TMDL target ensures that the SWQS will be met if the TMDL fish tissue target is met.

The following formula was used for this comparison:

WCV (µg/L) =[Fish Tissue Value (mg/kg)/BAF (L/kg) x 1000 µg/mg] / dissolved MeHg to total Hg

Where:

WCV = water column mercury concentration
Fish Tissue Value = 0.18 mg/kg
BAF = 1,690,000 L/kg

Therefore:

WCV (µg/L)(as total Hg) = [0.18 mg/Kg/1,690,000 L/kg x 1000 µg/mg]/ 0.005 = **0.021 µg/L total Hg**

In other words, when a fish tissue target of 0.18 mg/kg is met, the water column mercury concentration would be 0.021 µg/L, which is below the surface water quality criterion of 0.050 µg/L).

2.3 Area of Interest

In accordance with the *2008 Integrated Water Quality Monitoring and Assessment Methods*, although there is a State-wide fish consumption advisory for mercury, only waters with actual fish tissue monitoring data that exceed the threshold which results in a consumption restriction (greater than 0.07 mg/kg) are placed on Sublist 5. All other assessment units are listed on Sublist 3 for this use.

The *2008 List of Water Quality Limited Waters* currently identifies 256 assessment units as impaired due to mercury in surface water and/or fish tissue. This report establishes 122 TMDLs for mercury contamination based on fish tissue concentration whose source is largely air deposition. Waters where there are other significant sources of mercury in a waterbody, as indicated by a water column concentration in excess of the Surface Water Quality Standards (61 listings), documentation of high levels of mercury in ground water (15 listings) or the presence of hazardous waste sites where mercury is a contaminant of concern (8), are deferred at this time, pending additional study. Tidal waters (35) are also excluded because the approach used in this TMDL is intended for waters not affected by tidal dynamics. In addition, areas that are included in the spatial extent of the on-going interstate effort to address mercury impairments in the New York/New Jersey Harbor are excluded from this TMDL (6). A similar interstate effort is an appropriate means of addressing mercury impairments in the shared waters of the Atlantic Ocean (37) and the Delaware River and Estuary (9) and these waters are deferred as well. See Appendix A for a listing of the deferred assessment units.

Additional fish tissue data not available when the *2008 List of Water Quality Limited Waters* was developed were evaluated and 37 additional assessment units were found to have fish tissue concentrations that would have resulted in listing of those assessment units under the current assessment methodology (see those indicated with an asterisk in Table 1). These assessment units also meet the other criteria for being addressed under this TMDL (no other significant sources, non-tidal, outside the spatial extent of interstate study). Therefore, these assessment units will be addressed under this TMDL.

As additional fish tissue data is obtained, it is expected that other assessment units will be identified that conform to the parameters established for this TMDL approach and would appropriately be addressed by this TMDL, had the data been available. Therefore, in addition to the impaired waters listed Table 1, this TMDL may, in appropriate circumstances, also apply to waterbodies that are identified in the future as being impaired for mercury. For such waterbodies, this TMDL may apply if, after listing the waters for mercury impairment and taking into account all relevant comments submitted on the Impaired Waters List, the Department determines, with EPA approval of the list, that this TMDL should apply to future mercury impaired waterbodies. Under these circumstances, the assessment units will be placed on Sublist 4.

The assessment units addressed in this TMDL are listed in Table 1 and depicted in Figure 1. The assessment units encompass 724,236 acres throughout the state.

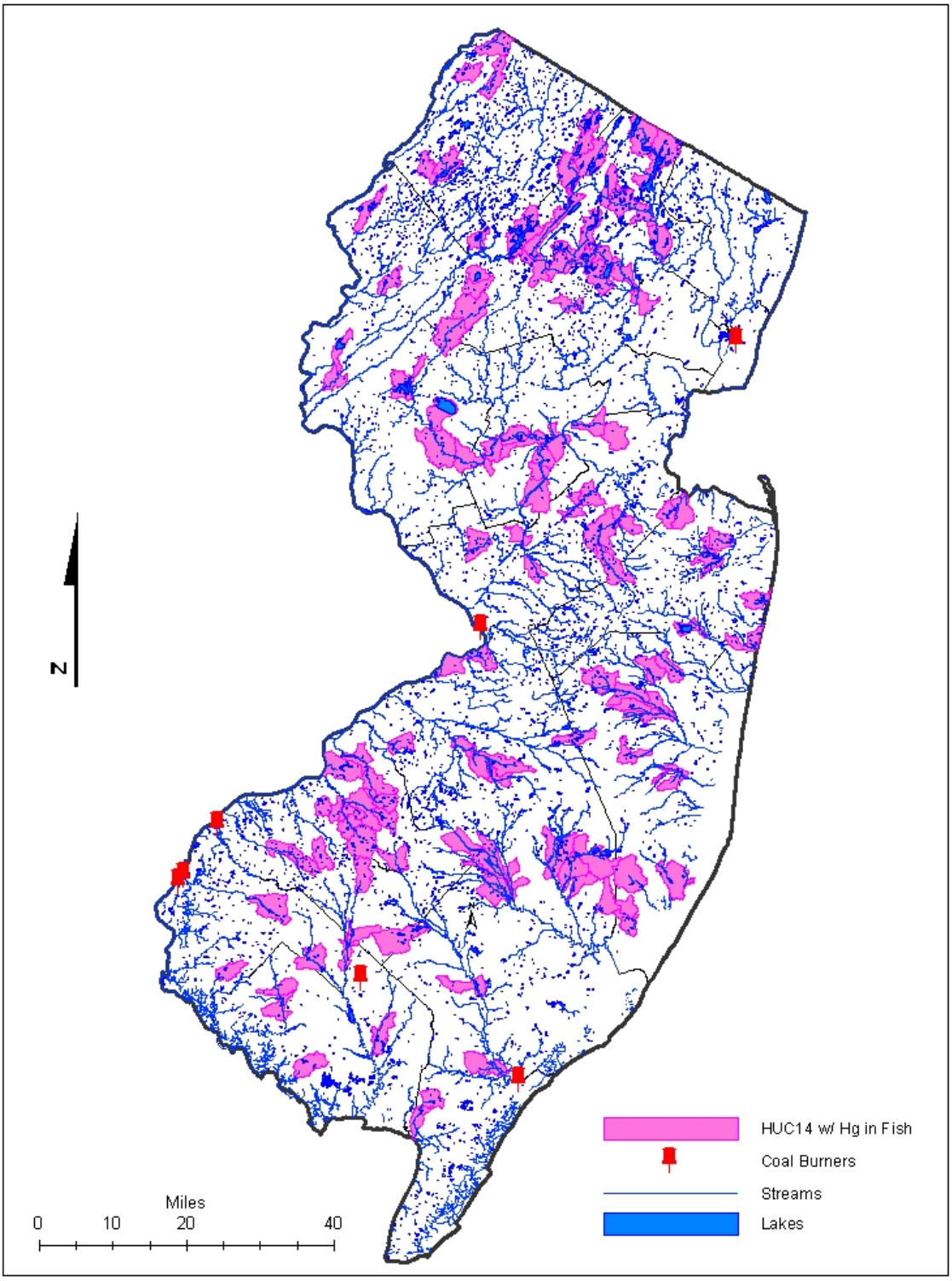


Figure 1. Assessment Units Addressed in this TMDL

3.0. Data Analysis

3.1 Fish Tissue Data

Beginning in 1994, research on freshwater fish found mercury concentrations exceeding the risk-based health advisories established by the State of New Jersey. Additional data were developed and reported in Academy of Natural Sciences, Philadelphia (ANSP) (1999), Ashley and Horwitz (2000), Horwitz et al. (2005) and Horwitz et al. (2006). The Department's Routine Monitoring Program for fish tissue began in 2002. The purpose of this monitoring program is to enhance waterbody assessments; amend existing advisories or, if necessary, develop new advisories; assist the NJDEP in evaluating trends in contaminant concentrations of these selected species; and to determine the need for additional research and monitoring studies. The sampling program is based on a rotating assessment of contamination in five regions of the state on a 5-year cycle. The regions consist of:

1. Passaic River Region;
2. Marine/Estuarine Coastal Region;
3. Raritan River Region;
4. Atlantic Coastal Inland Waterways Region; and
5. Upper and Lower Delaware River Region.

Sampling in the Passaic Region was conducted in 2002-2003 and the Marine/Estuarine Region in 2004-06. The results were reported in Horwitz, et al. (2005 and 2006). In the third year of the cycle, the Raritan River Region was sampled for freshwater fish, blue crabs and marine fish. In 2006-2007, species important to recreational anglers in the Raritan estuaries and adjacent oceanic waters and in two southern New Jersey coastal bays were sampled.

The initial data set consulted included 2,474 samples that had been analyzed for mercury in fish tissue in the waters of New Jersey collected through the above sampling programs and from localized investigations. All fish were analyzed using microwave digestion and cold vapor atomic absorption. Based on an evaluation of data quality, all samples before 1990 were excluded because of issues with background contamination in the labs analyzing samples. A small number of fish tissue samples were derived from whole fish samples. Only samples where the fillets were analyzed were retained to ensure a consistent basis for comparison. Locations with known mercury contamination from other sources were eliminated to avoid influences beyond air deposition (water column exceedances, presence of hazardous sites with mercury, groundwater levels with elevated mercury). All tidal areas were excluded, including those from the areas of on-going or anticipated interstate studies (New York/New Jersey Harbor, Atlantic Ocean and Delaware River and Bay). The final data set used for this TMDL analysis included 1,368 samples from 26 different species (see Appendix B).

This TMDL is based on the linear relationship between mercury levels in the air and water and that a BAF can relate fish tissue concentration to water column concentration. This means that if the existing load is responsible for the observed mercury levels in fish, then one can calculate the load that will result in the target concentration in fish and the associated water column

concentration using the BAF, to ensure the SWQS are attained. The steady state bioaccumulation equation is:

$$C_{\text{fish t1}} = BAF * C_{\text{water t1}}$$

where:
$C_{\text{fish t1}}$ and $C_{\text{water t1}}$ represent methyl mercury concentration in fish and water at time t_1, respectively;
BAF represents the bioaccumulation factor, which is constant for a given age and length fish in a specific water body.

For a future time, t_2, when mercury concentrations have changed, but all other parameters remain constant, the following equation applies:

$$C_{\text{fish t2}} = BAF * C_{\text{water t2}}.$$

Combining both equations produces the following:

$$C_{\text{fish t1}} / C_{\text{fish t2}} = C_{\text{water t1}} / C_{\text{water t2}}.$$

Then, with methyl mercury water column concentrations being proportional to mercury air deposition load, therefore:

$$C_{\text{fish t1}} / C_{\text{fish t2}} = L_{\text{air t1}} / L_{\text{air t2}}$$

where:
$L_{\text{air t1}}$ and $L_{\text{air t2}}$ represent mercury loads from the air deposition at time 1 and time 2.

Mercury concentration in fish increases with both age and length (see Figure 2). In order to derive a representative existing fish tissue concentration as a basis to calculate the load reduction required to achieve the target concentration, it is necessary to statistically standardize the data. The fish tissue mercury concentrations were statistically adjusted to a "standard-length fish". Because many fish are larger than the standard length and therefore higher in mercury, the TMDL analysis targets the 90^{th} percentile mercury tissue concentration of the distribution of all length-standardized fish evaluated. This will provide an implicit margin of safety and be more protective than using a mean or median concentration value. In addition, because growth rates and levels of mercury accumulation will vary between waterbodies, using the 90^{th} percentile tissue concentration will be protective of waterbodies with higher levels of accumulation.

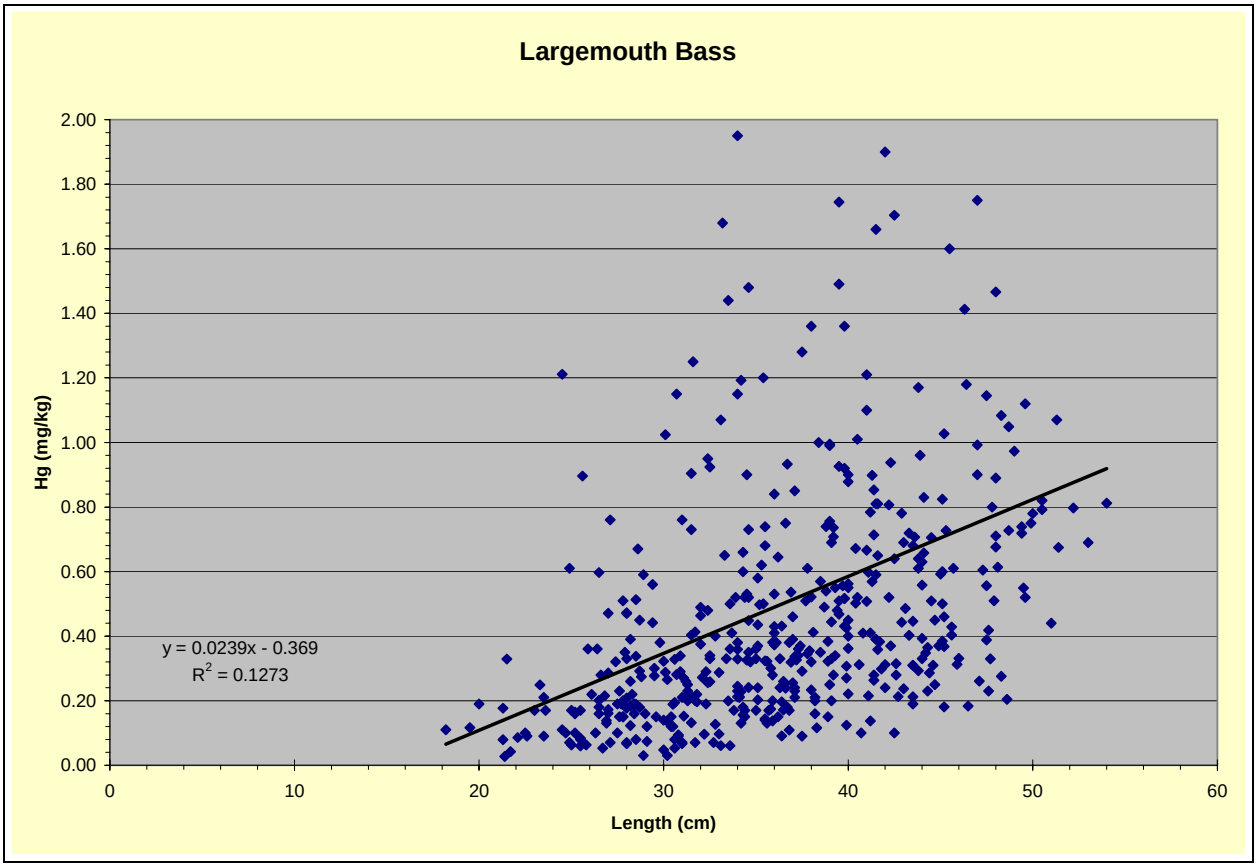


Figure 2. Relationship Between Length and Mercury Concentration in Fish Tissue

The Northeast Regional TMDL analyzed four different species of top trophic level fish, comparing the mean, 80th and 90th percentile concentrations. The authors chose the smallmouth bass (*Micropterous dolomieu*), because of the rate of bioaccumulation of mercury and its ubiquitous distribution throughout the Northeast States. The smallmouth bass is not well distributed throughout New Jersey, therefore it was not an appropriate indicator species for this TMDL. However, the largemouth bass (*Micropterus salmoides*), of the same genus and with the same diet of crayfish, frogs and fish, is well distributed throughout New Jersey. Samples are available from 69% of the listed assessment areas. The chain pickerel was also considered because it is represented by the second largest number of samples in the data set and has a high average mercury concentration (see tables 5 and 6 below). Its diet consists of invertebrates and fish. However, it is not as well distributed throughout New Jersey. Because of the larger sample size and better distribution, the largemouth bass was chosen to be the indicator for this TMDL effort. Using either fish yields a similar reduction factor.

Table 5. Data on Methyl Mercury Concentration in Fish Fillet Samples (n = number of samples, Average = arithmetic mean concentration)

Species List	2000-2007		1990-1999	
	n	Average	n	Average
American Eel	72	0.4	6	0.47
Black Crappie	15	0.15	32	0.19
Bluegill	75	0.14	2	0.03
Bluegill Sunfish	3	0.07	20	0.18
Brown Bullhead	32	0.07	79	0.19
Brown Trout	2	0.08	1	0.2
Chain Pickerel	82	0.658	166	0.685
Channel Catfish	9	0.22	10	0.15
Common Carp	36	0.11	5	0.04
Hybrid Striped Bass	0		6	0.27
Lake Trout	5	0.14	12	0.46
Largemouth Bass	152	0.54	224	0.56
Mud sunfish	0		3	1.01
Northern Pike	6	0.29	6	0.24
Pike	0		3	0.39
Pumpkinseed Sunfish	0		19	0.37
Rainbow Trout	0		6	0.11
Redbreast Sunfish	16	0.16	4	0.24
Rock Bass	19	0.33	4	0.46
Smallmouth Bass	13	0.34	22	0.47
Striped x White Bass Hybrid	5	0.29	0	
Walleye	10	0.4	6	0.74
White Catfish	8	0.19	15	0.27
White perch	12	0.18	22	0.42
White Sucker	3	0.23	0	
Yellow Bullhead	33	0.23	32	0.63
Yellow Perch	27	0.36	28	0.51

An analysis of covariance model was used to estimate the length-adjusted concentrations of mercury in largemouth bass. Scatter plots indicated that a log transformation for mercury would approximately linearize the relationship between mercury and length, so the model used the log to the base 10 of mercury as the dependent variable. The independent variables were length and water body. Water bodies were considered to be fixed effects. The result of this analysis was to create a length-adjusted mercury concentration for each water body.

A model was also run in order to determine whether the length-adjusted concentrations changed over time. In order to do this, an independent variable defining the decade in which the sample was taken (1992 – 1999 vs. 2000 – 2007) was included in the model along with length and water body. This model was significant ($p < 0.001$) with an R-square of 82%. Mercury concentrations varied significantly ($p < 0.001$) with length, waterbody and the decade in which the samples were taken.

Because decade was a significant effect, the two decades were analyzed separately. The adjusted estimates were calculated at the mean length of 35.11cm for data collected from 1992-1999 and 39.78 cm for data collected from 2000-2007.

For the 1992-1999, the data set included 49 water bodies. The number of fish sampled from each water body ranged from 1 to 12. The independent variables included length and water body. This model run was significant ($p < 0.001$) with an R-square of 89%. Mercury concentration varied significantly ($p < 0.001$) with both length and waterbody. The 90th percentile of the length-adjusted mercury concentration is $10^{(0.0448)} = 1.109$ µg/g.

The 2000-2007 dataset included 46 water bodies. The number of fish sampled from each water body ranged from 3 to 5. The independent variables included length and water body. This model run was significant ($p < 0.001$) with an R-square of 85%. Mercury concentration varied significantly ($p < 0.001$) with both length and waterbody. The 90th percentile of the length adjusted mercury concentration is $10^{(0.0607)} = 1.150$ µg/g.

The statistical analyses were performed in SAS version 9.1.3.

Because the mercury concentration varies with the waterbody, the 90th percentile fish tissue concentration is used to calculate the reduction factor. This will be protective of all the waterbodies, even those with higher fish tissue mercury concentrations.

Table 6. Mercury Concentrations Related to Fish Length for 2000-2007 Data

Species	Standard Length (cm)	Mean Hg Concentration (ppm) at Standard Length	80th percentile Hg Concentration (ppm) at Standard Length	90th percentile Hg Concentration (ppm) at Standard Length
Largemouth bass	35.11	0.531	0.64	1.15
Chain pickerel	41.61	0.59	1.26	1.29

Figure 3 shows the distribution of methyl mercury concentrations in all species in the 2000–2007 data set and concentrations in the largemouth bass for the same period. The graph shows that targeting the 90th percentile concentration in largemouth bass corresponds to the 93rd percentile concentration for all fish species. Therefore, targeting the concentration of 90th percentile for largemouth bass, means that approximately 93% of all fish populations tested will comply with

the TMDL target concentration. There is much environmental variability. Some lakes will show decreases in mercury more quickly, some more slowly. Both the Minnesota and the Northeast States regional TMDLs were based on the 90th percentile concentration. Therefore the 90th percentile target is in keeping with mercury TMDLs EPA has previously approved.

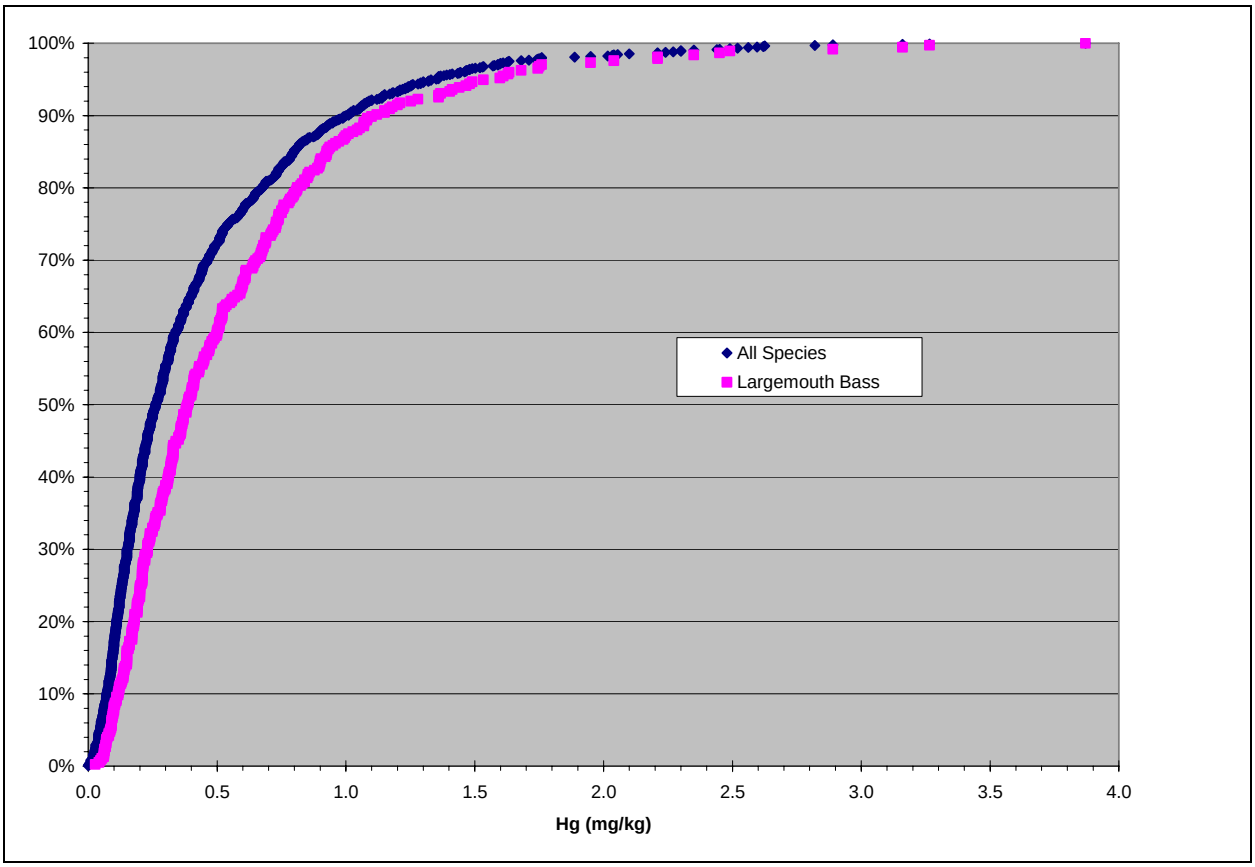


Figure 3. Cumulative Distribution of Mercury Concentrations in Fish Tissues

Based on the linear relationship premise, a Reduction Factor (RF) based on the existing and target fish tissue concentrations is calculated as follows:

RF= (EFMC-TFMC)/EFMC

where:
EFMC = the existing fish mercury concentration for the selected fish species.
TFMC = target fish mercury concentration

or:
0.84 = (1.15 µg/g-0.18 µg/g) /1.15 µg/g

As discussed above, the EFCM for this study is 1.15 µg/g, which represents the 90th percentile concentration based on standard length for largemouth bass. The target fish tissue concentration is 0.18 µg/g, which will allow a consumption rate of 1 meal per week for the high risk population. For unlimited consumption of fish for the high risk population, the reduction factor would need to be 0.94. As discussed below, natural sources of mercury, which cannot be reduced, make this reduction factor unattainable. However, the TMDL calculation includes an implicit margin of safety based on a number of conservative assumptions. Therefore, it is possible that unlimited consumption for the high risk population may be attainable if the identified anthropogenic reductions are achieved. In any case, although this TMDL target will not allow unlimited consumption of top trophic level fish for high risk groups using the multiple conservative assumptions in this analysis, mercury will be reduced at all trophic levels, allowing greater options for safe consumption of fish at the lower trophic levels and one meal per week of the top trophic levels by the high risk population.

4.0. Source Assessment

In order to evaluate and characterize mercury loadings on a statewide basis source assessments are critical. Source assessments include identifying the types of sources and their relative contributions to mercury loadings and are necessary to develop proper management responses to reduce loadings and attain water quality targets.

Air deposition is the primary source of the mercury impairments addressed in this TMDL. A recent study was undertaken in partnership with the states and USEPA Regional Air and Water Offices to use atmospheric deposition modeling to quantify contributions of specific sources and source categories to mercury deposition within each of the lower 48 states (ICF, 2008). The annual simulation was performed based on data that represented late 90's emission profiles for most source categories. The primary modeling system used for this study is the Regional Modeling System for Aerosols and Deposition (REMSAD). REMSAD is a three-dimensional grid model designed to calculate the concentrations of pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations. REMSAD simulates both wet and dry deposition of mercury. REMSAD also includes algorithms for the reemission of previously deposited mercury (originating from anthropogenic and natural sources) into the atmosphere from land and water surfaces. The Particle and Precursor Tagging Methodology (PPTM) feature allows the user to tag or track emissions from selected sources or groups of sources, and quantify their contribution to mercury deposition throughout the modeling domain and simulation period. Results from the Community Multiscale Air Quality (CMAQ) modeling system were used to enhance the analysis of the effects of global background on mercury deposition. The outputs from three global models were used to specify the boundary conditions for both REMSAD and CMAQ and thus represent a plausible range of global background contributions based on current scientific understanding.

Preparation and quality assurance of the mercury emissions inventory were critical for the air deposition load modeling. Based on the emissions data utilized by USEPA in the Clean Air Mercury Rule (CAMR) modeling, detailed summaries of the top emitters in the CAMR mercury inventory for each state were prepared and provided to the appropriate EPA regional offices and

state agencies for review. An effort was made to update emissions to the 2001 timeframe in addition to the general QA/QC that performed by the states and EPA regions. Then based on the state's input, any errors in the data were corrected. Table 7 lists New Jersey's emission inventory as it was used in the model. This inventory was developed based on the Department's 2001 mercury emission estimates (ICF, 2008). For the total of the three forms of mercury emission load, approximately 60% was due to air point sources and 40% from air nonpoint sources. Air point sources include fuel combustion-electric utilities, industrial facilities and other combustion facilities. Air nonpoint sources include human cremation, fluorescent lamp breakage, miscellaneous volatilization and other non-stationary sources.

Table 7. Summary of Emissions Inventory of New Jersey in Tons per Year (tpy) (ICF, 2008)

Facility Name	HG0* (tpy)	HG2* (tpy)	HGP* (tpy)	Total (tpy)
B.L. England	0.094	0.016	0.004	0.114
Hudson*	0.011	0.028	0.003	0.041
Mercer	0.030	0.015	0.011	0.057
Deepwater	0.002	0.004	0.000	0.006
Logan Generating Company - L.P.	0.001	0.000	0.000	0.002
Chambers Cogeneration - L.P.	0.010	0.006	0.004	0.021
Co Steel Raritan	0.090	0.011	0.011	0.112
Atlantics States Cast Iron Pipe	0.033	0.004	0.004	0.041
U.S. Pipe & Fndy. Co	0.019	0.011	0.000	0.030
Co Steel Sayreville*	0.178	0.022	0.022	0.222
Essex County RRF*	0.047	0.123	0.042	0.212
Camden RRF*	0.011	0.029	0.010	0.050
Union County RRF	0.003	0.008	0.003	0.014
Gloucester County	0.002	0.005	0.002	0.009
Warren Energy RF	0.001	0.001	0.001	0.003
Howarddown	0.002	0.001	0.001	0.004
Hoeganese	0.005	0.003	0.002	0.010
Camden County Muassi	0.005	0.003	0.002	0.010
Stony Brook Regional Sewerage Authority	0.011	0.007	0.005	0.023
Bayshore Regional Sewerage Authority	0.004	0.002	0.002	0.008
Somerset Raritan Valley Sewerage Authority	0.007	0.004	0.003	0.014
Northwest Bergen County Utilities Authority	0.005	0.003	0.002	0.010
Parsippany – Troy Hills Township WWTP	0.004	0.003	0.002	0.009
Atlantic County Utilities Authority	0.003	0.002	0.001	0.006
Gloucester County Utilities Authority	0.001	0.001	0.000	0.002
Point Source Total	0.579	0.312	0.137	1.030
Non-point Source	0.464	0.096	0.055	0.613
Total	1.043	0.408	0.192	1.643

*HG0 - elemental mercury vapor; HG2 - divalent mercury compounds in gas phase; HGP - divalent mercury compounds in particulate phase.

As summarized in Table 8 below, a total of 594 kg of annual mercury load due to air deposition was estimated for New Jersey. "Background" refers to the effects of initial and boundary concentrations and embodies the effects of global emissions, altogether, about 52% of the total

load. Emissions from New Jersey are contributing 12.5% of the total load. The emissions from five surrounding states contribute 26% of the total load.

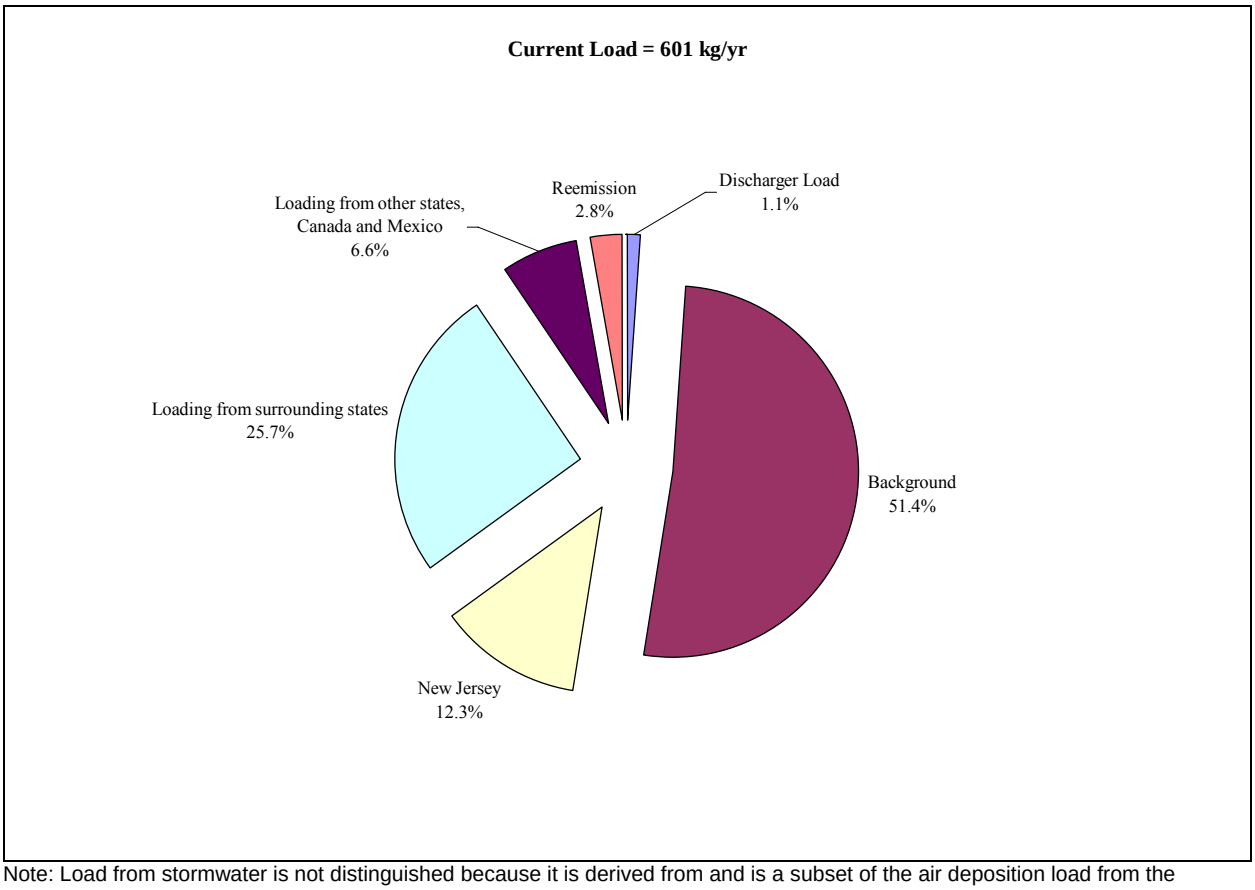
Table 8. Mercury Air Deposition Load for New Jersey (pers. com. D. Atkinson, March 26, 2009, see Appendix D)

Category	Load (kg/yr)	Percent of Total Load
Background	309.0	52.0%
Background-reemission	16.9	2.8%
New Jersey	74.1	12.5%
Loading from the surrounding state (Total)	154.6	26.0%
Pennsylvania	102.8	17.3%
Maryland	25.1	4.2%
New York	13.7	2.3%
Delaware	11.1	1.9%
Connecticut	1.8	0.3%
Loading from other states, Canada and Mexico	39.6	6.7%
Total	594.2	100%

Under the Clean Water Act (CWA), air deposition is a nonpoint source of mercury. Mercury deposited from air sources reaches the surface water as the result of direct deposition on the water surface and through stormwater runoff. Under the CWA, stormwater discharges subject to regulation under the National Pollutant Discharge Elimination System (NPDES) are a point source. In New Jersey, this includes facilities with individual or general industrial stormwater permits and Tier A municipalities and state and county facilities regulated under the New Jersey Pollutant Discharge Elimination System (NJPDES) municipal stormwater permitting program. Stormwater discharges that are not subject to regulation under NPDES, such as Tier B municipalities regulated under the NJPDES municipal stormwater permitting program, and direct stormwater runoff from land surfaces are nonpoint sources. Stormwater point sources derive their pollutant load from runoff from land surfaces and the necessary load reduction for this TMDL will be accomplished in the same way as for stormwater that is a nonpoint source, that is by reducing the air deposition load. The distinction is that, under the Clean Water Act stormwater point sources are assigned a WLA while nonpoint sources are assigned a LA. For this TMDL, the proportion of the air deposition loading attributed to stormwater point sources has been estimated by determining the amount of urban land located within Tier A municipalities. Based on NJDEP's 2002 land use coverage, the area of urban land use within the Tier A municipalities is about 25.6% of the entire state. Applying this percentage to the entire load due to air deposition is the best approximation of the air deposition load subject to stormwater regulation and this proportion of the air deposition load will be assigned a WLA.

Surface water discharges of sanitary and industrial wastewater that have the potential to discharge mercury are the other potential point source category which must be assigned a WLA. The Department reviewed over 240 existing major and minor municipal surface water discharge locations. Industrial surface water dischargers with mercury limits in their permits regulated under the New Jersey Pollutant Discharge Elimination System (NJPDES) were also included as the potential point sources for this TMDL. Since this TMDL is limited to non-tidal water, facilities discharging to coastal water were excluded. By examining the locations of the outfall pipes, approximately two-thirds of initially identified municipal and industrial surface water discharge facilities were used to estimate the point source loading from them.

Various sources of data were assessed in order to estimate an appropriate loading to attribute to discharge facilities. Due to the high detection limit of the standard method for analyzing the samples collected from the dischargers, mercury concentrations reported to date were generally listed as non-detected in the Monitoring Report Forms. Dental facilities are believed to be the largest source of mercury reaching wastewater treatment plants. Through the recently adopted New Jersey Pollutant Discharge Elimination System, Requirements for Indirect Users – Dental Facilities rules, N.J.A.C. 7:14A-21.12, dental facilities that generate amalgam waste are required to comply with best management practices and install amalgam separators. The amalgam separators will allow the mercury containing amalgam to be collected and recycled, thereby reducing the amount entering the environment through sludge incineration. The Department required major wastewater treatment facilities to carryout baseline monitoring of their effluent to determine mercury levels prior to implementation of the new dental requirements. However, the data from this monitoring effort are not yet available for use in this TMDL. As part of the New York-New Jersey Harbor TMDL development, in 2000 and 2001 a total of 30 samples were collected from 11 Publicly Owned Treatment Works (POTWs) in New Jersey which discharge to the Harbor (GLEC, 2008). Total recoverable mercury concentrations ranged from 8.32 to 74.9 ng/L, with a mean of 30.09 ng/L and a median of 19.75 ng/L. The Department believes that the mercury effluent concentrations found in these facilities will serve as an appropriate representation of effluent quality in the state. Therefore, the median concentration of 19.75 ng/L was used as a typical mercury concentration for treatment facilities. The total permitted flows for selected facilities is about 250 MGD. Using that flow and the selected median concentration, the total mercury load from these facilities is estimated to be 6.8 kg/year. This loading (6.8 kg/yr) is also a conservative assumption of the existing point source load since the permitted flow was used instead of the actual flow. The loading attributed to discharge facilities is insignificant at approximately 1% of the total load. Figure 4 shows the distribution of the current total load of mercury.



Note: Load from stormwater is not distinguished because it is derived from and is a subset of the air deposition load from the different air sources identified.

Figure 4. Distribution of the Current Mercury Load

5.0. TMDL Calculation

Methods similar to those used in the *Northeast Regional TMDL* (2007) are employed below to calculate the TMDL. A total source load (TSL), described in Section 4, and reduction factor (RF), as described in Section 3, are used to define the TMDL by applying the reduction factor to the total source load, as shown in Equation 1 below.

$$TMDL = TSL \times (1-RF)$$

where:

- TMDL is the total maximum daily load (kg/yr) that is expected to result in attainment of the target fish tissue mercury concentration.
- TSL is the existing total source load (kg/yr), and is equal to the sum of the existing point source load and the existing nonpoint source load
- RF is the reduction factor required to achieve the target fish mercury concentration.

To allow a consumption rate for the high risk population of one meal per week, the required reduction is 84.3 % (1 - 0.18/1.15 = 84.3%). The total existing loading from air deposition and the treatment facilities discharging into non-tidal waters is 601.kg/yr. In this load, 6.8 kg/yr (about 1%) comes from NJPDES regulated facilities with discharges to surface water in non-tidal waters. Due to the insignificant percentage contribution from this source category, reductions from this source category are not required in this TMDL. Therefore, individual WLAs are not being assigned to the various facilities through this TMDL. Individual facilities have been and will continue to be assessed to determine if a water quality based effluent limit should be assigned to prevent localized exceedances of SWQS and to ensure that the aggregate WLA is not exceeded. As discussed above and in the Reasonable Assurance section below, the recently implemented dental amalgam rules are expected to significantly reduce the amounts of mercury entering wastewater treatment facilities. At this time, it is not known what effect this will have on effluent concentrations. The post-implementation monitoring will be assessed to determine the effect of best management practices (BMPs) for the handling of dental amalgam waste and installation and proper operation of amalgam separators and the need for adaptive management with regard to this source in air deposition impacted waterbodies. Waterbodies that may be impacted by NJPDES regulated facilities with discharges to surface water (those with water column exceedances of the SWQS) have been excluded from the TMDL and will be addressed individually at a later date.

Based on results of several paleolimnological studies (NEIWPCC, et.al. 2007) in the Northeast, the natural mercury deposition is estimated to range between 15 % and 25 % of deposition fluxes for circa 2000. Natural sources cannot be controlled and are expected to remain at the same long-term average. It is assumed, in this study, that 25% of the background and background reemission is due to natural sources and can not be reduced (Ruth Chemerys and John Graham Pers. Comm. April 28, 2009). Twenty-five percent of the background and background reemission load is about 81.5 kg/yr, which is 13.6% of the total existing load. Including the load of 6.8 kg/yr attributed to surface water dischargers, the portion of the existing load that is not expected to be reduced is about 14.7%. If 0.07 ug/g (the fish concentration for unlimited consumption by the high risk population) were used as the TMDL target, the required reduction would be 93.9% of the existing load, which is greater than the entire anthropogenic load of 85.3% (1-14.7%) and clearly unattainable. For this reason, the concentration level (0.18 ug/g) that allows the high risk population to consume fish once per week was used as the target for this TMDL and will also be used as the threshold in future assessments of impairment. In order to achieve the overall 84.3% reduction of the existing load to attain the target of 0.18 mg/kg in fish tissue, a reduction of 98.8% of the anthropogenic source load would be needed. An implicit margin of safety (MOS) is used in this study, therefore, the MOS term of the TMDL equation is set to zero. Figure 5 presents the distribution of the TMDL to achieve the target concentration that will allow one meal per week by the high risk population.

Table 9. Mercury TMDL for One Meal per Week by High Risk Population

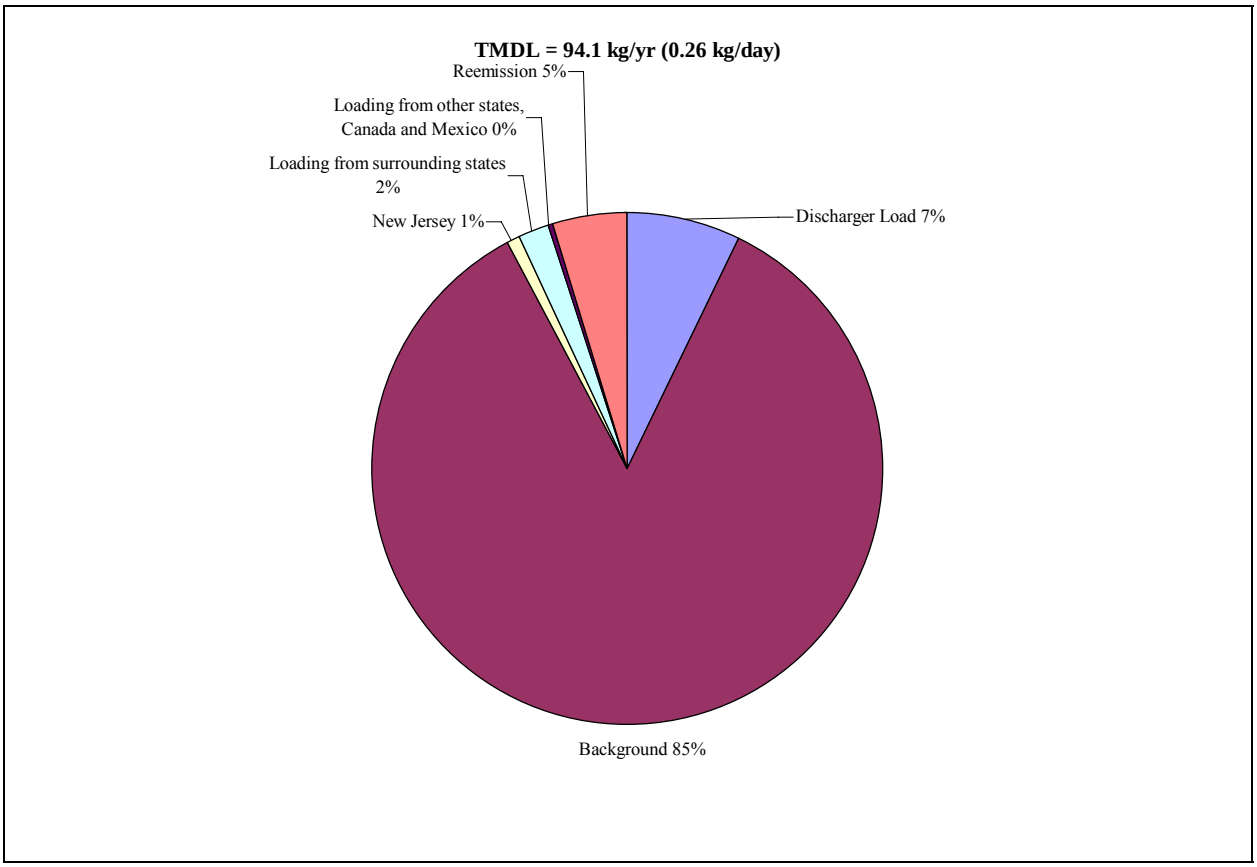
Category	Existing Load (kg/yr)	TMDL Load		Percent Reduction
		kg/yr	kg/day	
Total Annual Load	**601.0**	**94.1**	**0.26**	**84.3%**
Discharger Load (WLA)	6.8	6.8	0.02	-
Air Deposition Load (LA/WLA)	594.2	87.3	0.24	85.3%
Background due to natural source	77.3	77.3	0.21	-
Background due to anthropogenic sources	231.8	2.6	0.01	98.9%
New Jersey	74.1	0.8	0.002	98.9%
Loading from surrounding states	154.6	1.8	0.005	98.9%
Loading from other states, Canada and Mexico	39.6	0.4	0.001	98.9%
reemission due to natural source	4.2	4.2	0.01	-
Reemission due to anthropogenic source	12.7	0.1	0.0004	98.9%

Note: The TMDL loadings presented in the above table were rounded to 0.1 kg/yr. Percents of required reductions were calculated based on values with more significant digits. Using the values from the table to calculate the percent reduction may generate inaccurate results.

Table 10. Distribution of Air Deposition Load between LA and WLA under the TMDL Condition

Air Deposition Load	Annual Load (kg/yr)	Daily Load (kg/day)	Percent of Loading Capacity
Total	87.3	0.24	92.8%
WLA	22.3	0.06	23.7%
LA	65.0	0.18	69.1%

The urban storm water WLA portion of the air deposition load is derived by applying the percentage of urban land within Tier A municipalities (25.6%) to the overall air deposition load (87.3 kg/yr) based on the assumption that this load reaches the water bodies through regulated stormwater sources (see discussion in Section 4). Thus, under the TMDL conditions the WLA has been approximated to be 22.3 kg/yr (87.3 * 0.256), equivalent to 0.06 kg/day (Table 10). The air deposition rate under the TMDL condition is not available to conduct a more precise calculation of the stormwater WLA. More accuracy in developing this WLA is not necessary because the major source of mercury in stormwater is air deposition. Mercury in stormwater must be reduced by reducing air deposition and not through the usual stormwater measures. Therefore a WLA that represents an approximation of the total stormwater load is sufficient for the purposes of this TMDL. Individual stormwater WLAs would not change the response.



Note: Load from stormwater is not distinguished because it is derived from and is a subset of the air deposition load from the different air sources identified.

Figure 5. Distribution of TMDL for One Meal per Week by High Risk Population

As discussed in Section 5.2, multiple conservative assumptions have been made so that the calculated TMDL includes an implicit Margin of Safety (MOS). Therefore, the MOS term of the TMDL equation is set equal to zero. As explained above, a reduction of 85.3% (1-88.3/601) is the highest possible overall reduction that can be expected. The required reduction to achieve unlimited consumption for the high risk population is higher, (1 – 0.07/1.15 = 93.9%). Nevertheless, given the multiple conservative assumptions, this reduction may be achievable. Data gathered following implementation of the TMDL will be used to evaluate success in achieving goals.

5.1. Seasonal Variation/Critical Conditions

40 CFR 130.7(c)(1) requires that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical WQS with seasonal variations". Calculated TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters."

The relative contribution of local, regional, and long-range sources of mercury to fish tissue levels in a waterbody are affected by the speciation of natural and anthropogenic emission sources. The amount of bioavailable methyl mercury in water and sediments is a function of the relative rates of mercury methylation and demethylation. Factors such as pH, length of the aquatic food chain, temperature and dissolved organic carbon can affect bioaccumulation. (EPA, 2009). These factors influence the extent to which mercury bioaccumulates in fish and may vary seasonally and spatially. However, mercury concentrations in fish tissue represent accumulation of the life span of a fish. Use of a fish tissue target integrates spatial and temporal variability, making seasonal variation and critical conditions less significant. In addition, the TMDL fish target value is human health-based, reflecting a longer- term exposure.

In New Jersey, data show levels of mercury in some species of fish in the Pinelands sampling region are generally higher compared to fish in other sampling regions of the state. The reductions called for in this TMDL will attain the target fish tissue concentration in the Pinelands, thereby ensuring that the target is met statewide, within the areas addressed by the TMDL.

5.2. Margin of Safety

A TMDL must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA 303(d)(1)(C), 40C.F.R.130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described.

The MOS included in this TMDL is implicit because of the following conservative assumptions:

- The 90th percentile fish mercury concentration based on the largemouth bass, *Micropterus salmoides*. This species of fish has the highest concentration of the species that are ubiquitous throughout the state
- The percent reduction does not account for additional reductions in methyl mercury that may occur as a result of the implementation of ongoing state and federal programs to reduce sulfur emissions. Reductions in sulfur deposition and sulfate-reducing bacterial activity will decrease the rate of mercury methylation. This TMDL does not account for potential mercury reductions associated with decreased sulfur deposition.

6.0. Monitoring

The Department has engaged in various monitoring efforts that have provided significant insight into mercury contamination issues, some of which are described below. In order to effectively assess progress toward achieving mercury reduction objectives, several monitoring programs are recommended, including:

- A primary monitoring strategy for measuring the levels of mercury and calculating trends is the previously mentioned Routine Fish Monitoring Program for Toxics in Fish. This comprehensive program divides the State's waters into five regions that are sampled on a rotating basis for contaminants in fish. Since mercury is persistent in the environment, accumulates in biological tissue, and biomagnifies in the food chain, adverse impacts to non-aquatic, piscivorous (fish eating) organisms may arise from very low surface water concentrations. Fish tissue sampling provides a cost-effective measure to understanding the effects of mercury in the food chain and the environment.

- A mercury water monitoring program is needed to understand the extent and magnitude of the State's mercury contamination and its effect on aquatic organisms. Such a program must have a comprehensive scope and long-term sampling period. Recent mercury studies from the United State Geological Survey (USGS) have suggested the use of screening tools to target areas where elevated concentrations of mercury may occur. These studies have suggested looking at the presence of wetlands within watersheds, dissolved organic carbon and suspended sediment concentrations, and stream flow. High dissolved oxygen content (DOC) and suspended sediment concentrations, increased stream flow, and larger wetland areas may point to elevated mercury concentrations. The sampling requirements would consist of total and methyl mercury in the water column as well as methyl mercury in fish tissue. The locations would extend to all regions of the state such as the Pinelands, Northern New Jersey, Delaware Estuary, and Atlantic Estuary. Each region would have at least five randomized sampling locations as well as a reference site, which are small undeveloped watersheds with no known sources of mercury contamination other than air deposition. This sampling is not needed on a yearly basis, but quarterly sampling once every 2-5 years is appropriate. An ongoing project, that is targeting local air source reduction by sampling for mercury in fish, water column, and leaves at four locations from 2007 to 2013, is expected to impact the development of the statewide mercury monitoring program by refining sampling frequencies, protocols, and objectives. In addition, an ongoing study in collaboration with USGS involves establishing a baseline for natural background levels for mercury in surface waters to discern the location of impairments that may have anthropogenic sources in addition to atmospheric deposition e.g. mercurial pesticides on orchard, crops and golf courses and which may have other natural sources, e.g. geologic. This evaluative monitoring has been completed in the Inner and Outer Coastal Plain, Raritan River Basin, Papakating and Wallkill River Watersheds. The investigation is ongoing in the Millstone River Basin, Crosswicks Creek Watershed and Passaic River Basin.

- One hundred POTWs in New Jersey submitted baseline data on mercury concentrations in their treatment plant effluent. These samples were analyzed using the most sensitive analytical method for mercury in wastewater, Method 1631E. This baseline data will be used to determine the effectiveness of the implementation of the dental BMPs and the installation of the amalgam separators. These POTWs are

required to conduct additional mercury sampling and analyses, using the same analytical method, after amalgam separator installation.

- In-stream monitoring to evaluate effectiveness of the dental amalgam rule is required at target locations upstream and downstream of the POTW discharge. The monitoring sites will be sampled semi-annually to evaluate ambient water quality before and after the rule's implementation to observe the significance of the reductions. Currently, only one site has been targeted. This project needs to expand by selecting suitable locations based on reviewing the POTW effluent data.

- Air sampling under the National Mercury Monitoring Deposition Network is required to continue to monitor long-term loadings and trends from atmospheric deposition. This program currently has only one site in the New Brunswick area. Additional sites in southern and northern portions of the state this network are needed to improve knowledge of depositional rates for different regions of the state and assist in atmospheric deposition source track down.

Monitoring studies already carried out have provided the following information:

- The Department's Air Program has collected speciated ambient mercury concentration data from several Tekran units that can be used to estimate dry deposition. To date, over two years' data from units at two locations, Elizabeth and New Brunswick have been checked for quality and are in the process of being evaluated. Data on wet deposition is being collected in New Brunswick and is analyzed by the National Mercury Deposition Network.

- Water monitoring data collected by NJDEP/USGS in the Ambient and Supplemental Surface Water Networks show that of the 1,752 results since 1997, nearly 67% had concentrations less than the detection levels. None of the total mercury values exceeded the current acute freshwater aquatic life criterion for dissolved mercury of 1.4 microgram per liter (ug/l) or the chronic criterion of 0.77 ug/l, but 3% of the samples exceeded the human health criterion of 0.05 ug/l. Other mercury studies and projects by NJDEP and USGS over the years show similar results, the majority of mercury concentrations are below detection levels. Detection levels have improved since 1997 with detection levels between 0.04 and 0.1 ug/l to detection levels between 0.01 and 0.02 ug/l since 2004.

- In response to the need for detection of low levels of mercury, the Department initiated a preliminary study of low level mercury occurrence in surface waters. Using EPA's method 1631E, the project consisted of 33 filtered samples with accompanying field blanks at 23 unique stations across the state. The detection level at the Wisconsin laboratory being used was 0.04 ppt. Results did not exceed any of the existing surface water quality criteria. Mercury concentrations did not appear to be influenced by land use, but did appear to increase with stream flow. The findings suggest that air deposition is a major influence on in-stream mercury concentrations. In 2007, the Department conducted a follow-up study to determine seasonal

variability in total and methyl mercury concentrations at 7 reference stations, small undeveloped watersheds with no known sources of mercury contamination other than air deposition. Although total mercury showed no seasonal patterns, methyl mercury had elevated levels during the summer due to higher methylation rates during the warmer months. In addition, the project verified new sampling protocols that allow one person to conduct low level mercury sampling, thereby reducing manpower requirements and allowing this sampling to be incorporated into an ambient or routine program.

- A 150 well, statewide, shallow Ground Water Quality Monitoring Network, which was stratified as a function of land use, has been established and is sampled on a 5 year cycle for mercury and other contaminants. During the first 5 year sampling cycle from 1999 to 2004, mercury concentrations were found to range from <0.01 to 1.7 ug/L in ground water from 148 wells and only 5 of those were detectable above the laboratory reporting limits. In addition, other ground water data has been collected under the Private Well Testing Act that required private wells in 9 Southern New Jersey counties to test for mercury. A total of 25,270 wells were tested with a concentration range of 114.2 ug/l to "not detected". Approximately 1% had concentrations above the drinking water maximum contaminate level (MCL) of 2 ug/l. An analysis of the data showed no obvious geographic or land use patterns for the elevated mercury results.

7.0. Reasonable Assurance

New Jersey has a long history of working toward the reduction of mercury contamination within the state and working with interstate organizations to reduce the mercury both coming into and leaving the state. Much progress has been made. Because of New Jersey's past successes in the reduction of mercury, the actions New Jersey has underway and its commitment to implementing further actions as necessary, including working with neighboring states to reduce sources originating from outside the state, there is reasonable assurance that the goals of the TMDL will be met.

New Jersey began working to reduce mercury releases to the environment in 1992 with the formation of a Mercury Task Force. That Task Force examined the many routes and sources of mercury exposure and found air emissions to be the number one source of mercury contamination in New Jersey. The Task Force identified the largest source of mercury air emissions in New Jersey as Municipal Solid Waste (MSW) Incinerators. The Task Force recommended a statewide mercury emission standard for MSW Incinerators, which was implemented in 1996. In addition to the MSW incinerator standards, New Jersey passed the "Dry Cell Battery Management Act" in 1992, banning the use of mercury in certain batteries. These two efforts reduced MSW incinerator mercury emissions by 97% between 1992 and 2006.

In 1998, New Jersey convened a second Mercury Task Force. The second Task Force consisted of representatives from government, emission sources, public interest groups, academia, and fishing organizations. This Task Force was charged with reviewing the current science on

mercury impacts on human health and ecosystems, inventorying and assessing mercury sources, and developing a comprehensive mercury reduction plan for NJ. The "New Jersey Mercury Task Force Report" published in December 2001 established a goal of the virtual elimination of anthropogenic sources of mercury and provided recommendations and targets for further reducing mercury emissions in New Jersey. The Task Force Report is available at http://www.nj.gov/dep/dsr/mercury_task_force.htm

In 2007 the Department's Mercury Workgroup evaluated New Jersey's progress towards meeting the goals and recommendations of the Task Force and began putting together a Mercury Reduction Plan to identify the necessary additional actions to continue to reduce mercury emissions in New Jersey. The reduction plan will serve as the implementation plan for these TMDLs.

Below is a summary of actions that have been taken to reduce New Jersey's mercury loadings.

- To participate in and support regional, national, and global efforts to reduce mercury uses, releases, and exposures New Jersey is a member of the Interstate Mercury Education and Reduction Clearinghouse (IMERC), a member of the Northeast Waste Management Officials Association (NEWMOA), the Quicksilver Caucus, Northeast States for Consolidated Air Use Management (NESCAUM), Environmental Council of the States (ECOS), and Toxics in Packaging.

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- In conjunction with NEWMOA, informational brochures were developed for tanning salons and property managers concerning the management of mercury containing fluorescent lamps. The brochures were sent to every tanning salon and property management company in the state.

- New Jersey works with interstate organizations to assist in the development of federal legislation that minimizes the use of mercury in products. The Department is a member of and works with the Northeast Waste Management Officials Association (NEWMOA) on mercury issues. The Department will participate in any effort conducted by NEWMOA or other interstate organization to develop federal legislation to minimize the use of mercury in products.

- On December 6, 2004, New Jersey adopted regulations to establish new requirements for coal-fired boilers, in order to decrease emissions of mercury. These rules are located at http://www.state.nj.us/dep/aqm/Sub27-120604.pdf.

- On December 6, 2004, New Jersey adopted regulations to establish new requirements for iron or steel melters in order to decrease emissions of mercury. The Department provided three years to reduce mercury contamination of scrap through elimination and separation measures. If the source reduction measures do not achieve emission reduction, the rule requires the installation and operation of mercury air pollution control and requires achieving mercury standard starting 1/2010. These rules are located at http://www.state.nj.us/dep/aqm/Sub27-120604.pdf.

- On December 6, 2004, New Jersey adopted regulations to establish new requirements for Hospital/medical/infectious waste (HMIW) incinerators in order to prevent or decrease emissions of mercury by ensuring that the mercury emissions from HMIW incinerators will be maintained at low levels. These rules are located at http://www.state.nj.us/dep/aqm/Sub27-120604.pdf.

- The Department has closely monitored mercury sewage sludge levels and has taken action where existing authority would allow the imposition of a sewage sludge limit or a discharge limitation. For example, the POTW with the highest sewage sludge mercury concentrations was identified and the industry responsible voluntarily agreed to shut down all production of mercury-containing diagnostic kits. Increased focus on removing mercury from products, as well as the proposed dental rule noted above, should continue the decreasing trend of detectable concentrations of mercury found in sewage sludge.

- On December 6, 2004, New Jersey adopted revised regulations to establish new requirements for municipal solid waste (MSW) incinerators in order to prevent or decrease emissions of mercury by requiring MSW incinerators to further reduce their mercury emissions. These rules are located at http://www.state.nj.us/dep/aqm/Sub27-120604.pdf.

- The Department has included all mercury containing products in the Universal Waste Rule which allows generators of waste mercury containing products to manage the waste under less stringent regulations than the Hazardous Waste Regulations. In addition, every county in the state holds at least one household hazardous waste (HHW) collection per year. Most counties hold multiple collections and 3 counties (Burlington, Monmouth, and Morris) have permanent collection sites. Households generating mercury containing products can properly dispose of the items at their county's collection.

- Legislation banning the sale of mercury thermometers was passed in April 2005.

- The New Jersey Legislature passed the Mercury Switch Removal Act of 2005 requiring automobile recycling facilities to remove mercury auto switches from vehicles prior to sending the vehicles for recycling. Automobile recyclers located in New Jersey were required to begin removing the mercury auto switches in May 2006. Manufacturers have stopped using mercury switches in convenience lighting.

- The Department adopted new rules on October 1, 2007 to curtail the release of mercury from dental facilities into the environment. The new rules, under most circumstances, exempt a dental facility from the requirement to obtain an individual permit for its discharge to a POTW, if it implements best management practices (BMPs) for the handling of dental amalgam waste and installs and properly operates an amalgam separator. Dental facilities were required to implement the BMPs by October 1, 2008 and must install and operate an amalgam separator by October 1, 2009. These measures are expected to prevent at least 95 percent of the mercury wastes from being sent to the

POTW and result in approximately 2,550 pounds of mercury removed from the environment each year.

- The Department participated in the Quicksilver Caucus, which developed methods for the retirement and sequestering of mercury.

The out of state contributions to the depositional load of mercury are too great for New Jersey to eliminate mercury contamination of fish tissue by reducing sources originating within its borders alone. New Jersey will work with EPA and other states to eliminate mercury sources nationwide. EPAs efforts to issue MACT (Maximum Achievable Control Technology) standards for utilities to reduce the depositional load of mercury are supported by New Jersey. In October 2008, the New England Interstate Water Pollution Control Commission (NEIWPCC), on behalf of seven states, submitted a petition under the Clean Water Act Section 319(g) requesting EPA to convene an interstate conference to address mercury deposition to the Northeast from upwind states. The petition builds on the Northeast States' regional mercury TMDL (approved by EPA in 2007), which indicates that reductions in mercury deposition from outside the region are needed to meet water quality standards. New Jersey will participate actively in this conference when it is held.

8.0. Implementation Plan

The implementation actions below are the recommendations of the Department's Mercury Task Force (NJDEP, 2009) intended to reduce anthropogenic sources of mercury:

1) Consider developing legislation that reflects the provisions of the Mercury Education and Reduction Model Act prepared by the Northeast Waste Management Officials' Association (NEWMOA), as part of the New England Governors' Mercury Action Plan. This plan addresses mercury-containing products and limits the sale of mercury for approved purposes. Provisions of the model legislation have been adopted by 16 states, including all of the New England states.

2) Continue monitoring of mercury in environmental media. Needed follow-up monitoring is described in Section 6 and is essential for determining the effectiveness of the mercury Total Maximum Daily Load (TMDL).

3) New Jersey contributes only 12.5% to the state mercury deposition; 52% is background deposition (natural and anthropogenic) and the remaining percentage comes from surrounding states, Mexico, and Canada. Reductions required in this TMDL can not be achieved from the New Jersey anthropogenic air sources alone. Mercury reductions on the nationwide and global scales are necessary to meet the TMDL targets set up above.

4) The Department plans to update its mercury water quality criteria based upon the EPA recommended Clean Water Act Section 304(a) for methyl mercury in fish tissue. This criterion requires the development of regional bioaccumulation factors (BAFs) to address differences in the rate of methylation based on other water quality parameters such as pH and

dissolved organic carbon. While the EPA's recommended Clean Water Act Section 304(a) water quality criterion is based on a methyl mercury fish tissue concentration value of 0.3 mg/kg, New Jersey plans to develop criteria based upon a methyl mercury fish tissue concentration of 0.18 mg/kg which is based upon consumption of 1 meal per week by high risk individuals. Updating the mercury criteria based on EPA's recommendation will require calculating BAFs for New Jersey that involves additional surface water and fish tissue sampling. This information will also be used to reevaluate the previously proposed wildlife mercury criteria using updated regional BAFs. The revised mercury criteria will be used to develop TMDLs for areas of the State not covered by the Total Maximum Daily Load for Mercury Impairments Based on Concentration in Fish Tissue Caused Mainly by Air Deposition. In calculating an updated, revised mercury SWQS for human health and wildlife, the Department will divide the state into four regional waters: Pinelands, Non-Pinelands, Delaware Estuary tidal waters, and Atlantic tidal waters. Surface water and fish tissue data will be collected and used to develop new BAFs for each region of the state. The data results will then be applied in calculating the mercury criteria for each region. In 2009, the Department expects to begin data collection in the Pinelands region with plans to continue collection in non-Pinelands water the following year. The next action is to collect data for the Delaware Estuary and Atlantic tidal waters.

5) The existing regulations concerning mercury will continue to be implemented, enforced, and evaluated for effectiveness. This includes the regulations on mercury emissions from air sources, the removal of automobile mercury switches and the dental amalgam regulations.

9.0. Public Participation

There have been various efforts to inform and educate the general public as well as the regulated community about the effects of mercury and the need to reduce anthropogenic sources. The regulatory controls regarding mercury are described in Section 7 and some of the outreach to the general public are noted below.

Over the years the Department, in cooperation with the Department of Health and Senior Services has conducted a great deal of public outreach to the fishing community to inform them of the fish consumption advisories. Surveys were done to determine how best to reach the public. As a result the fish advisories are posted in both Spanish and English. Brochures have been developed and are distributed to doctors and WIC (the federal Women, Infants and Children nutrition program) centers. The Department of Health seafood inspectors distribute and check for postings as part of their inspections.

Currently the Department's Urban Fishing Program educates children from the Newark Bay Complex and throughout New Jersey about their local watershed. Children learn about how people's actions affect the water and human health, and what they can do to help. The NJDEP's Divisions of Watershed Management and Science, Research and Technology in conjunction with the Division of Fish and Wildlife, the Hackensack RiverKeeper, the City of Bayonne and the Municipal Utilities Authority of Bayonne have offered the program for over 10 years. The first several years of the Urban Watershed Program were conducted only in the Newark Bay

Complex. The program has now expanded to other urban areas around the state. Trenton and Camden have participated over the last three years, and we hope to add several more cities in the future.

In conjunction with NEWMOA, informational brochures were developed for tanning salons and property managers concerning the management of mercury containing fluorescent lamps. The brochures were sent to every tanning salon and property management company in the state.

There has been additional public outreach and opportunity for comment for the TMDL itself. In accordance with N.J.A.C. 7:15–7.2(g), this TMDL was proposed by the Department as an amendment to the Atlantic, Cape May, Lower Delaware, Lower Raritan-Middlesex, Mercer, Monmouth, Northeast, Ocean, Sussex, Tri-County, Upper Delaware and Upper Raritan Water Quality Management Plans.

Notice proposing this TMDL was published on June 15, 2009 in the New Jersey Register and in newspapers of general circulation in the affected area in order to notify the public of the opportunity to review the TMDL and submit comments. In addition, an informational presentation followed by a public hearing for the proposed TMDL was held on July 15, 2009. Notice of the proposal and the hearing was also provided to affected Designated Planning Agencies and dischargers in the affected watersheds. One member of the public attended the hearing and declined to comment. No comments were submitted during the public comment period. Various minor edits to the proposal document have been made for clarification.

10.0. Data Sources

Geographic Information System (GIS) data from the Department was used extensively to describe the areas addressed in this document.

- State Boundary of New Jersey, Published by New Jersey Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS), May 20, 2008. On line at: https://njgin.state.nj.us/NJ_NJGINExplorer/jviewer.jsp?pg=DataDownloads

- Watersheds (Subwatersheds by name - DEPHUC14), Drainage basins are delineated from 1:24,000-scale (7.5-minute) USGS quadrangles. The delineations have been developed for general purpose use by USGS District staff over the past 20 years. Arc and polygon attributes have been included in the coverage with basin names and ranks of divides, and 14-digit hydrologic unit codes. *Originator:* U.S. Geological Survey, William H. Ellis, Jr. *Publication_Date:* 19991222 http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip

- NJDEP 2002 Waters of New Jersey (Lakes and Ponds), *Edition* 2008-05-01. The data was created by extracting water polygons which represented lakes and ponds from the 2002 land use/land cover (LU/LC) layer from NJ DEP's geographical information systems (GIS) database http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njwaterbody.zip

- NJDEP 2002 Waters of New Jersey (Rivers, Bays and Oceans), *Version* 20080501; *Edition:* 20080501. The data was created by extracting water polygons which represented Rivers, Bays and Oceans from the 2002 land use/land cover (LU/LC) layer from NJ DEP's geographical information systems (GIS) database. *Online Linkage* http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njarea.zip

- NJPDES Surface Water Discharges in New Jersey, (1:12,000), Version 20090126, *Edition:* 2009-01-26. This is a 2009 update of the 2002 data. New Jersey Pollutant Discharge Elimination System (NJPDES) surface water discharge pipe GIS point coverage compiled from GPSed locations, NJPDES databases, and permit applications. This coverage contains the surface water discharge points and the receiving waters coordinates for the active as well as terminated pipes. *Online Linkeage*: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njpdesswd.zip

- NJDEP Surface Water Quality Standards of New Jersey *Edition:* 200812. This data is a digital representation of New Jersey's Surface Water Quality Standards in accordance with "Surface Water Quality Standards for New Jersey Waters" as designated in N.J.A.C. 7:9 B. The Surface Water Quality Standards (SWQS) establish the designated uses to be achieved and specify the water quality (criteria) necessary to protect the State's waters. Designated uses include potable water, propagation of fish and wildlife, recreation, agricultural and industrial supplies, and navigation. These are reflected in use classifications assigned to specific waters. When interpreting the stream classifications and anti-degradation designations, the descriptions specified in the SWQS at N.J.A.C. 7:9B-1.15 always take precedence. The GIS layer reflects the stream classifications and anti-degradation designations adopted as of June 16, 2008, and it is only supplemental to SWQS and is not legally binding. http://www.state.nj.us/dep/gis/digidownload/zips/statewide/swqs.zip

- "Water Management Areas", created 03/2002 by NJDEP, Division of Watershed Management, the last update January, 2009. *Online Linkage*. http://www.state.nj.us/dep/gis/digidownload/zips/statewide/depwmas.zip

- NJDEP Known Contaminated Site List for New Jersey, 2005, *Edition:* 200602; The Known Contaminated Sites List for New Jersey 2005 are those sites and properties within the state where contamination of soil or ground water has been identified or where there has been, or there is suspected to have been, a discharge of contamination. This list of Known Contaminated Sites may include sites where remediation is either currently under way, required but not yet initiated or has been completed. http://www.state.nj.us/dep/gis/digidownload/zips/statewide/kcsl.zip

- Groundwater Contamination Areas (CKE); this data layer contains information about areas in the state which are specified as the Currently Known Extent (CKE) of ground water pollution. CKE areas are geographically defined areas within which the local ground water resources are known to be compromised because the water quality exceeds drinking water and ground water quality standards for specific contaminants. NJDEP Currently Known Extent of Groundwater Contamination (CKE) for New Jersey, 2007. *Edition:* 200703. *Online Linkage:* http://www.state.nj.us/dep/gis/digidownload/zips/statewide/cke.zip

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Appendix A

Listed Assessment units that were excluded from the Statewide TMDL

Waterbody	Name	Reason for Exclusion from TMDL
02030103120070-01	Passaic River Lwr (Fair Lawn Ave to Goffle)	Mercury in surface water
02030103120080-01	Passaic River Lwr (Dundee Dam to F.L. Ave)	Mercury in surface water
02030103120090-01	Passaic River Lwr (Saddle R to Dundee Dam)	Mercury in surface water
02030103150030-01	Passaic River Lwr (Second R to Saddle R)	Mercury in surface water
02030103150040-01	Passaic River Lwr (4th St br to Second R)	Mercury in surface water
02030103150050-01	Passaic River Lwr (Nwk Bay to 4th St brdg)	Mercury in surface water
02030103170030-01	Hackensack River (above Old Tappan gage)	Mercury in surface water
02030103170060-01	Hackensack River (Oradell to Old Tappan gage)	Mercury in surface water
02030103180030-01	Hackensack River (Ft Lee Rd to Oradell gage)	Mercury in surface water
02030103180080-01	Hackensack River (Rt 3 to Bellmans Ck)	Mercury in surface water
02030103180090-01	Hackensack River (Amtrak bridge to Rt 3)	Mercury in surface water
02030103180100-01	Hackensack River (below Amtrak bridge)	Mercury in surface water
02030104010020-01	Kill Van Kull West	Mercury in surface water
02030104010020-02	Newark Bay / Kill Van Kull (74d 07m 30s)	Mercury in surface water
02030104010030-01	Kill Van Kull East	Mercury in surface water
02030104010030-02	Upper NY Bay / Kill Van Kull (74d07m30s)	Mercury in surface water
02030104020030-01	Arthur Kill North	Mercury in surface water
02030104030010-01	Arthur Kill South	Mercury in surface water
02030104050120-01	Arthur Kill waterfront (below Grasselli)	Mercury in surface water
02040105210060-01	Jacobs Creek (above Woolsey Brook)	Mercury in surface water
02040105230050-01	Assunpink Creek (Shipetaukin to Trenton Rd)	Mercury in surface water
02040201050040-01	Crosswicks Creek (Walnford to Lahaway Ck)	Mercury in surface water
02040201050050-01	Crosswicks Creek (Ellisdale trib - Walnford)	Mercury in surface water
02040201050070-01	Crosswicks Creek (Doctors Ck-Ellisdale trib)	Mercury in surface water
02040206140040-01	Blackwater Branch (above/incl Pine Br)	Mercury in surface water
02040206140050-01	Blackwater Branch (below Pine Branch)	Mercury in surface water
02040206200010-01	Middle Branch / Slab Branch	Mercury in surface water
02040206200020-01	Muskee Creek	Mercury in surface water
02040301020040-01	Muddy Ford Brook	Mercury in surface water
02040301070080-01	Manapaqua Brook	Mercury in surface water
02040301170010-01	Hammonton Creek (above 74d43m)	Mercury in surface water
02040301170020-01	Hammonton Creek (Columbia Rd to 74d43m)	Mercury in surface water
02040302020020-01	Absecon Creek SB	Mercury in surface water
02040302020030-01	Absecon Creek (AC Reserviors) (gage to SB)	Mercury in surface water
02030103010180-01	Passaic River Upr (Pine Bk br to Rockaway)	Mercury in surface water
02030103040010-01	Passaic River Upr (Pompton R to Pine Bk)	Mercury in surface water
02030103120100-01	Passaic River Lwr (Goffle Bk to Pompton R)	Mercury in surface water
02030103180060-01	Berrys Creek (above Paterson Ave)	Mercury in surface water
02030103180070-01	Berrys Creek (below Paterson Ave)	Mercury in surface water
02030105160070-01	South River (below Duhernal Lake)	Mercury in surface water
02040202020030-01	Rancocas Creek NB (incl Mirror Lk-Gaunts Bk)	Mercury in surface water
02040202020040-01	Rancocas Creek NB (NL dam to Mirror Lk)	Mercury in surface water
02040202100060-01	Pennsauken Creek (below NB / SB)	Mercury in surface water
02040301020050-01	Metedeconk River NB (confluence to Rt 9)	Mercury in surface water
02040301040020-01	Metedeconk River (Beaverdam Ck to confl)	Mercury in surface water
02040302050060-01	Great Egg Harbor River (Miry Run to Lake Lenape)	Mercury in surface water

02040302050130-01	Great Egg Harbor River (GEH Bay to Miry Run)	Mercury in surface water
Delaware River 1	Delaware River 1C2	Mercury in surface water
Delaware River 2	Delaware River 1C3	Mercury in surface water
Delaware River 3	Delaware River 1C4	Mercury in surface water
Delaware River 4	Delaware River 1D1	Mercury in surface water
Delaware River 5	Delaware River 1D2	Mercury in surface water
Delaware River 6	Delaware River 1D3	Mercury in surface water
Delaware River 7	Delaware River 1D4	Mercury in surface water
Delaware River 8	Delaware River 1D5	Mercury in surface water
Delaware River 9	Delaware River 1D6	Mercury in surface water
Delaware River 10	Delaware River 1E1	Mercury in surface water
Delaware River 11	Delaware River 1E2	Mercury in surface water
Delaware River 12	Delaware River 1E3	Mercury in surface water
Delaware River 13	Delaware River 1E4	Mercury in surface water
Delaware River 14	Delaware River 1E5	Mercury in surface water
Delaware River 15	Delaware River 2	Mercury in surface water
Delaware River 16	Delaware River 3	Mercury in surface water
Delaware River 17	Delaware River 4	DRBC
Delaware River 18	Delaware River 5A	DRBC
Delaware River 19	Delaware River 5B	DRBC
Delaware River 20	Delaware River 5C	DRBC
02040204910010-02	Delaware Bay (Cape May Pt to Dennis Ck) offshore	DRBC
02040204910010-01	Delaware Bay (CapeMay Pt to Dennis Ck) inshore	DRBC
02040204910040-01	Delaware Bay (Cohansey R to FishingCk)	DRBC
02040204910020-02	Delaware Bay (Dennis Ck to Egg Islnd Pt) offshore	DRBC
02040204910020-01	Delaware Bay (DennisCk to Egg Islnd Pt) inshore	DRBC
02040301200030-02	Wading River (below Rt 542)	Tidal
02040301200080-02	Mullica River (GSP bridge to Turtle Ck)	Tidal
02040301210010-02	Mullica River (below GSP bridge)	Tidal
02030104020030-02	Elizabeth River (below Elizabeth CORP BDY)	Tidal
02030104030010-02	Morses Creek / Piles Creek	Tidal
02030104080040-01	Shrewsbury River (above Navesink River)	Tidal
02030104090040-01	Shark River (above Remsen Mill gage)	Tidal
02030104090060-01	Shark River (below Remsen Mill gage)	Tidal
02030104910020-01	Sandy Hook Bay (east of Thorns Ck)	Tidal
02040201030010-01	Duck Creek and UDRV to Assunpink Ck	Tidal
02030104060010-01	Cheesequake Creek / Whale Creek	Tidal
02030104070110-01	Navesink River (below Rt 35) / Lower Shrewsbury	Tidal
02040301080060-01	Toms River Lwr (Rt 166 to Oak Ridge Pkwy)	Tidal
02030104070110-01	Navesink River (below Rt 35) / Lower Shrewsbury	Tidal
02030104060060-01	Pews Creek to Shrewsbury River	Tidal
02040301080060-01	Toms River Lwr (Rt 166 to Oak Ridge Pkwy)	Tidal
02040301200030-02	Wading River (below Rt 542)	Tidal
02030104080010-01	Little Silver Creek / Town Neck Creek	Tidal
02040301200080-02	Mullica River (GSP bridge to Turtle Ck)	Tidal
02040301210010-02	Mullica River (below GSP bridge)	Tidal
02040302020010-01	Absecon Creek NB	Tidal
02040302020040-01	Absecon Creek (below gage)	Tidal

02030104080010-01	Little Silver Creek / Town Neck Creek	Tidal
02030104080020-01	Parkers Creek / Oceanport Creek	Tidal
02030104080030-01	Branchport Creek	Tidal
02040201070030-01	Shady Brook / Spring Lake / Rowan Lake	Tidal
02040202120080-01	Big Timber Creek (below NB/SB confl)	Tidal
02040202130040-01	Mantua Creek (Edwards Run to rd to Sewell)	Tidal
02040202140040-01	Moss Branch / Little Timber Creek (Repaupo)	Tidal
02040202140050-01	Repaupo Creek (below Tomlin Sta Rd) / Cedar Swamp	Tidal
02040202160020-01	Oldmans Creek (Rt 45 to Commissioners Rd)	Tidal
02040206090080-01	Cohansey River (Greenwich to 75d17m50s)	Tidal
02040206090100-01	Cohansey River (below Greenwich)	Tidal
02030104010010-01	Newark Airport Peripheral Ditch	Tidal
02040206100040-01	Cedar Creek (above Rt 553)	Tidal
02040206160030-01	Maurice River (Union Lake to Sherman Ave)	Other sources of Hg
02030103030070-01	Rockaway River (74d 33m 30s to Stephens Bk)	Other sources of Hg
02030103100070-01	Ramapo River (below Crystal Lake bridge)	Other sources of Hg
02040201050060-01	Ellisdale Trib (Crosswicks Creek)	Other sources of Hg
02040201070020-01	Crosswicks Creek (below Doctors Creek)	Other sources of Hg
02030103100060-01	Crystal Lake / Pond Brook	Other sources of Hg
02030104060040-01	Chingarora Creek to Thorns Creek	Other sources of Hg
02030104060050-01	Waackaack Creek	Other sources of Hg
02030105160090-01	Red Root Creek / Crows Mill Creek	Hg in groundwater
02030105160100-01	Raritan River Lwr (below Lawrence Bk)	Hg in groundwater
02040105230020-01	Assunpink Creek (New Sharon Br to/incl Lake)	Hg in groundwater
02040105230030-01	New Sharon Branch (Assunpink Creek)	Hg in groundwater
02040105230040-01	Assunpink Creek (Trenton Rd to New Sharon Br)	Hg in groundwater
02040105240010-01	Shabakunk Creek	Hg in groundwater
02040105240050-01	Assunpink Creek (below Shipetaukin Ck)	Hg in groundwater
02040201030010-01	Duck Creek and UDRV to Assunpink Ck	Hg in groundwater
02040201040040-01	Jumping Brook (Monmouth Co)	Hg in groundwater
02040301160020-01	Mullica River (above Jackson Road)	Hg in groundwater
02040301170040-01	Mullica River (Batsto R to Pleasant Mills)	Hg in groundwater
02040301170060-01	Mullica River (Rt 563 to Batsto River)	Hg in groundwater
02040301170080-01	Mullica River (Lower Bank Rd to Rt 563)	Hg in groundwater
02040301170130-01	Mullica River (Turtle Ck to Lower Bank Rd)	Hg in groundwater
02040301190050-01	Wading River WB (Jenkins Rd to Rt 563)	Hg in groundwater
02040301200020-01	Wading River (Rt 542 to Oswego River)	Hg in groundwater
02030103180040-01	Overpeck Creek	HEP
02030103180050-01	Hackensack River (Bellmans Ck to Ft Lee Rd)	HEP
02030104050060-01	Rahway River (Robinsons Br to Kenilworth Blvd)	HEP
02030104050100-01	Rahway River (below Robinsons Branch)	HEP
02030105120170-01	Raritan River Lwr (Lawrence Bk to Mile Run)	HEP
02030105160100-01	Raritan River Lwr (below Lawrence Bk)	HEP
02040302940010-01	Atlantic Ocean (34th St to Corson Inl) inshore	Tidal
02040302940010-02	Atlantic Ocean (34th St to Corson Inl) offshore	Tidal
02040302920010-01	Atlantic Ocean (Absecon In to Ventnor) inshore	Tidal
02040302920010-02	Atlantic Ocean (Absecon In to Ventnor) offshore	Tidal
02040301920010-02	Atlantic Ocean (Barnegat to Surf City) offshore	Tidal
02040301920010-01	Atlantic Ocean (Barnegat to Surf City)inshore	Tidal

02040302940050-01	Atlantic Ocean (CM Inlet to Cape May Pt) inshore	Tidal
02040302940050-02	Atlantic Ocean (CM Inlet to Cape May Pt) offshore	Tidal
02030902940020-01	Atlantic Ocean (Corson to Townsends Inl) inshore	Tidal
02030902940020-02	Atlantic Ocean (Corson to Townsends Inl) offshore	Tidal
02040302930010-01	Atlantic Ocean (Great Egg to 34th St) inshore	Tidal
02040302930010-02	Atlantic Ocean (Great Egg to 34th St) offshore	Tidal
02040301920030-01	Atlantic Ocean (Haven Bch to Lit Egg) inshore	Tidal
02040301920030-02	Atlantic Ocean (Haven Bch to Lit Egg) offshore	Tidal
02040302940040-01	Atlantic Ocean (Hereford to Cape May In) inshore	Tidal
02040302940040-02	Atlantic Ocean (Hereford to Cape May In) offshore	Tidal
02040301910020-01	Atlantic Ocean (Herring Is to Rt 37) inshore	Tidal
02040301910020-02	Atlantic Ocean (Herring Is to Rt 37) offshore	Tidal
02040302910010-01	Atlantic Ocean (Ltl Egg to Absecon In) inshore	Tidal
02040302910010-02	Atlantic Ocean (Ltl Egg to Absecon In) offshore	Tidal
02040301910010-01	Atlantic Ocean (Manasquan/Herring Is) inshore	Tidal
02040301910010-02	Atlantic Ocean (Manasquan/Herring Is) offshore	Tidal
02030104920020-01	Atlantic Ocean (Navesink R to Whale Pond) inshore	Tidal
02030104920020-02	Atlantic Ocean (Navesink R to Whale Pond) offshore	Tidal
02040301910030-01	Atlantic Ocean (Rt 37 to Barnegat Inlet) inshore	Tidal
02040301910030-02	Atlantic Ocean (Rt 37 to Barnegat Inlet) offshore	Tidal
02030104920010-01	Atlantic Ocean (Sandy H to Navesink R) inshore	Tidal
02030104920010-02	Atlantic Ocean (Sandy H to Navesink R) offshore	Tidal
02030104930020-01	Atlantic Ocean (Shark R to Manasquan) inshore	Tidal
02030104930020-02	Atlantic Ocean (Shark R to Manasquan) offshore	Tidal
02040301920020-01	Atlantic Ocean (Surf City to Haven Be) inshore	Tidal
02040301920020-02	Atlantic Ocean (Surf City to Haven Be) offshore	Tidal
02030902940030-01	Atlantic Ocean (Townsends to Hereford In) inshore	Tidal
02030902940030-02	Atlantic Ocean (Townsends to Hereford In) offshore	Tidal
02040302920020-01	Atlantic Ocean (Ventnor to Great Egg) inshore	Tidal
02040302920020-02	Atlantic Ocean (Ventnor to Great Egg) offshore	Tidal
02030104930010-01	Atlantic Ocean (Whale Pond to Shark R) inshore	Tidal

Appendix B

Fish Tissue Data

Location	Species	Field (or lab) Total Length (cm)	Hg (mg/kg) ug/g wet wt	Year
Alcyon Lake	Largemouth Bass	28.6	0.67	1992
Alcyon Lake	Largemouth Bass	33.7	0.41	1992
Batsto Lake	Yellow Bullhead	23.7	0.23	1992
Batsto Lake	Brown Bullhead	26.5	0.18	1992
Batsto Lake	Chain Pickerel	57.3	1.06	1992
Batsto Lake	Largemouth Bass	27.1	0.76	1992
Batsto Lake	Largemouth Bass	35.4	1.20	1992
Batsto Lake	Largemouth Bass	37.5	1.28	1992
Big Timber Creek	Black Crappie	15.5	0.07	1992
Big Timber Creek	Brown Bullhead	29.4	0.05	1992
Big Timber Creek	Brown Bullhead	31	0.06	1992
Big Timber Creek	Channel Catfish	42.3	0.09	1992
Big Timber Creek	White Catfish	33.4	0.08	1992
Big Timber Creek	White Catfish	29.6	0.09	1992
Big Timber Creek	Largemouth Bass	33.0	0.10	1992
Big Timber Creek	Largemouth Bass	28.2	0.12	1992
Big Timber Creek	Largemouth Bass	25.5	0.06	1992
Clementon Lake	Chain Pickerel	35.5	0.14	1992
Clementon Lake	Chain Pickerel	33	0.16	1992
Clementon Lake	Chain Pickerel	40	0.16	1992
Clementon Lake	Chain Pickerel	50.5	0.32	1992
Clementon Lake	Chain Pickerel	48.6	0.37	1992
Clementon Lake	Chain Pickerel	47.6	0.38	1992
Clementon Lake	Largemouth Bass	35.9	0.28	1992
Clementon Lake	Largemouth Bass	38.7	0.49	1992
Clinton Reservoir	Largemouth Bass	28.2	0.39	1992
Clinton Reservoir	Largemouth Bass	34.3	0.60	1992
Clinton Reservoir	Largemouth Bass	34.6	0.73	1992
Clinton Reservoir	Largemouth Bass	44.1	0.83	1992
Clinton Reservoir	Largemouth Bass	36.0	0.84	1992
Clinton Reservoir	Largemouth Bass	37.1	0.85	1992
Cooper River Park Lake	Black Crappie	16.7	0.04	1992
Cooper River Park Lake	Black Crappie	18.1	0.10	1992
Cooper River Park Lake	Black Crappie	18.4	0.12	1992
Cooper River Park Lake	Largemouth Bass	19.5	0.12	1992
Cooper River Park Lake	Largemouth Bass	21.4	0.03	1992
Cooper River Park Lake	Largemouth Bass	21.7	0.04	1992
Cooper River Park Lake	Largemouth Bass	25.5	0.08	1992
Cooper River Park Lake	Largemouth Bass	28	0.07	1992
Cooper River Park Lake	Largemouth Bass	30.8	0.09	1992

Cooper River Park Lake	Largemouth Bass	32.2	0.10	1992
Cooper River Park Lake	Largemouth Bass	32.8	0.13	1992
Cooper River Park Lake	Largemouth Bass	35.5	0.14	1992
Cooper River Park Lake	Largemouth Bass	43.5	0.31	1992
Cooper River Park Lake	Largemouth Bass	44	0.56	1992
Cooper River Park Lake	Largemouth Bass	22.1	0.09	1992
Cooper River Park Lake	Largemouth Bass	25.5	0.08	1992
Cooper River Park Lake	Largemouth Bass	28	0.07	1992
Cooper River Park Lake	Largemouth Bass	30.8	0.09	1992
Cooper River Park Lake	Largemouth Bass	35.5	0.14	1992
Cooper River Park Lake	Largemouth Bass	43.5	0.31	1992
Cranberry Lake	Chain Pickerel	42.4	0.27	1992
Cranberry Lake	Chain Pickerel	56.9	0.37	1992
Cranberry Lake	Chain Pickerel	55.5	0.37	1992
Cranberry Lake	Hybrid Striped Bass	38.2	0.29	1992
Cranberry Lake	Hybrid Striped Bass	37	0.31	1992
Cranberry Lake	Hybrid Striped Bass	52	0.43	1992
Crystal Lake	Brown Bullhead	19.8	0.02	1992
Crystal Lake	Brown Bullhead	20	0.05	1992
Dundee Lake	Brown Bullhead	27.1	0.19	1992
Dundee Lake	Brown Bullhead	29.3	0.20	1992
East Creek Lake	Chain Pickerel	31.5	0.79	1992
East Creek Lake	Chain Pickerel	34..5	1.03	1992
East Creek Lake	Chain Pickerel	41.4	1.33	1992
East Creek Lake	Chain Pickerel	39	1.33	1992
East Creek Lake	Chain Pickerel	51	1.59	1992
East Creek Lake	Chain Pickerel	40	1.76	1992
East Creek Lake	Chain Pickerel	50	2.30	1992
East Creek Lake	Chain Pickerel	46.2	2.44	1992
East Creek Lake	Chain Pickerel	52.5	2.82	1992
East Creek Lake	Yellow Bullhead	26.8	1.29	1992
East Creek Lake	Yellow Bullhead	27.4	1.47	1992
Evans Lake	Largemouth Bass	27.8	0.15	1992
Evans Lake	Largemouth Bass	21.5	0.33	1992
Harrisville Lake	Chain Pickerel	40	0.99	1992
Harrisville Lake	Chain Pickerel	33.5	1.21	1992
Harrisville Lake	Chain Pickerel	28.3	1.71	1992
Harrisville Lake	Chain Pickerel	45.7	1.74	1992
Harrisville Lake	Chain Pickerel	51.4	2.10	1992
Harrisville Lake	Yellow Bullhead	27.5	1.36	1992
Lake Carasaljo	Chain Pickerel	34.9	0.28	1992
Lake Hopatcong	Chain Pickerel	35.1	0.19	1992
Lake Hopatcong	Chain Pickerel	48	0.22	1992
Lake Hopatcong	Chain Pickerel	47.3	0.35	1992
Lake Hopatcong	Chain Pickerel	45	0.37	1992
Lake Hopatcong	Chain Pickerel	53	0.64	1992
Lake Hopatcong	Largemouth Bass	39.9	0.27	1992
Lake Hopatcong	Largemouth Bass	41.4	0.28	1992
Lake Hopatcong	Largemouth Bass	29.5	0.30	1992

Lake Nummy	Chain Pickerel	35	1.36	1992
Lake Nummy	Yellow Bullhead	26.7	0.32	1992
Lake Nummy	Yellow Bullhead	27.8	0.32	1992
Lake Nummy	Yellow Bullhead	28.1	0.32	1992
Lenape Lake	Chain Pickerel	35.5	0.25	1992
Lenape Lake	Chain Pickerel	44.8	0.54	1992
Lenape Lake	Chain Pickerel	49.7	0.89	1992
Marlton Lake	Largemouth Bass	38	1.36	1992
Maskells Mill Lake	Chain Pickerel	28	0.37	1992
Merrill Creek	Rainbow Trout	25.3	0.04	1992
Merrill Creek	Rainbow Trout	24.7	0.08	1992
Merrill Creek Reservoir	Rainbow Trout	32.1	0.14	1992
Merrill Creek Reservoir	Rainbow Trout	37.5	0.14	1992
Merrill Creek Reservoir	Rainbow Trout	38.6	0.24	1992
Merrill Creek Reservoir	Lake Trout	51.3	0.44	1992
Merrill Creek Reservoir	Lake Trout	51.6	0.77	1992
Merrill Creek Reservoir	Lake Trout	53.2	0.79	1992
Merrill Creek Reservoir	Lake Trout	56.4	0.69	1992
Merrill Creek Reservoir	Largemouth Bass	30.9	0.29	1992
Merrill Creek Reservoir	Largemouth Bass	43.9	0.96	1992
Merrill Creek Reservoir	Largemouth Bass	41.0	1.21	1992
Monksville Reservoir	Chain Pickerel	39.3	0.21	1992
Monksville Reservoir	Chain Pickerel	42.4	0.36	1992
Monksville Reservoir	Chain Pickerel	64	1.14	1992
Monksville Reservoir	Largemouth Bass	28.7	0.45	1992
Monksville Reservoir	Largemouth Bass	33.9	0.52	1992
Monksville Reservoir	Largemouth Bass	38.4	1.00	1992
Mountain Lake	Largemouth Bass	31.8	0.22	1992
Mountain Lake	Largemouth Bass	37.4	0.37	1992
Mountain Lake	Largemouth Bass	47.0	0.90	1992
New Brooklyn Lake	Chain Pickerel	18.7	0.10	1992
New Brooklyn Lake	Chain Pickerel	37.7	0.23	1992
New Brooklyn Lake	Chain Pickerel	46.6	0.79	1992
Newton Creek, North	Brown Bullhead	29	0.02	1992
Newton Creek, North	Brown Bullhead	34.4	0.03	1992
Newton Creek, North	Brown Bullhead	32.3	0.03	1992
Newton Creek, North	Brown Bullhead	32.4	0.03	1992
Newton Creek, North	Channel Catfish	36.5	0.08	1992
Newton Creek, North	Channel Catfish	47.1	0.12	1992
Newton Creek, South	Brown Bullhead	25.9	0.04	1992
Newton Creek, South	Brown Bullhead	26.1	0.06	1992
Newton Creek, South	Brown Bullhead	29.5	0.18	1992
Newton Creek, South	Chain Pickerel	25.3	0.10	1992
Newton Creek, South	Largemouth Bass	37.1	0.23	1992
Newton Creek, South	Largemouth Bass	36.6	0.24	1992
Newton Creek, South	Largemouth Bass	30.7	1.15	1992
Newton Lake	Black Crappie	18.4	0.09	1992
Newton Lake	Black Crappie	19.4	0.11	1992
Newton Lake	Black Crappie	20.4	0.13	1992

Newton Lake	Largemouth Bass	30	0.05	1992
Newton Lake	Largemouth Bass	30.6	0.05	1992
Newton Lake	Largemouth Bass	33.6	0.06	1992
Newton Lake	Largemouth Bass	33.1	0.06	1992
Newton Lake	Largemouth Bass	25.8	0.06	1992
Newton Lake	Largemouth Bass	25.0	0.06	1992
Newton Lake	Largemouth Bass	31.0	0.07	1992
Newton Lake	Largemouth Bass	31.0	0.07	1992
Newton Lake	Largemouth Bass	29.1	0.07	1992
Newton Lake	Largemouth Bass	45.2	0.18	1992
Newton Lake	Largemouth Bass	41.1	0.22	1992
Newton Lake	Largemouth Bass	45.6	0.40	1992
Rancocas Creek	Channel Catfish	45.6	0.11	1992
Rockaway River	Brown Bullhead	31	0.12	1992
Rockaway River	Chain Pickerel	34	0.15	1992
Rockaway River	Chain Pickerel	30.6	0.15	1992
Rockaway River	Chain Pickerel	38.8	0.25	1992
Rockaway River	Chain Pickerel	40.7	0.29	1992
Rockaway River	Chain Pickerel	44.7	0.31	1992
Rockaway River	Rainbow Trout	53.6	0.04	1992
Rockaway River	Yellow Bullhead	21.2	0.15	1992
Rockaway River near Whippany	Largemouth Bass	26.4	0.36	1992
Rockaway River near Whippany	Largemouth Bass	28.9	0.59	1992
Rockaway River near Whippany	Largemouth Bass	31.5	0.73	1992
Round Valley Reservoir	Lake Trout	40	0.06	1992
Round Valley Reservoir	Lake Trout	54.4	0.14	1992
Round Valley Reservoir	Lake Trout	75.5	0.14	1992
Saw Mill Lake	Brown Bullhead	36.5	0.05	1992
Saw Mill Lake	Brown Bullhead	33.1	0.06	1992
Saw Mill Lake	Brown Bullhead	39.5	0.07	1992
Saw Mill Lake	Brown Bullhead	37.9	0.07	1992
Saw Mill Lake	Northern Pike	53.4	0.27	1992
Shadow Lake	Largemouth Bass	29.1	0.12	1992
Shadow Lake	Largemouth Bass	30.4	0.15	1992
Shadow Lake	Largemouth Bass	36.7	0.18	1992
Shadow Lake	Largemouth Bass	31.2	0.26	1992
Spring Lake	Largemouth Bass	37.1	0.21	1992
Spring Lake	Largemouth Bass	49.9	0.75	1992
Spring Lake	Largemouth Bass	47.8	0.80	1992
Spruce Run Reservoir	Hybrid Striped Bass	33.1	0.17	1992
Spruce Run Reservoir	Hybrid Striped Bass	37.1	0.19	1992
Spruce Run Reservoir	Hybrid Striped Bass	38.2	0.22	1992
Spruce Run Reservoir	Largemouth Bass	25.2	0.10	1992
Spruce Run Reservoir	Largemouth Bass	28.4	0.19	1992
Spruce Run Reservoir	Largemouth Bass	41.2	0.41	1992
Spruce Run Reservoir	Largemouth Bass	43.8	0.64	1992
Stafford Forge Main Line	Chain Pickerel	26.6	0.59	1992
Stafford Forge Main Line	Chain Pickerel	27.7	0.63	1992
Stafford Forge Main Line	Chain Pickerel	29.9	0.85	1992

Strawbridge Lake	Black Crappie	15.3	0.13	1992
Strawbridge Lake	Black Crappie	14.8	0.24	1992
Strawbridge Lake	Black Crappie	14.3	0.24	1992
Swartswood Lake	Chain Pickerel	39.6	0.09	1992
Swartswood Lake	Chain Pickerel	43.3	0.10	1992
Swartswood Lake	Chain Pickerel	42.3	0.12	1992
Swartswood Lake	Smallmouth Bass	30.8	0.12	1992
Swartswood Lake	Smallmouth Bass	35.5	0.18	1992
Swartswood Lake	Smallmouth Bass	37.5	0.29	1992
Wading River	Chain Pickerel	39.4	0.66	1992
Wading River	Chain Pickerel	40.8	0.68	1992
Wading River	Chain Pickerel	34.3	0.82	1992
Wading River	Chain Pickerel	37.3	1.09	1992
Wading River	Chain Pickerel	43.6	1.23	1992
Wanaque Reservoir	Chain Pickerel	38.7	0.33	1992
Wanaque Reservoir	Chain Pickerel	55.5	0.93	1992
Wanaque Reservoir	Smallmouth Bass	27.5	0.34	1992
Wanaque Reservoir	Smallmouth Bass	37.9	0.51	1992
Wanaque Reservoir	Largemouth Bass	32.8	0.40	1992
Wanaque Reservoir	Largemouth Bass	37.8	0.61	1992
Wanaque Reservoir	Largemouth Bass	36.6	0.75	1992
Wanaque Reservoir	Largemouth Bass	40.5	1.01	1992
Wanaque Reservoir	Largemouth Bass	43.8	1.17	1992
Wanaque Reservoir	Largemouth Bass	46.4	1.18	1992
Wilson Lake	Chain Pickerel	37.8	0.24	1992
Wilson Lake	Chain Pickerel	36.3	0.38	1992
Wilson Lake	Chain Pickerel	50.6	1.06	1992
Wilson Lake	Chain Pickerel	34.4	1.53	1992
Woodstown Memorial Lake	Black Crappie	17.5	0.08	1992
Woodstown Memorial Lake	Largemouth Bass	24.5	0.11	1992
Woodstown Memorial Lake	Largemouth Bass	27.8	0.20	1992
Woodstown Memorial Lake	Largemouth Bass	27.6	0.23	1992
Woodstown Memorial Lake	Largemouth Bass	39.3	0.34	1992
Woodstown Memorial Lake	Largemouth Bass	45.1	0.50	1992
Big Timber Creek	Channel Catfish	42.3	0.09	1993
Budd Lake	White Catfish	33.8	0.17	1993
Budd Lake	Northern Pike	54.8	0.11	1993
Budd Lake	Northern Pike	64	0.11	1993
Budd Lake	Northern Pike	68.5	0.14	1993
Canistear Reservoir	Largemouth Bass	36	0.41	1993
Canistear Reservoir	Largemouth Bass	42.2	0.52	1993
Canistear Reservoir	Largemouth Bass	40	0.55	1993
Canistear Reservoir	Largemouth Bass	45.7	0.61	1993
Canistear Reservoir	Largemouth Bass	43.5	0.68	1993
Canistear Reservoir	Largemouth Bass	39.1	0.69	1993
Canistear Reservoir	Largemouth Bass	38.8	0.74	1993
Carnegie Lake	Largemouth Bass	39.1	0.20	1993
Carnegie Lake	Largemouth Bass	32.3	0.29	1993
Carnegie Lake	Largemouth Bass	35.1	0.37	1993

Carnegie Lake	Largemouth Bass	44.7	0.45	1993
Carnegie Lake	Largemouth Bass	35.1	0.58	1993
Carnegie Lake	Largemouth Bass	51.3	1.07	1993
Corbin City Impoundment #3	Brown Bullhead	26.7	0.07	1993
Crystal Lake	Black Crappie	19.1	0.04	1993
Crystal Lake	Black Crappie	20.7	0.18	1993
Crystal Lake	Largemouth Bass	23.5	0.09	1993
Crystal Lake	Largemouth Bass	30.0	0.14	1993
Crystal Lake	Largemouth Bass	42.6	0.28	1993
Manasquan Reservoir	Largemouth Bass	31	0.76	1993
Manasquan Reservoir	Largemouth Bass	38.9	2.35	1993
Manasquan Reservoir	Largemouth Bass	36.4	2.45	1993
Manasquan Reservoir	Largemouth Bass	40	2.49	1993
Manasquan Reservoir	Largemouth Bass	38	2.89	1993
Manasquan Reservoir	Largemouth Bass	41.1	3.16	1993
Manasquan Reservoir	Largemouth Bass	40.3	3.87	1993
Maskells Mill Lake	Black Crappie	20.8	0.20	1993
Maskells Mill Lake	Black Crappie	26.3	0.29	1993
Maskells Mill Lake	Brown Bullhead	25.4	0.23	1993
Maskells Mill Lake	Brown Bullhead	28.9	0.31	1993
Maskells Mill Lake	Brown Bullhead	28.9	0.47	1993
Maskells Mill Lake	Largemouth Bass	25.9	0.36	1993
Maskells Mill Lake	Largemouth Bass	32.4	0.48	1993
Mullica River	Chain Pickerel	40.7	1.21	1993
New Brooklyn Lake	Chain Pickerel	46.2	0.82	1993
New Brooklyn Lake	Chain Pickerel	59.7	1.30	1993
Round Valley Reservoir	Largemouth Bass	25.2	0.16	1993
Round Valley Reservoir	Largemouth Bass	37.1	0.24	1993
Round Valley Reservoir	Largemouth Bass	35.1	0.24	1993
Spruce Run Reservoir	Northern Pike	63.2	0.41	1993
Spruce Run Reservoir	Northern Pike	64.2	0.39	1993
Woodstown Memorial Lake	Black Crappie	19.5	0.10	1993
Woodstown Memorial Lake	Black Crappie	37.3	0.22	1993
Batsto Lake	Bluegill sunfish	18.5	0.31	1994
Batsto Lake	Bluegill sunfish	22	0.33	1994
Batsto Lake	Bluegill sunfish	20	0.56	1994
Batsto Lake	Brown bullhead	30.5	0.16	1994
Batsto Lake	Brown bullhead	30	0.16	1994
Batsto Lake	Brown bullhead	28	0.16	1994
Batsto Lake	Brown bullhead	30	0.21	1994
Batsto Lake	Brown bullhead	30	0.25	1994
Batsto Lake	Chain pickerel	29	0.38	1994
Batsto Lake	Chain pickerel	29.5	0.43	1994
Batsto Lake	Chain pickerel	28.5	0.44	1994
Batsto Lake	Chain pickerel	30	0.44	1994
Batsto Lake	Chain pickerel	38	0.79	1994
Batsto Lake	Largemouth bass	27	0.47	1994
Batsto Lake	Largemouth bass	26.5	0.60	1994
Batsto Lake	Largemouth bass	31.5	0.90	1994

Batsto Lake	Largemouth bass	32.5	0.92	1994
Batsto Lake	Largemouth bass	34	1.15	1994
Carnegie Lake	Bluegill sunfish	16.2	0.06	1994
Carnegie Lake	Bluegill sunfish	16.8	0.02	1994
Carnegie Lake	Bluegill sunfish	17.5	0.05	1994
Carnegie Lake	White perch	20	0.13	1994
Carnegie Lake	White perch	20.5	0.19	1994
Carnegie Lake	White perch	21.1	0.11	1994
Carnegie Lake	White perch	21.2	0.20	1994
Carnegie Lake	White perch	21.4	0.19	1994
Carnegie Lake	Largemouth bass	43.0	0.24	1994
Carnegie Lake	Largemouth bass	45.2	0.37	1994
Carnegie Lake	Largemouth bass	43.5	0.45	1994
Carnegie Lake	Largemouth bass	48.0	0.68	1994
Carnegie Lake	Largemouth bass	54.0	0.81	1994
Merrill Creek Reservoir	Largemouth bass	41.0	0.67	1994
Merrill Creek Reservoir	Largemouth bass	39.5	0.93	1994
Merrill Creek Reservoir	Largemouth bass	36.7	0.93	1994
Merrill Creek Reservoir	Largemouth bass	41.0	1.10	1994
Merrill Creek Reservoir	Largemouth bass	49.6	1.12	1994
Monksville Reservoir	Largemouth bass	31.3	0.20	1994
Monksville Reservoir	Largemouth bass	31.2	0.21	1994
Monksville Reservoir	Largemouth bass	28.5	0.51	1994
Monksville Reservoir	Largemouth bass	41.2	0.78	1994
Monksville Reservoir	Largemouth bass	39	1.00	1994
Wilson Lake	Pumpkinseed sunfish	20.4	0.26	1994
Wilson Lake	Pumpkinseed sunfish	18.5	0.60	1994
Wilson Lake	Pumpkinseed sunfish	18.2	1.52	1994
Wilson Lake	Yellow perch	22	0.48	1994
Wilson Lake	Yellow perch	24.5	0.65	1994
Wilson Lake	Yellow perch	26.1	0.72	1994
Wilson Lake	Yellow perch	30	1.08	1994
Wilson Lake	Yellow perch	2.95	1.23	1994
Wilson Lake	Largemouth bass	35.5	0.74	1994
Wilson Lake	Largemouth bass	40.0	0.88	1994
Wilson Lake	Largemouth bass	25.6	0.90	1994
Wilson Lake	Largemouth bass	34.5	0.90	1994
Wilson Lake	Largemouth bass	47.0	1.75	1994
Carnegie Lake	Brown bullhead	30.1	0.03	1995
Carnegie Lake	Brown bullhead	31.1	0.05	1995
Carnegie Lake	Brown bullhead	28.2	0.06	1995
Carnegie Lake	Brown bullhead	28.5	0.10	1995
Carnegie Lake	Brown bullhead	29.4	0.12	1995
Carnegie Lake	Channel catfish	56.6	0.12	1995
Carnegie Lake	Channel catfish	61.8	0.16	1995
Carnegie Lake	Channel catfish	56.2	0.18	1995

Carnegie Lake	Channel catfish	41.2	0.44	1995
East Creek Lake	Brown bullhead	33.2	2.62	1995
East Creek Lake	Chain pickerel	31.2	0.65	1995
East Creek Lake	Chain pickerel	33.5	0.78	1995
East Creek Lake	Chain pickerel	35	0.99	1995
East Creek Lake	Chain pickerel	33.3	1.14	1995
East Creek Lake	Chain pickerel	33.7	1.35	1995
East Creek Lake	Pumpkinseed sunfish	11.3	0.35	1995
East Creek Lake	Pumpkinseed sunfish	11.4	0.43	1995
East Creek Lake	Pumpkinseed sunfish	11.4	0.53	1995
East Creek Lake	Yellow bullhead	11.7	0.30	1995
East Creek Lake	Yellow bullhead	22.3	0.73	1995
East Creek Lake	Yellow perch	18	0.67	1995
East Creek Lake	Yellow perch	20	0.82	1995
East Creek Lake	Yellow perch	22	0.90	1995
East Creek Lake	Yellow perch	24	0.95	1995
East Creek Lake	Yellow perch	20.1	1.01	1995
East Creek Lake	Largemouth bass	33.1	1.07	1995
East Creek Lake	Largemouth bass	33.5	1.44	1995
East Creek Lake	Largemouth bass	34	1.95	1995
East Creek Lake	Largemouth bass	38	2.04	1995
East Creek Lake	Largemouth bass	42	2.21	1995
Harrisville Lake	Chain pickerel	27.5	0.90	1995
Harrisville Lake	Chain pickerel	24.5	0.94	1995
Harrisville Lake	Chain pickerel	25	1.20	1995
Harrisville Lake	Chain pickerel	33.5	1.48	1995
Harrisville Lake	Chain pickerel	45	2.27	1995
Harrisville Lake	mud sunfish	11.1	0.76	1995
Harrisville Lake	mud sunfish	17.5	0.95	1995
Harrisville Lake	mud sunfish	18.5	1.32	1995
Harrisville Lake	Yellow bullhead	15.5	0.96	1995
Harrisville Lake	Yellow bullhead	32.5	2.52	1995
Lake Nummy	Chain pickerel	33.3	0.47	1995
Lake Nummy	Chain pickerel	33.3	0.49	1995
Lake Nummy	Chain pickerel	33.6	0.60	1995
Lake Nummy	Chain pickerel	33.7	0.63	1995
Lake Nummy	Chain pickerel	33.2	0.64	1995
Lake Nummy	Yellow bullhead	25.7	0.21	1995
Lake Nummy	Yellow bullhead	11	0.23	1995
Lake Nummy	Yellow bullhead	25.5	0.31	1995
Lake Nummy	Yellow bullhead	25.1	0.34	1995
Lake Nummy	Yellow perch	22.3	0.52	1995
Lake Nummy	Yellow perch	20	0.53	1995
Lake Nummy	Yellow perch	22.3	0.53	1995
Lake Nummy	Yellow perch	22.3	0.54	1995
Lake Nummy	Yellow perch	22.1	0.59	1995

Manasquan Reservoir	Black crappie	17.5	0.35	1995
Manasquan Reservoir	Black crappie	16.5	0.51	1995
Manasquan Reservoir	Black crappie	16.5	0.53	1995
Manasquan Reservoir	Bluegill sunfish	15	0.16	1995
Manasquan Reservoir	Bluegill sunfish	15.5	0.22	1995
Manasquan Reservoir	Bluegill sunfish	16.8	0.22	1995
Manasquan Reservoir	Bluegill sunfish	16.5	0.31	1995
Manasquan Reservoir	Bluegill sunfish	16.5	0.37	1995
Manasquan Reservoir	Brown bullhead	24	0.06	1995
Manasquan Reservoir	Brown bullhead	21.5	0.11	1995
Manasquan Reservoir	Brown bullhead	22	0.12	1995
Manasquan Reservoir	Brown bullhead	26	0.15	1995
Manasquan Reservoir	Brown bullhead	24	0.16	1995
Manasquan Reservoir	Chain pickerel	21.6	0.08	1995
Manasquan Reservoir	Chain pickerel	20	0.13	1995
Manasquan Reservoir	Chain pickerel	24.1	0.15	1995
Manasquan Reservoir	Chain pickerel	39.8	0.48	1995
Manasquan Reservoir	Yellow perch	19.5	0.11	1995
Manasquan Reservoir	Yellow perch	18	0.12	1995
Manasquan Reservoir	Yellow perch	21	0.17	1995
Manasquan Reservoir	Largemouth bass	27	0.29	1995
Manasquan Reservoir	Largemouth bass	28	0.47	1995
Manasquan Reservoir	Largemouth bass	39.5	1.49	1995
Manasquan Reservoir	Largemouth bass	39.5	1.75	1995
Manasquan Reservoir	Largemouth bass	44.5	2.21	1995
Merrill Creek Reservoir	Black crappie	25.3	0.09	1995
Merrill Creek Reservoir	Black crappie	26.1	0.12	1995
Merrill Creek Reservoir	Bluegill sunfish	14.6	0.05	1995
Merrill Creek Reservoir	Bluegill sunfish	172	0.09	1995
Merrill Creek Reservoir	Bluegill sunfish	25.4	0.16	1995
Merrill Creek Reservoir	Brown bullhead	26	0.12	1995
Merrill Creek Reservoir	Brown bullhead	27.9	0.14	1995
Merrill Creek Reservoir	Brown bullhead	29.5	0.14	1995
Merrill Creek Reservoir	Brown bullhead	25.4	0.16	1995
Merrill Creek Reservoir	Brown bullhead	25.1	0.17	1995
Merrill Creek Reservoir	Lake trout	56.7	0.38	1995
Merrill Creek Reservoir	Lake trout	56.5	0.44	1995
Merrill Creek Reservoir	Lake trout	60	0.46	1995
Merrill Creek Reservoir	Lake trout	58.6	0.51	1995
Merrill Creek Reservoir	Lake trout	64	0.73	1995
Merrill Creek Reservoir	Smallmouth bass	38.5	0.44	1995
Merrill Creek Reservoir	Smallmouth bass	40.1	0.44	1995
Merrill Creek Reservoir	Smallmouth bass	42.5	0.49	1995
Merrill Creek Reservoir	Smallmouth bass	39.3	0.63	1995
Merrill Creek Reservoir	Smallmouth bass	43.3	0.68	1995
Merrill Creek Reservoir	Yellow perch	31.2	0.20	1995
Merrill Creek Reservoir	Yellow perch	30.1	0.22	1995
Merrill Creek Reservoir	Yellow perch	34	0.32	1995
Monksville Reservoir	Brown bullhead	31.8	0.04	1995

Monksville Reservoir	Brown bullhead	31	0.06	1995
Monksville Reservoir	Brown bullhead	29	0.06	1995
Monksville Reservoir	Brown bullhead	28.5	0.09	1995
Monksville Reservoir	Brown bullhead	29.2	0.13	1995
Monksville Reservoir	Brown trout	45	0.20	1995
Monksville Reservoir	Pumpkinseed sunfish	19.2	0.09	1995
Monksville Reservoir	Pumpkinseed sunfish	18.1	0.14	1995
Monksville Reservoir	Pumpkinseed sunfish	18	0.25	1995
Monksville Reservoir	Smallmouth bass	31.6	0.26	1995
Monksville Reservoir	Smallmouth bass	27	0.28	1995
Monksville Reservoir	Smallmouth bass	37	0.33	1995
Monksville Reservoir	Walleye	35.5	0.30	1995
Monksville Reservoir	Walleye	41.4	0.42	1995
Monksville Reservoir	Walleye	42	0.48	1995
Monksville Reservoir	Walleye	47.6	0.80	1995
Monksville Reservoir	Walleye	45.9	0.98	1995
Monksville Reservoir	Walleye	52.2	1.44	1995
Monksville Reservoir	White perch	24.5	0.19	1995
Monksville Reservoir	White perch	26.8	0.55	1995
Monksville Reservoir	White perch	27	0.58	1995
Monksville Reservoir	White perch	28.5	0.74	1995
Monksville Reservoir	White perch	32.1	0.79	1995
Mullica River	Brown bullhead	25.5	0.26	1995
Mullica River	Brown bullhead	24.5	0.28	1995
Mullica River	Brown bullhead	22	0.40	1995
Mullica River	Chain pickerel	23.5	0.25	1995
Mullica River	Chain pickerel	30	0.45	1995
Mullica River	Chain pickerel	33.2	0.49	1995
Mullica River	Chain pickerel	46	0.62	1995
Mullica River	Chain pickerel	50.5	0.92	1995
Mullica River	Pumpkinseed sunfish	13	0.12	1995
Mullica River	Pumpkinseed sunfish	13	0.21	1995
Mullica River	Pumpkinseed sunfish	17	0.52	1995
Mullica River	White catfish	29.6	0.23	1995
Mullica River	White catfish	29	0.25	1995
Mullica River	White catfish	29	0.35	1995
Mullica River	White perch	18.3	0.34	1995
Mullica River	White perch	17.4	0.35	1995
Mullica River	White perch	20	0.36	1995
Mullica River	White perch	19	0.36	1995
Mullica River	White perch	21	0.51	1995
New Brooklyn Lake	Black crappie	21	0.08	1995
New Brooklyn Lake	Black crappie	21.8	0.16	1995
New Brooklyn Lake	Black crappie	21.5	0.19	1995

New Brooklyn Lake	Chain pickerel	20.5	0.13	1995
New Brooklyn Lake	Chain pickerel	29.7	0.20	1995
New Brooklyn Lake	Chain pickerel	34	0.25	1995
New Brooklyn Lake	Chain pickerel	43.9	0.48	1995
New Brooklyn Lake	Chain pickerel	32.5	0.64	1995
New Brooklyn Lake	Pumpkinseed sunfish	15.4	0.22	1995
New Brooklyn Lake	Pumpkinseed sunfish	16	0.28	1995
New Brooklyn Lake	Pumpkinseed sunfish	16.5	0.30	1995
New Brooklyn Lake	Yellow bullhead	20	0.05	1995
New Brooklyn Lake	Yellow bullhead	24.1	0.06	1995
New Brooklyn Lake	Yellow bullhead	23,8	0.08	1995
New Brooklyn Lake	Yellow bullhead	25.9	0.09	1995
New Brooklyn Lake	Yellow bullhead	26.9	0.20	1995
New Brooklyn Lake	Largemouth bass	23.3	0.25	1995
New Brooklyn Lake	Largemouth bass	27.4	0.32	1995
New Brooklyn Lake	Largemouth bass	31.7	0.41	1995
Wading River	Brown bullhead	31.5	0.62	1995
Wading River	Chain pickerel	42.5	0.46	1995
Wading River	Chain pickerel	35.1	0.49	1995
Wading River	Chain pickerel	28.5	0.55	1995
Wading River	Chain pickerel	22.3	0.55	1995
Wading River	Chain pickerel	32	0.71	1995
Wading River	White catfish	30.3	0.49	1995
Wading River	White catfish	30	0.60	1995
Wading River	Yellow bullhead	20.2	1.01	1995
Wading River	Yellow bullhead	30.3	1.59	1995
Wanaque Reservoir	Bluegill sunfish	17.2	0.07	1995
Wanaque Reservoir	Brown bullhead	35.8	0.01	1995
Wanaque Reservoir	Brown bullhead	36.2	0.03	1995
Wanaque Reservoir	Brown bullhead	34	0.07	1995
Wanaque Reservoir	Chain pickerel	51	0.12	1995
Wanaque Reservoir	Chain pickerel	47.5	0.18	1995
Wanaque Reservoir	Chain pickerel	50.5	0.37	1995
Wanaque Reservoir	Chain pickerel	47	0.41	1995
Wanaque Reservoir	Chain pickerel	50.6	0.43	1995
Wanaque Reservoir	Chain pickerel	56	0.73	1995
Wanaque Reservoir	Smallmouth bass	38.5	0.27	1995
Wanaque Reservoir	Smallmouth bass	29.6	0.29	1995
Wanaque Reservoir	Smallmouth bass	46.2	0.36	1995
Wanaque Reservoir	White catfish	41.5	0.12	1995
Wanaque Reservoir	White catfish	40.5	0.17	1995
Wanaque Reservoir	White catfish	37.1	0.17	1995
Wanaque Reservoir	White catfish	37.7	0.28	1995
Wanaque Reservoir	White catfish	42.9	0.33	1995
Wanaque Reservoir	White perch	27.2	0.35	1995
Wanaque Reservoir	White perch	30.7	0.63	1995

Wanaque Reservoir	White perch	36.8	0.65	1995
Wanaque Reservoir	White perch	32.1	0.75	1995
Wanaque Reservoir	White perch	33.9	1.18	1995
Wanaque Reservoir	Yellow bullhead	23.9	0.03	1995
Wanaque Reservoir	Largemouth bass	37.9	0.36	1995
Wanaque Reservoir	Largemouth bass	34.6	0.45	1995
Wanaque Reservoir	Largemouth bass	39.5	0.51	1995
Wanaque Reservoir	Largemouth bass	41.4	0.71	1995
Wanaque Reservoir	Largemouth bass	41.4	0.85	1995
Wilson Lake	Chain pickerel	29.5	0.66	1995
Wilson Lake	Chain pickerel	30.5	0.88	1995
Wilson Lake	Chain pickerel	25.7	0.91	1995
Wilson Lake	Chain pickerel	47	1.14	1995
Wilson Lake	Chain pickerel	47	1.30	1995
Boonton Reservoir	Brown Bullhead	30.5	0.01	1996
Boonton Reservoir	Brown Bullhead	32.8	0.02	1996
Boonton Reservoir	White Catfish	40	0.54	1996
Boonton Reservoir	Largemouth Bass	35	0.33	1996
Boonton Reservoir	Largemouth Bass	45.1	0.60	1996
Boonton Reservoir	Largemouth Bass	41.6	0.81	1996
Butterfly Bogs	Brown Bullhead	30.6	0.08	1996
Butterfly Bogs	Chain Pickerel	33.9	0.78	1996
Cedar Lake	Brown Bullhead	31.5	0.06	1996
Cedar Lake	Chain Pickerel	47.9	0.24	1996
Cedar Lake	Chain Pickerel	49.6	0.31	1996
Cedar Lake	Chain Pickerel	64.7	0.76	1996
Cedar Lake	Largemouth Bass	39	0.25	1996
Cedar Lake	Largemouth Bass	41.5	0.59	1996
Cedar Lake	Largemouth Bass	43.8	0.61	1996
Crater Lake	Brown Bullhead	30	0.39	1996
Crater Lake	Yellow Perch	21.6	0.29	1996
Crater Lake	Yellow Perch	19.9	0.43	1996
Crater Lake	Yellow Perch	27.9	0.58	1996
DeVoe Lake	Brown Bullhead	27	0.09	1996
DeVoe Lake	Chain Pickerel	41.5	0.14	1996
DeVoe Lake	Chain Pickerel	43	0.25	1996
DeVoe Lake	Chain Pickerel	48.5	0.27	1996
DeVoe Lake	Largemouth Bass	31.7	0.07	1996
DeVoe Lake	Largemouth Bass	34.1	0.21	1996
DeVoe Lake	Largemouth Bass	36.5	0.26	1996
Double Trouble Lake	Chain Pickerel	18.1	0.74	1996
Double Trouble Lake	Chain Pickerel	37.7	1.24	1996
Double Trouble Lake	Chain Pickerel	46.7	1.60	1996
Double Trouble Lake	Chain Pickerel	52.4	2.24	1996
Double Trouble Lake	Chain Pickerel	57.6	2.30	1996
Double Trouble Lake	Yellow Bullhead	26.1	0.82	1996
Double Trouble Lake	Yellow Bullhead	28.3	1.09	1996
Double Trouble Lake	Yellow Bullhead	26.6	1.18	1996
Echo Lake Reservoir	Largemouth Bass	30.4	0.12	1996

Echo Lake Reservoir	Largemouth Bass	34.4	0.15	1996
Echo Lake Reservoir	Largemouth Bass	29	0.16	1996
Echo Lake Reservoir	Largemouth Bass	35	0.17	1996
Green Turtle Lake	Chain Pickerel	28.1	0.11	1996
Green Turtle Lake	Chain Pickerel	44.7	0.14	1996
Green Turtle Lake	Chain Pickerel	44.6	0.15	1996
Green Turtle Lake	Yellow Perch	20.8	0.09	1996
Green Turtle Lake	Yellow Perch	24.6	0.10	1996
Green Turtle Lake	Largemouth Bass	23.6	0.17	1996
Green Turtle Lake	Largemouth Bass	26.1	0.22	1996
Green Turtle Lake	Largemouth Bass	34.7	0.32	1996
Greenwood Lake	White perch	18.3	0.00	1996
Greenwood Lake	White perch	19.2	0.02	1996
Greenwood Lake	Largemouth Bass	36.2	0.15	1996
Greenwood Lake	Largemouth Bass	34.3	0.18	1996
Greenwood Lake	Largemouth Bass	31.4	0.21	1996
Greenwood Lake	Largemouth Bass	36.3	0.24	1996
Greenwood Lake	Largemouth Bass	40	0.40	1996
Grovers Mill Pond	Brown Bullhead	33	0.08	1996
Grovers Mill Pond	Brown Bullhead	32.2	0.40	1996
Grovers Mill Pond	Chain Pickerel	35.3	0.12	1996
Grovers Mill Pond	Chain Pickerel	35.2	0.16	1996
Grovers Mill Pond	Chain Pickerel	37.2	0.16	1996
Grovers Mill Pond	Chain Pickerel	36.5	0.18	1996
Grovers Mill Pond	Largemouth Bass	31.3	0.25	1996
Grovers Mill Pond	Largemouth Bass	35.8	0.30	1996
Grovers Mill Pond	Largemouth Bass	35	0.36	1996
Grovers Mill Pond	Largemouth Bass	41.5	0.39	1996
Grovers Mill Pond	Largemouth Bass	28	0.47	1996
Hainesville Pond	Chain Pickerel	39.3	0.14	1996
Hainesville Pond	Chain Pickerel	36.6	0.14	1996
Hainesville Pond	Chain Pickerel	36.5	0.15	1996
Hainesville Pond	Largemouth Bass	30.3	0.13	1996
Hainesville Pond	Largemouth Bass	31.0	0.21	1996
Hainesville Pond	Largemouth Bass	31.3	0.23	1996
Malaga Lake	Chain Pickerel	32	0.73	1996
Malaga Lake	Chain Pickerel	29.3	0.88	1996
Malaga Lake	Chain Pickerel	36.2	0.97	1996
Malaga Lake	Chain Pickerel	31	0.99	1996
Malaga Lake	Chain Pickerel	34	1.38	1996
Malaga Lake	Largemouth Bass	32.4	0.95	1996
Passaic River at Hatfield Swamp	Pumpkinseed Sunfish	12.4	0.08	1996
Passaic River at Hatfield Swamp	Pumpkinseed Sunfish	12.6	0.09	1996
Passaic River at Hatfield Swamp	Black Crappie	18.1	0.30	1996
Passaic River at Hatfield Swamp	Black Crappie	18.9	0.32	1996
Passaic River at Hatfield Swamp	Bluegill Sunfish	18.9	0.19	1996
Passaic River at Hatfield Swamp	Black Crappie	20	0.21	1996

Passaic River at Hatfield Swamp	Black Crappie	20	0.22	1996
Passaic River at Hatfield Swamp	Yellow Bullhead	21.4	0.11	1996
Passaic River at Hatfield Swamp	Largemouth Bass	23	0.17	1996
Passaic River at Hatfield Swamp	Largemouth Bass	23.5	0.21	1996
Passaic River at Hatfield Swamp	Largemouth Bass	36	0.53	1996
Pompton River at Lincoln Park	Pike	27.8	0.17	1996
Pompton River at Lincoln Park	Pike	42	0.41	1996
Pompton River at Lincoln Park	Pike	66.6	0.59	1996
Pompton River at Lincoln Park	Yellow Perch	21	0.21	1996
Pompton River at Lincoln Park	Yellow Perch	24	0.26	1996
Pompton River at Lincoln Park	Largemouth Bass	35.4	0.50	1996
Pompton River at Lincoln Park	Largemouth Bass	35.5	0.68	1996
Raritan River at Millstone River	Brown Bullhead	25.4	0.06	1996
Raritan River at Millstone River	Brown Bullhead	27.5	0.07	1996
Raritan River at Millstone River	Channel Catfish	39.8	0.15	1996
Raritan River at Millstone River	Largemouth Bass	32.5	0.33	1996
Raritan River at Millstone River	Largemouth Bass	36.3	0.33	1996
Raritan River at Millstone River	Largemouth Bass	44.9	0.37	1996
Raritan River at Millstone River	Largemouth Bass	37	0.46	1996
Ridgeway Branch of Tom's River	Brown Bullhead	26.4	0.17	1996
Ridgeway Branch of Tom's River	Brown Bullhead	27	0.44	1996
Ridgeway Branch of Tom's River	Brown Bullhead	22.8	1.15	1996
Ridgeway Branch of Tom's River	Brown Bullhead	25.6	1.57	1996
Ridgeway Branch of Tom's River	Chain Pickerel	36	1.22	1996
Rockaway River near Whippany	Black Crappie	17.9	0.21	1996
Rockaway River near Whippany	Bluegill Sunfish	14.5	0.12	1996
Rockaway River near Whippany	Largemouth Bass	39.8	0.92	1996
South Branch Raritan River at Neshanic Station	Brown Bullhead	17.2	0.08	1996
South Branch Raritan River at Neshanic Station	Redbreast Sunfish	15.7	0.09	1996
South Branch Raritan River at Neshanic Station	Redbreast Sunfish	15.9	0.15	1996
South Branch Raritan River at Neshanic Station	Rock Bass	15	0.09	1996
South Branch Raritan River at Neshanic Station	Smallmouth Bass	20.7	0.18	1996
South Branch Raritan River at Neshanic Station	Largemouth Bass	18.2	0.11	1996
Speedwell Lake	Bluegill Sunfish	18.3	0.12	1996
Speedwell Lake	Bluegill Sunfish	19.7	0.13	1996
Speedwell Lake	Brown Bullhead	21	0.01	1996
Speedwell Lake	Largemouth Bass	27.5	0.10	1996
Speedwell Lake	Largemouth Bass	32.5	0.34	1996
Speedwell Lake	Largemouth Bass	36.1	0.38	1996
Steenykill Lake	Largemouth Bass	26.5	0.16	1996
Steenykill Lake	Largemouth Bass	27.5	0.19	1996
Steenykill Lake	Largemouth Bass	27.7	0.19	1996
Steenykill Lake	Largemouth Bass	27.8	0.15	1996
Steenykill Lake	Largemouth Bass	28.3	0.22	1996

Steenykill Lake	Largemouth Bass	29.6	0.15	1996
Sunset Lake	Bluegill Sunfish	11.2	0.05	1996
Sunset Lake	Chain Pickerel	30.7	0.09	1996
Sunset Lake	Largemouth Bass	22.5	0.10	1996
Sunset Lake	Largemouth Bass	33.8	0.17	1996
Sunset Lake	Largemouth Bass	38.2	0.21	1996
Sunset Lake	Largemouth Bass	38.5	0.35	1996
Sunset Lake	Largemouth Bass	53	0.69	1996
Wawayanda Lake	Chain Pickerel	35	0.25	1996
Wawayanda Lake	Chain Pickerel	39.5	0.28	1996
Wawayanda Lake	Chain Pickerel	40.5	0.29	1996
Wawayanda Lake	Chain Pickerel	37.9	0.31	1996
Wawayanda Lake	Chain Pickerel	42	0.34	1996
Wawayanda Lake	Chain Pickerel	42.4	0.44	1996
Oak Ridge Reservoir	Yellow Bullhead	24.5	0.25	1997
Oak Ridge Reservoir	Chain Pickerel	25	0.24	1997
Oak Ridge Reservoir	Chain Pickerel	28	0.29	1997
Oak Ridge Reservoir	Chain Pickerel	30.6	0.30	1997
Oak Ridge Reservoir	Brown Bullhead	33	0.02	1997
Oak Ridge Reservoir	Brown Bullhead	34.5	0.02	1997
Oak Ridge Reservoir	Smallmouth Bass	40.2	0.49	1997
Oak Ridge Reservoir	Chain Pickerel	58	0.30	1997
Oak Ridge Reservoir	Largemouth Bass	36.8	0.38	1997
Oak Ridge Reservoir	Largemouth Bass	42.5	0.64	1997
Oak Ridge Reservoir	Largemouth Bass	48	0.71	1997
Oak Ridge Reservoir	Largemouth Bass	48	0.89	1997
Pompton River at Pequannock River	Black Crappie	19.3	0.24	1997
Pompton River at Pequannock River	Pumpkinseed Sunfish	14.5	0.35	1997
Pompton River at Pequannock River	Pumpkinseed Sunfish	14.1	0.78	1997
Pompton River at Pequannock River	Redbreast Sunfish	13.7	0.32	1997
Pompton River at Pequannock River	Redbreast Sunfish	15.8	0.41	1997
Pompton River at Pequannock River	Rock Bass	19.2	0.54	1997
Pompton River at Pequannock River	Rock Bass	21.1	0.54	1997
Pompton River at Pequannock River	Rock Bass	22	0.68	1997
Pompton River at Pequannock River	Smallmouth Bass	29.6	0.57	1997
Pompton River at Pequannock River	Smallmouth Bass	36.8	1.02	1997
Pompton River at Pequannock River	Smallmouth Bass	25.4	1.10	1997
Pompton River at Pequannock River	Smallmouth Bass	27.8	1.14	1997
Pompton River at Pequannock River	Yellow Bullhead	26.2	0.80	1997
Pompton River at Pequannock River	Largemouth Bass	39	0.99	1997
Pompton River at Pequannock River	Largemouth Bass	39.8	1.36	1997
Whitesbog Pond	Chain Pickerel	23	0.43	1997
Whitesbog Pond	Chain Pickerel	31.5	0.58	1997
Whitesbog Pond	Chain Pickerel	34.3	0.74	1997
Whitesbog Pond	Chain Pickerel	32.5	0.76	1997
Whitesbog Pond	Chain Pickerel	39.6	1.02	1997
Willow Grove Lake	Brown Bullhead	33	0.23	1997

Willow Grove Lake	Brown Bullhead	32.4	0.28	1997
Willow Grove Lake	Chain Pickerel	31	0.76	1997
Willow Grove Lake	Chain Pickerel	48.1	1.03	1997
Willow Grove Lake	Chain Pickerel	36.5	1.13	1997
Willow Grove Lake	Chain Pickerel	45.2	1.26	1997
Willow Grove Lake	Chain Pickerel	53	1.29	1997
Willow Grove Lake	White Catfish	43	0.17	1997
Willow Grove Lake	Yellow Bullhead	28	0.82	1997
Willow Grove Lake	Yellow Bullhead	30.5	0.91	1997
Willow Grove Lake	Largemouth Bass	33.2	1.68	1997
Mullica River @ Green Bank	American Eel	45.7	0.51	1999
Mullica River @ Green Bank	American Eel	69	0.49	1999
Mullica River @ New Gretna	American Eel	42.5	0.3	1999
Mullica River, below dam @ Batsto Village	American Eel	29.7	0.65	1999
Mullica River, below dam @ Batsto Village	American Eel	39.5	0.04	1999
Mullica River, below dam @ Batsto Village	American Eel	46.3	0.8	1999
Stewart Lake (Woodbury)	Bluegill	15.9	0.03	1999
Stewart Lake (Woodbury)	Bluegill	16.4	0.03	1999
Stewart Lake (Woodbury)	Black Crappie	18.3	0.1	1999
Stewart Lake (Woodbury)	Brown Bullhead	25.4	0.01	1999
Stewart Lake (Woodbury)	Brown Bullhead	27.3	0.01	1999
Stewart Lake (Woodbury)	Brown Bullhead	31.1	0.04	1999
Stewart Lake (Woodbury)	Common Carp	43.8	0.01	1999
Stewart Lake (Woodbury)	Common Carp	49.3	0.04	1999
Stewart Lake (Woodbury)	Common Carp	54.5	0.08	1999
Stewart Lake (Woodbury)	Common Carp	59.8	0.03	1999
Stewart Lake (Woodbury)	Common Carp	65.8	0.03	1999
Stewart Lake (Woodbury)	Largemouth Bass	35.9	0.2	1999
Stewart Lake (Woodbury)	Largemouth Bass	38.9	0.15	1999
Stewart Lake (Woodbury)	Largemouth Bass	43.5	0.19	1999
Boonton Reservoir	rock bass	20.7	0.13	2002
Boonton Reservoir	rock bass	22.2	0.27	2002
Boonton Reservoir	rock bass	22.3	0.22	2002
Boonton Reservoir	rock bass	22.3	0.26	2002
Boonton Reservoir	smallmouth bass	38.9	0.39	2002
Boonton Reservoir	smallmouth bass	41.0	0.39	2002
Boonton Reservoir	smallmouth bass	43.4	0.52	2002
Boonton Reservoir	smallmouth bass	48.4	0.75	2002
Boonton Reservoir	largemouth bass	41.6	0.36	2002
Boonton Reservoir	largemouth bass	45.0	0.59	2002
Boonton Reservoir	largemouth bass	48.3	1.08	2002
Boonton Reservoir	largemouth bass	48.7	0.73	2002
Boonton Reservoir	largemouth bass	52.2	0.80	2002
Branch Brook Park	bluegill	14.5	0.16	2002
Branch Brook Park	bluegill	15.3	0.15	2002
Branch Brook Park	bluegill	15.5	0.24	2002

Branch Brook Park	common carp	60.5	0.10	2002
Branch Brook Park	common carp	69.0	0.19	2002
Branch Brook Park	common carp	69.5	0.19	2002
Branch Brook Park	common carp	72.5	0.07	2002
Canistear Reservoir	bluegill	18.5	0.11	2002
Canistear Reservoir	yellow perch	20.5	0.29	2002
Canistear Reservoir	bluegill	21.0	0.10	2002
Canistear Reservoir	bluegill	21.8	0.11	2002
Canistear Reservoir	yellow bullhead	24.5	0.12	2002
Canistear Reservoir	yellow bullhead	25.1	0.17	2002
Canistear Reservoir	yellow perch	25.3	0.18	2002
Canistear Reservoir	yellow perch	27.5	0.22	2002
Canistear Reservoir	yellow bullhead	27.6	0.16	2002
Canistear Reservoir	yellow bullhead	28.6	0.19	2002
Canistear Reservoir	chain pickerel	41.5	0.19	2002
Canistear Reservoir	chain pickerel	41.8	0.25	2002
Canistear Reservoir	chain pickerel	44.0	0.14	2002
Canistear Reservoir	chain pickerel	47.2	0.16	2002
Canistear Reservoir	bluegill	21.2	0.23	2002
Canistear Reservoir	largemouth bass	41.7	0.38	2002
Canistear Reservoir	largemouth bass	43.8	0.29	2002
Canistear Reservoir	largemouth bass	44.5	0.51	2002
Canistear Reservoir	largemouth bass	51.4	0.67	2002
Clinton Reservoir	redbreast sunfish	12.7	0.25	2002
Clinton Reservoir	redbreast sunfish	13.2	0.19	2002
Clinton Reservoir	redbreast sunfish	13.8	0.16	2002
Clinton Reservoir	redbreast sunfish	14.1	0.16	2002
Clinton Reservoir	rock bass	15.8	0.18	2002
Clinton Reservoir	rock bass	15.9	0.19	2002
Clinton Reservoir	rock bass	18.2	0.65	2002
Clinton Reservoir	yellow bullhead	28.2	0.43	2002
Clinton Reservoir	yellow bullhead	28.3	0.74	2002
Clinton Reservoir	yellow bullhead	28.4	0.44	2002
Clinton Reservoir	yellow bullhead	29.7	0.45	2002
Clinton Reservoir	white sucker	44.5	0.25	2002
Clinton Reservoir	chain pickerel	45.2	0.61	2002
Clinton Reservoir	white sucker	45.5	0.19	2002
Clinton Reservoir	white sucker	46.8	0.24	2002
Clinton Reservoir	chain pickerel	53.0	0.43	2002
Echo Lake Reservoir	bluegill	16.4	0.10	2002
Echo Lake Reservoir	bluegill	17.9	0.06	2002
Echo Lake Reservoir	bluegill	18.5	0.11	2002
Echo Lake Reservoir	bluegill	19.0	0.11	2002
Echo Lake Reservoir	yellow bullhead	22.4	0.09	2002
Echo Lake Reservoir	yellow bullhead	22.9	0.14	2002
Echo Lake Reservoir	yellow bullhead	26.4	0.16	2002
Echo Lake Reservoir	yellow bullhead	28.6	0.07	2002
Echo Lake Reservoir	chain pickerel	43.5	0.20	2002
Echo Lake Reservoir	chain pickerel	45.6	0.27	2002

Echo Lake Reservoir	chain pickerel	62.8	0.37	2002
Echo Lake Reservoir	largemouth bass	45.6	0.43	2002
Echo Lake Reservoir	largemouth bass	48.1	0.61	2002
Echo Lake Reservoir	largemouth bass	49.4	0.72	2002
Echo Lake Reservoir	largemouth bass	50.5	0.79	2002
Green Turtle Lake	bluegill	17.7	0.07	2002
Green Turtle Lake	bluegill	17.9	0.09	2002
Green Turtle Lake	bluegill	18.6	0.14	2002
Green Turtle Lake	bluegill	19.9	0.58	2002
Green Turtle Lake	largemouth bass	31.7	0.20	2002
Green Turtle Lake	largemouth bass	32.5	0.26	2002
Green Turtle Lake	largemouth bass	38.9	0.32	2002
Green Turtle Lake	largemouth bass	40.0	0.36	2002
Green Turtle Lake	largemouth bass	49.4	0.74	2002
Greenwood Lake	bluegill	19.0	0.08	2002
Greenwood Lake	bluegill	19.1	0.13	2002
Greenwood Lake	bluegill	19.2	0.07	2002
Greenwood Lake	bluegill	20.1	0.09	2002
Greenwood Lake	yellow bullhead	21.4	0.06	2002
Greenwood Lake	yellow bullhead	23.6	0.09	2002
Greenwood Lake	yellow bullhead	23.7	0.07	2002
Greenwood Lake	yellow bullhead	23.8	0.11	2002
Greenwood Lake	walleye		0.18	2002
Greenwood Lake	walleye		0.28	2002
Greenwood Lake	walleye		0.28	2002
Greenwood Lake	walleye		0.30	2002
Greenwood Lake	walleye		0.47	2002
Greenwood Lake	largemouth bass	39.9	0.31	2002
Greenwood Lake	largemouth bass	42.0	0.31	2002
Greenwood Lake	largemouth bass	42.6	0.31	2002
Greenwood Lake	largemouth bass	42.7	0.21	2002
Greenwood Lake	largemouth bass	44.4	0.29	2002
Monksville reservoir	bluegill	17.8	0.11	2002
Monksville reservoir	bluegill	18.5	0.08	2002
Monksville reservoir	yellow bullhead	19.4	0.11	2002
Monksville reservoir	bluegill	19.8	0.17	2002
Monksville reservoir	bluegill	19.9	0.13	2002
Monksville reservoir	yellow bullhead	23.0	0.13	2002
Monksville reservoir	yellow perch	27.6	0.17	2002
Monksville reservoir	yellow perch	34.9	0.17	2002
Monksville reservoir	chain pickerel	35.5	0.15	2002
Monksville reservoir	chain pickerel	38.4	0.19	2002
Monksville reservoir	walleye	44.4	0.44	2002
Monksville reservoir	walleye	47.8	0.55	2002
Monksville reservoir	chain pickerel	51.1	0.31	2002
Monksville reservoir	walleye	51.6	0.42	2002
Monksville reservoir	walleye	54.0	0.35	2002
Monksville reservoir	walleye	59.8	0.78	2002
Monksville Reservoir	Largemouth bass	26.5	0.20	2002

Monksville Reservoir	Largemouth bass	28.0	0.18	2002
Monksville Reservoir	Largemouth bass	31.5	0.13	2002
Monksville Reservoir	Largemouth bass	36.9	0.32	2002
Monksville Reservoir	Largemouth bass	44.0	0.39	2002
Oak Ridge Reservoir	bluegill	17.5	0.15	2002
Oak Ridge Reservoir	bluegill	18.1	0.11	2002
Oak Ridge Reservoir	bluegill	19.9	0.24	2002
Oak Ridge Reservoir	bluegill	20.0	0.28	2002
Oak Ridge Reservoir	yellow bullhead	23.8	0.10	2002
Oak Ridge Reservoir	yellow bullhead	28.5	0.23	2002
Oak Ridge Reservoir	largemouth bass	41.3	0.90	2002
Oak Ridge Reservoir	largemouth bass	41.6	0.65	2002
Oak Ridge Reservoir	largemouth bass	42.2	0.81	2002
Oak Ridge Reservoir	largemouth bass	45.1	0.82	2002
Pompton River at Lincoln Park	black crappie	17.5	0.19	2002
Pompton River at Lincoln Park	black crappie	20.3	0.29	2002
Pompton River at Lincoln Park	rock bass	20.8	0.64	2002
Pompton River at Lincoln Park	black crappie	21.4	0.15	2002
Pompton River at Lincoln Park	rock bass	21.5	0.60	2002
Pompton River at Lincoln Park	rock bass	23.7	0.83	2002
Pompton River at Lincoln Park	common carp	49.5	0.22	2002
Pompton River at Lincoln Park	common carp	49.9	0.47	2002
Pompton River at Lincoln Park	common carp	57.5	0.28	2002
Pompton River at Lincoln Park	common carp	58.7	0.39	2002
Pompton River at Lincoln Park	largemouth bass	34.6	0.35	2002
Pompton River at Lincoln Park	largemouth bass	35.2	0.50	2002
Pompton River at Lincoln Park	largemouth bass	39.2	0.74	2002
Rockaway River at Powerville	bluegill	15.8	0.11	2002
Rockaway River at Powerville	bluegill	16.0	0.11	2002
Rockaway River at Powerville	bluegill	16.1	0.13	2002
Rockaway River at Powerville	yellow bullhead	16.6	0.10	2002
Rockaway River at Powerville	yellow bullhead	22.5	0.28	2002
Rockaway River at Powerville	rock bass	23.3	0.29	2002
Rockaway River at Powerville	yellow bullhead	23.5	0.14	2002
Rockaway River at Powerville	rock bass	23.9	0.41	2002
Rockaway River at Powerville	rock bass	24.1	0.34	2002
Rockaway River at Powerville	rock bass	24.5	0.32	2002
Shepherds lake	redbreast sunfish	14.6	0.19	2002
Shepherds lake	rock bass	15.3	0.20	2002
Shepherds lake	redbreast sunfish	15.6	0.18	2002
Shepherds lake	redbreast sunfish	15.9	0.20	2002
Shepherds lake	rock bass	20.9	0.15	2002
Shepherds lake	brown bullhead	28.9	0.06	2002
Shepherds lake	brown bullhead	29.5	0.13	2002
Shepherds lake	brown bullhead	36.1	0.07	2002
Shepherds lake	largemouth bass	39.0	0.76	2002
Shepherds Lake	largemouth bass	39.2	0.71	2002
Shepherds Lake	largemouth bass	39.7	0.56	2002
Shepherds Lake	largemouth bass	40.4	0.67	2002

Shepherds Lake	largemouth bass	41.1	0.60	2002
Speedwell Lake	bluegill	15.4	0.10	2002
Speedwell Lake	bluegill	15.8	0.10	2002
Speedwell Lake	bluegill	18.6	0.13	2002
Speedwell Lake	bluegill	20.5	0.16	2002
Speedwell Lake	chain pickerel	25.9	0.09	2002
Speedwell Lake	chain pickerel	31.8	0.11	2002
Speedwell Lake	common carp	57.7	0.13	2002
Speedwell Lake	chain pickerel	59.6	0.26	2002
Speedwell Lake	common carp	61.7	0.10	2002
Speedwell Lake	common carp	62.5	0.14	2002
Speedwell Lake	common carp	63.6	0.05	2002
Split Rock Reservoir	bluegill	21.2	0.13	2002
Split Rock Reservoir	bluegill	21.4	0.21	2002
Split Rock Reservoir	bluegill	22.0	0.10	2002
Split Rock Reservoir	bluegill	22.6	0.12	2002
Split Rock Reservoir	yellow perch	26.2	0.10	2002
Split Rock Reservoir	yellow perch	29.5	0.15	2002
Split Rock Reservoir	yellow perch	30.0	0.13	2002
Split Rock Reservoir	yellow perch	30.0	0.34	2002
Split Rock Reservoir	brown bullhead	30.7	0.04	2002
Split Rock Reservoir	brown bullhead	39.0	0.04	2002
Split Rock Reservoir	chain pickerel	46.8	0.30	2002
Split Rock Reservoir	chain pickerel	49.0	0.32	2002
Split Rock Reservoir	chain pickerel	54.5	0.30	2002
Split Rock Reservoir	chain pickerel	57.0	0.32	2002
Split Rock Reservoir	chain pickerel	61.0	0.26	2002
Split Rock Reservoir	largemouth bass	35.5	0.32	2002
Split Rock Reservoir	largemouth bass	35.9	0.38	2002
Split Rock Reservoir	largemouth bass	38.0	0.32	2002
Split Rock Reservoir	largemouth bass	39.4	0.48	2002
Split Rock Reservoir	largemouth bass	40.5	0.52	2002
Wanaque Reservoir	yellow bullhead	18.8	0.10	2002
Wanaque Reservoir	yellow bullhead	19.9	0.08	2002
Wanaque Reservoir	bluegill	20.2	0.22	2002
Wanaque Reservoir	bluegill	20.4	0.23	2002
Wanaque Reservoir	bluegill	20.6	0.27	2002
Wanaque Reservoir	bluegill	21.2	0.41	2002
Wanaque Reservoir	yellow bullhead	22.2	0.16	2002
Wanaque Reservoir	yellow bullhead	22.9	0.17	2002
Wanaque Reservoir	largemouth bass	30.7	0.28	2002
Wanaque Reservoir	largemouth bass	34.2	0.23	2002
Wanaque Reservoir	largemouth bass	45.2	1.03	2002
Wanaque Reservoir	largemouth bass	48.0	1.47	2002
Wawayanda Lake	bluegill	17.9	0.14	2002
Wawayanda Lake	bluegill	18.2	0.21	2002
Wawayanda Lake	bluegill	18.3	0.21	2002
Wawayanda Lake	chain pickerel	26.4	0.23	2002
Wawayanda Lake	chain pickerel	27.1	0.23	2002
Wawayanda Lake	yellow bullhead	27.1	0.30	2002

Wawayanda Lake	chain pickerel	28.0	0.23	2002
Wawayanda Lake	yellow bullhead	28.3	0.45	2002
Wawayanda Lake	yellow bullhead	29.9	0.36	2002
Wawayanda Lake	chain pickerel	33.9	0.50	2002
Wawayanda Lake	chain pickerel	44.5	0.44	2002
Wawayanda Lake	largemouth bass	33.0	0.29	2002
Wawayanda Lake	largemouth bass	33.4	0.33	2002
Wawayanda Lake	largemouth bass	42.9	0.78	2002
Wawayanda Lake	largemouth bass	44.1	0.66	2002
Wawayanda Lake	largemouth bass	45.3	0.73	2002
Weequachic Lake	bluegill	16.4	0.12	2002
Weequachic Lake	bluegill	17.3	0.15	2002
Weequachic Lake	bluegill	17.4	0.09	2002
Weequachic Lake	white perch	17.7	0.10	2002
Weequachic Lake	white perch	17.9	0.08	2002
Weequachic Lake	white perch	18.0	0.09	2002
Weequachic Lake	brown bullhead	27.2	0.03	2002
Weequachic Lake	brown bullhead	30.0	0.03	2002
Weequachic Lake	brown bullhead	31.0	0.03	2002
Weequachic Lake	common carp	50.5	0.04	2002
Weequachic Lake	common carp	56.2	0.08	2002
Weequachic Lake	common carp	71.0	0.10	2002
Weequachic Lake	largemouth bass	34.0	0.21	2002
Weequachic Lake	largemouth bass	35.1	0.20	2002
Weequachic Lake	largemouth bass	45.9	0.31	2002
Weequachic Lake	largemouth bass	47.5	0.39	2002
Mullica River	American Eel	49.5	0.29	2004
Mullica River	American Eel	63.5	0.33	2004
Mullica River	American Eel	64.9	0.18	2004
Mullica River	American Eel	73.2	0.2	2004
Mullica River	American Eel	77	0.2	2004
Below New Market Pond Dam	American eel	68.2	0.08673	2006
Below New Market Pond Dam	American eel	69.9	0.11418	2006
Bound Brook @ Shepard Rd.	American eel	51.3	0.08569	2006
Bound Brook @ Shepard Rd.	American eel	54.3	0.08921	2006
Bound Brook @ Shepard Rd.	American eel	61.3	0.20208	2006
Budd Lake	bluegill	17.8	0.09949	2006
Budd Lake	bluegill	18.2	0.1561	2006
Budd Lake	bluegill	18.8	0.12716	2006
Budd Lake	brown bullhead	25.6	0.02337	2006
Budd Lake	brown bullhead	27.2	0.0193	2006
Budd Lake	brown bullhead	31.5	0.01034	2006
Budd Lake	white catfish	34.3	0.18067	2006
Budd Lake	white catfish	35.6	0.21846	2006
Budd Lake	white catfish	42.1	0.27947	2006
Budd Lake	northern pike	74.1	0.30651	2006
Budd Lake	northern pike	78.4	0.45883	2006
Budd Lake	northern pike	81	0.19917	2006
Budd Lake	largemouth bass	35.7	0.16964	2006
Budd Lake	largemouth bass	36.4	0.43134	2006

Budd Lake	largemouth bass	36.9	0.53606	2006
Budd Lake	largemouth bass	43.1	0.48615	2006
Budd Lake	largemouth bass	47.6	0.41803	2006
Carnegie Lake	Bluegill sunfish	16.7	0.06306	2006
Carnegie Lake	Bluegill sunfish	17.9	0.05655	2006
Carnegie Lake	Bluegill sunfish	19	0.10097	2006
Carnegie Lake	white perch	20.8	0.23403	2006
Carnegie Lake	white perch	20.8	0.14171	2006
Carnegie Lake	white perch	21	0.16152	2006
Carnegie Lake	largemouth bass	34.3	0.15636	2006
Carnegie Lake	largemouth bass	38.3	0.11614	2006
Carnegie Lake	largemouth bass	43.3	0.40243	2006
Carnegie Lake	largemouth bass	44.3	0.36529	2006
Carnegie Lake	largemouth bass	49.6	0.51996	2006
Davidson Mill Pond	bluegill	18.1	0.18292	2006
Davidson Mill Pond	bluegill	19	0.0504	2006
Davidson Mill Pond	bluegill	20.3	0.14941	2006
Davidson Mill Pond	chain pickerel	43.5	0.27161	2006
Davidson Mill Pond	chain pickerel	43.9	0.24405	2006
Davidson Mill Pond	chain pickerel	48.3	0.35285	2006
Davidson Mill Pond	American eel	75.2	0.20145	2006
Davidson Mill Pond	American eel	79	0.20049	2006
Davidson Mill Pond	largemouth bass	37.7	0.5091	2006
Davidson Mill Pond	largemouth bass	40.4	0.50194	2006
Davidson Mill Pond	largemouth bass	41.3	0.56886	2006
DeVoe Lake	brown bullhead	30.9	0.07703	2006
DeVoe Lake	brown bullhead	32.5	0.12689	2006
DeVoe Lake	brown bullhead	35.7	0.16058	2006
DeVoe Lake	chain pickerel	45.8	0.26277	2006
DeVoe Lake	chain pickerel	50	0.38873	2006
DeVoe Lake	chain pickerel	50.5	0.50737	2006
Duhernal Lake	bluegill	18.4	0.04042	2006
Duhernal Lake	bluegill	20.2	0.07774	2006
Duhernal Lake	bluegill	22.3	0.16006	2006
Duhernal Lake	brown bullhead	31.6	0.03663	2006
Duhernal Lake	brown bullhead	33.5	0.02588	2006
Duhernal Lake	brown bullhead	34.5	0.05482	2006
Duhernal Lake	largemouth bass	36.4	0.19646	2006
Duhernal Lake	largemouth bass	36.5	0.1712	2006
Duhernal Lake	largemouth bass	39.2	0.2798	2006
Farrington Lake	bluegill	17.2	0.09828	2006
Farrington Lake	bluegill	17.8	0.1512	2006
Farrington Lake	bluegill	18.7	0.11982	2006
Farrington Lake	yellow perch	20.6	0.17985	2006
Farrington Lake	yellow perch	20.7	0.22166	2006
Farrington Lake	yellow perch	25.7	0.41141	2006
Farrington Lake	brown bullhead	29.8	0.03402	2006
Farrington Lake	brown bullhead	34.7	0.04048	2006
Farrington Lake	brown bullhead	36.5	0.01656	2006
Farrington Lake	chain pickerel	43.2	0.19105	2006

Farrington Lake	chain pickerel	45.8	0.20378	2006
Farrington Lake	chain pickerel	48.8	0.48139	2006
Farrington Lake	largemouth bass	39.8	0.51737	2006
Farrington Lake	largemouth bass	41	0.50762	2006
Farrington Lake	largemouth bass	42.3	0.93764	2006
Farrington Lake	largemouth bass	46.3	1.41272	2006
Farrington Lake	largemouth bass	49	0.97277	2006
Lamington River @ Lamington	redbreast sunfish	15.8	0.12666	2006
Lamington River @ Lamington	redbreast sunfish	16.1	0.16744	2006
Lamington River @ Lamington	redbreast sunfish	16.6	0.14858	2006
Lamington River @ Lamington	smallmouth bass	18.6	0.13566	2006
Lamington River @ Lamington	smallmouth bass	20.6	0.18452	2006
Lamington River @ Lamington	smallmouth bass	22	0.12535	2006
Lamington River @ Lamington	brown trout	23.7	0.07503	2006
Lamington River @ Lamington	brown trout	26.1	0.08884	2006
Lamington River @ Lamington	American eel	53.7	0.18808	2006
Lamington River @ Lamington	American eel	60.2	0.39376	2006
Lamington River @ Lamington	American eel	63.2	0.24738	2006
Manalapan Lake	bluegill	18.4	0.04791	2006
Manalapan Lake	bluegill	18.4	0.07113	2006
Manalapan Lake	bluegill	18.6	0.04947	2006
Manalapan Lake	black crappie	21	0.09823	2006
Manalapan Lake	black crappie	21.4	0.10733	2006
Manalapan Lake	black crappie	22.8	0.14389	2006
Manalapan Lake	American eel	49.5	0.07662	2006
Manalapan Lake	American eel	53.4	0.12536	2006
Manalapan Lake	American eel	59.7	0.17554	2006
Manalapan Lake	largemouth bass	38	0.23315	2006
Manalapan Lake	largemouth bass	39.1	0.32996	2006
Manalapan Lake	largemouth bass	40.8	0.40945	2006
New Market Pond	bluegill	16.5	0.06683	2006
New Market Pond	bluegill	17	0.06511	2006
New Market Pond	bluegill	17.3	0.0888	2006
New Market Pond	black crappie	20.6	0.05647	2006
New Market Pond	black crappie	22.5	0.08984	2006
New Market Pond	black crappie	24.1	0.05213	2006
New Market Pond	brown bullhead	33.3	0.02354	2006
New Market Pond	brown bullhead	33.5	0.00063	2006
New Market Pond	American eel	34	0.02819	2006
New Market Pond	brown bullhead	34.5	0.00419	2006
New Market Pond	American eel	46.6	0.04004	2006
New Market Pond	American eel	48.5	0.10651	2006
New Market Pond	common carp	50.7	0.04819	2006
New Market Pond	common carp	52.7	0.05352	2006
New Market Pond	common carp	53	0.03293	2006
New Market Pond	largemouth bass	35.9	0.13736	2006
New Market Pond	largemouth bass	36.8	0.10944	2006
New Market Pond	largemouth bass	41.4	0.26315	2006
Raritan River @ Millstone River	redbreast sunfish	18.2	0.13396	2006
Raritan River @ Millstone River	redbreast sunfish	18.2	0.16323	2006

Raritan River @ Millstone River	redbreast sunfish	19.3	0.10685	2006
Raritan River @ Millstone River	smallmouth bass	30.9	0.29331	2006
Raritan River @ Millstone River	smallmouth bass	31	0.33445	2006
Raritan River @ Millstone River	white catfish	32.6	0.20333	2006
Raritan River @ Millstone River	white catfish	35.7	0.21395	2006
Raritan River @ Millstone River	smallmouth bass	37.3	0.26906	2006
Raritan River @ Millstone River	white catfish	40.1	0.23869	2006
Raritan River @ Millstone River	channel catfish	48.7	0.35862	2006
Raritan River @ Millstone River	channel catfish	53	0.17138	2006
Raritan River @ Millstone River	American eel	57.6	0.10876	2006
Raritan River @ Millstone River	common carp	57.9	0.12682	2006
Raritan River @ Millstone River	common carp	59.7	0.15017	2006
Raritan River @ Millstone River	channel catfish	63.7	0.16402	2006
Raritan River @ Millstone River	common carp	65.9	0.00431	2006
Raritan River @ Millstone River	American eel	70.6	0.24336	2006
Raritan River @ Millstone River	American eel	71	0.29174	2006
Raritan River at Millstone River	largemouth bass	32.4	0.25569	2006
Raritan River at Millstone River	largemouth bass	37.2	0.32619	2006
Raritan River at Millstone River	largemouth bass	43	0.6896	2006
Rosedale Lake in Pennington	bluegill	18.4	0.05062	2006
Rosedale Lake in Pennington	bluegill	18.7	0.06377	2006
Rosedale Lake in Pennington	bluegill	20.2	0.10783	2006
Rosedale Lake in Pennington	black crappie	24.1	0.10195	2006
Rosedale Lake in Pennington	black crappie	25.7	0.11855	2006
Rosedale Lake in Pennington	black crappie	30.8	0.12335	2006
Rosedale Lake in Pennington	common carp	62.2	0.11683	2006
Rosedale Lake in Pennington	common carp	64.1	0.10668	2006
Rosedale Lake in Pennington	common carp	66.8	0.10278	2006
Rosedale Lake in Pennington	largemouth bass	40	0.22114	2006
Rosedale Lake in Pennington	largemouth bass	47.6	0.22991	2006
Rosedale Lake in Pennington	largemouth bass	47.7	0.3298	2006
Round Valley Reservoir	bluegill	21.5	0.11044	2006
Round Valley Reservoir	bluegill	21.9	0.11996	2006
Round Valley Reservoir	bluegill	22	0.09508	2006
Round Valley Reservoir	white catfish	36.8	0.08206	2006
Round Valley Reservoir	white catfish	40	0.0991	2006
Round Valley Reservoir	lake trout	43.9	0.08773	2006
Round Valley Reservoir	channel catfish	50.2	0.11492	2006
Round Valley Reservoir	lake trout	52.2	0.10409	2006
Round Valley Reservoir	lake trout	53.7	0.2057	2006
Round Valley Reservoir	lake trout	54.9	0.12745	2006
Round Valley Reservoir	channel catfish	58.7	0.4599	2006
Round Valley Reservoir	channel catfish	61.8	0.06823	2006
Round Valley Reservoir	lake trout	66.5	0.18896	2006
Round Valley Reservoir	largemouth bass	30.6	0.19463	2006
Round Valley Reservoir	largemouth bass	41.8	0.2981	2006
Round Valley Reservoir	largemouth bass	45.1	0.38514	2006
South Branch Raritan River at Neshanic Station	redbreast sunfish	16.9	0.10381	2006

South Branch Raritan River at Neshanic Station	redbreast sunfish	17.7	0.09302	2006
South Branch Raritan River at Neshanic Station	redbreast sunfish	17.9	0.12138	2006
South Branch Raritan River at Neshanic Station	rock bass	20.4	0.24498	2006
South Branch Raritan River at Neshanic Station	rock bass	20.6	0.16647	2006
South Branch Raritan River at Neshanic Station	rock bass	21.1	0.2056	2006
South Branch Raritan River at Neshanic Station	smallmouth bass	34.9	0.31523	2006
South Branch Raritan River at Neshanic Station	common carp	37.2	0.05298	2006
South Branch Raritan River at Neshanic Station	smallmouth bass	41.1	0.38035	2006
South Branch Raritan River at Neshanic Station	common carp	42.7	0.05706	2006
South Branch Raritan River at Neshanic Station	common carp	46.1	0.04491	2006
South Branch Raritan River at Neshanic Station	smallmouth bass	49.9	0.39461	2006
South Branch Raritan River at Neshanic Station	American eel	63	0.29096	2006
South Branch Raritan River at Neshanic Station	American eel	69.9	0.22739	2006
South Branch Raritan River at Neshanic Station	American eel	72.5	0.25548	2006
South Branch Raritan River at Neshanic Station	largemouth bass	20	0.18969	2006
South Branch Raritan River at Neshanic Station	largemouth bass	21.3	0.17653	2006
South Branch Raritan River at Neshanic Station	largemouth bass	26.9	0.1382	2006
Spring Lake	common carp	48.3	0.04448	2006
Spring Lake	common carp	54.5	0.00202	2006
Spring Lake	common carp	64.6	0.0799	2006
Spruce Run Reservoir	channel catfish	41	0.06091	2006
Spruce Run Reservoir	striped x white bass hybrid	42.4	0.14346	2006
Spruce Run Reservoir	striped x white bass hybrid	48	0.18523	2006
Spruce Run Reservoir	striped x white bass hybrid	49.2	0.22875	2006
Spruce Run Reservoir	striped x white bass hybrid	53.6	0.39913	2006
Spruce Run Reservoir	striped x white bass hybrid	54.3	0.51704	2006
Spruce Run Reservoir	channel catfish	55.6	0.22611	2006
Spruce Run Reservoir	channel catfish	56.3	0.32477	2006
Spruce Run Reservoir	common carp	57.8	0.12598	2006
Spruce Run Reservoir	common carp	58.1	0.12418	2006
Spruce Run Reservoir	common carp	58.3	0.13401	2006
Spruce Run Reservoir	northern pike	65.5	0.31375	2006

Spruce Run Reservoir	northern pike	68.5	0.24939	2006
Spruce Run Reservoir	northern pike	76.8	0.20958	2006
Spruce Run Reservoir	largemouth bass	28.7	0.17957	2006
Spruce Run Reservoir	largemouth bass	35.8	0.17422	2006
Spruce Run Reservoir	largemouth bass	39.8	0.43026	2006
Spruce Run Reservoir	largemouth bass	42.9	0.44294	2006
Spruce Run Reservoir	largemouth bass	47.3	0.60489	2006
Weston Mill Pond	bluegill	17.7	0.06793	2006
Weston Mill Pond	bluegill	18.6	0.11264	2006
Weston Mill Pond	bluegill	18.9	0.2196	2006
Weston Mill Pond	yellow perch	25.3	0.27386	2006
Weston Mill Pond	black crappie	25.8	0.19928	2006
Weston Mill Pond	yellow perch	26.3	0.14497	2006
Weston Mill Pond	black crappie	26.9	0.28312	2006
Weston Mill Pond	black crappie	26.9	0.22769	2006
Weston Mill Pond	brown bullhead	27.1	0.01612	2006
Weston Mill Pond	brown bullhead	28.2	0.05252	2006
Weston Mill Pond	yellow perch	29.3	0.39874	2006
Weston Mill Pond	brown bullhead	35.7	0.0256	2006
Weston Mill Pond	chain pickerel	38.9	0.16182	2006
Weston Mill Pond	chain pickerel	45.9	0.28877	2006
Weston Mill Pond	chain pickerel	48	0.48049	2006
Weston Mill Pond	American eel	49.8	0.10278	2006
Weston Mill Pond	American eel	50.2	0.11332	2006
Weston Mill Pond	American eel	55.1	0.13674	2006
Weston Mill Pond	largemouth bass	38	0.52104	2006
Weston Mill Pond	largemouth bass	38.1	0.41189	2006
Weston Mill Pond	largemouth bass	39.5	0.46808	2006
Atsion Lake	American eel	31.2	0.33	2007
Atsion Lake	American eel	32.1	0.27	2007
Atsion Lake	American eel	51.7	0.52	2007
Atsion Lake	chain pickerel	33.2	0.47	2007
Atsion Lake	chain pickerel	39.6	0.69	2007
Atsion Lake	chain pickerel	44.7	0.82	2007
Batsto Lake	brown bullhead	32.9	0.29	2007
Batsto Lake	brown bullhead	33.4	0.22	2007
Batsto Lake	brown bullhead	36.18	0.16	2007
Batsto Lake	chain pickerel	23.7	0.30	2007
Batsto Lake	chain pickerel	35	0.78	2007
Batsto Lake	chain pickerel	35.5	0.85	2007
Batsto Lake	chain pickerel	35.9	0.44	2007
Batsto Lake	largemouth bass	35.5	1.25	2007
Batsto Lake	largemouth bass	35.6	1.07	2007
Batsto Lake	largemouth bass	36.7	0.85	2007
Batsto Lake	largemouth bass	37.2	0.10	2007
Cedar Lake	American eel	48.7	0.16	2007
Cedar Lake	American eel	54.2	0.18	2007
Cedar Lake	American eel	63.9	0.22	2007
Cedar Lake	largemouth bass	32.8	0.18	2007
Cedar Lake	largemouth bass	38.8	0.31	2007

Cedar Lake	largemouth bass	47	1.63	2007
Cedar Lake	white perch	30.7	0.33	2007
Cedar Lake	white perch	31.8	0.22	2007
Cedar Lake	white perch	37.4	0.51	2007
Cedarville Ponds	chain pickerel	30.6	0.65	2007
Cedarville Ponds	chain pickerel	32.5	0.46	2007
Cedarville Ponds	chain pickerel	34.4	0.53	2007
Cedarville Ponds	chain pickerel	35.4	0.54	2007
Cedarville Ponds	chain pickerel	43.1	0.69	2007
Cedarville Ponds	yellow perch	28	0.31	2007
Cedarville Ponds	yellow perch	28.8	0.33	2007
Cedarville Ponds	yellow perch	29.8	0.35	2007
Deal Lake	American eel	31	0.30	2007
Deal Lake	American eel	60	0.05	2007
Deal Lake	largemouth bass	38	0.09	2007
Deal Lake	largemouth bass	39.8	0.12	2007
Deal Lake	largemouth bass	40.2	0.14	2007
Deal Lake	white perch	16.3	0.02	2007
Deal Lake	white perch	18.1	0.04	2007
Deal Lake	white perch	20.2	0.18	2007
East Creek Lake	American eel	43.2	1.05	2007
East Creek Lake	American eel	51.8	1.02	2007
East Creek Lake	American eel	53.9	1.24	2007
East Creek Lake	chain pickerel	33.6	1.14	2007
East Creek Lake	chain pickerel	41.1	1.46	2007
East Creek Lake	chain pickerel	42.9	1.05	2007
East Creek Lake	largemouth bass	30.5	1.05	2007
East Creek Lake	largemouth bass	39.4	1.40	2007
East Creek Lake	largemouth bass	44.6	1.37	2007
Harrisville Lake	American eel	27.4	0.47	2007
Harrisville Lake	American eel	40.5	0.58	2007
Harrisville Lake	American eel	54.1	0.73	2007
Harrisville Lake	chain pickerel	27.6	1.05	2007
Harrisville Lake	chain pickerel	29.4	0.61	2007
Harrisville Lake	chain pickerel	30.4	0.91	2007
Harrisville Lake	chain pickerel	31.3	1.05	2007
Lake Absegami	American eel	31.6	0.36	2007
Lake Absegami	American eel	32.7	0.29	2007
Lake Absegami	American eel	47.5	0.80	2007
Lake Absegami	chain pickerel	35.3	1.32	2007
Lake Absegami	chain pickerel	35.4	1.26	2007
Lake Absegami	chain pickerel	43.5	1.24	2007
Lake Absegami	chain pickerel	47.6	1.62	2007
Lake Absegami	chain pickerel	58.7	1.39	2007
Lake Manahawkin	American eel	46.3	1.50	2007
Lake Manahawkin	American eel	56.1	1.43	2007
Lake Manahawkin	American eel	79.6	1.89	2007
Lake Manahawkin	largemouth bass	33.6	1.08	2007
Lake Manahawkin	largemouth bass	35.2	0.93	2007

Lake Manahawkin	largemouth bass	45.1	1.76	2007
Lake Nummy	yellow bullhead	29.2	0.44	2007
Lake Nummy	yellow bullhead	29.7	0.26	2007
Lake Nummy	yellow bullhead	33.4	0.79	2007
Lake Nummy	chain pickerel	46.2	1.07	2007
Lake Nummy	chain pickerel	56	2.56	2007
Lake Oswego	American eel	49.6	0.70	2007
Lake Oswego	American eel	60.5	0.46	2007
Lake Oswego	chain pickerel	26.6	0.82	2007
Lake Oswego	chain pickerel	27.7	0.76	2007
Lake Oswego	chain pickerel	42.1	0.42	2007
Lake Oswego	chain pickerel	46.8	2.05	2007
Lefferts Lake	brown bullhead	27.8	0.07	2007
Lefferts Lake	brown bullhead	28.8	0.10	2007
Lefferts Lake	brown bullhead	29.1	0.10	2007
Lefferts Lake	chain pickerel	43.9	0.11	2007
Lefferts Lake	chain pickerel	44.7	0.19	2007
Lefferts Lake	chain pickerel	46.7	0.21	2007
Lefferts Lake	yellow perch	23.8	0.10	2007
Lefferts Lake	yellow perch	24.4	0.12	2007
Lefferts Lake	yellow perch	25.3	0.09	2007
Lenape Lake	American eel	53	0.42	2007
Lenape Lake	American eel	58.7	1.06	2007
Lenape Lake	American eel	62.4	0.89	2007
Lenape Lake	largemouth bass	40	1.60	2007
Lenape Lake	largemouth bass	44.6	1.04	2007
Lenape Lake	largemouth bass	45.9	1.61	2007
Manasquan Reservoir	American eel	54.2	0.08	2007
Manasquan Reservoir	American eel	58	0.05	2007
Manasquan Reservoir	American eel	82.4	0.17	2007
Manasquan Reservoir	largemouth bass	40.1	0.10	2007
Manasquan Reservoir	largemouth bass	44.5	0.21	2007
Manasquan Reservoir	largemouth bass	49.2	0.40	2007
Maple Lake	American eel	44.1	0.81	2007
Maple Lake	American eel	48.6	0.81	2007
Maple Lake	American eel	53.6	1.02	2007
Maple Lake	largemouth bass	33.1	0.43	2007
Maple Lake	largemouth bass	33.7	0.84	2007
Maple Lake	largemouth bass	34.7	0.86	2007
Maple Lake	largemouth bass	38	1.48	2007
Marlu Lake	common carp	64.4	0.04	2007
Marlu Lake	common carp	66.6	0.04	2007
Marlu Lake	common carp	67.9	0.04	2007
Marlu Lake	largemouth bass	34.5	0.08	2007
Marlu Lake	largemouth bass	41.4	0.09	2007
Marlu Lake	largemouth bass	44.2	0.14	2007
Parvin Lake	American eel	63.1	0.12	2007
Parvin Lake	American eel	64.9	0.12	2007
Parvin Lake	chain pickerel	45.7	0.24	2007
Parvin Lake	chain pickerel	47.7	0.21	2007

Parvin Lake	chain pickerel	51.4	0.19	2007
Parvin Lake	largemouth bass	35.9	0.16	2007
Parvin Lake	largemouth bass	39.5	0.21	2007
Parvin Lake	largemouth bass	43.3	0.26	2007
Parvin Lake	largemouth bass	44.6	0.19	2007
Parvin Lake	largemouth bass	49	0.27	2007
Pohatcong Lake	American eel	44.3	0.44	2007
Pohatcong Lake	American eel	45.3	0.95	2007
Pohatcong Lake	American eel	66.2	0.72	2007
Pohatcong Lake	largemouth bass	41.7	0.78	2007
Pohatcong Lake	largemouth bass	41.7	0.69	2007
Pohatcong Lake	largemouth bass	42.7	0.61	2007
Pohatcong Lake	largemouth bass	43	0.64	2007
Pohatcong Lake	yellow perch	26.5	0.14	2007
Pohatcong Lake	yellow perch	31.2	0.36	2007
Pohatcong Lake	yellow perch	34.6	0.83	2007
Shenandoah Lake	American eel	46.8	0.42	2007
Shenandoah Lake	American eel	47.9	0.24	2007
Shenandoah Lake	American eel	75.5	0.42	2007
Shenandoah Lake	chain pickerel	35.3	0.34	2007
Shenandoah Lake	chain pickerel	41.2	0.23	2007
Shenandoah Lake	chain pickerel	41.4	0.32	2007
Shenandoah Lake	largemouth bass	40.5	0.37	2007
Shenandoah Lake	largemouth bass	41.6	0.46	2007
Shenandoah Lake	largemouth bass	43.2	0.65	2007
Swimming River Reservoir	American eel	42.2	0.04	2007
Swimming River Reservoir	American eel	66.1	0.07	2007
Swimming River Reservoir	American eel	68.9	0.08	2007
Swimming River Reservoir	largemouth bass	40	0.09	2007
Swimming River Reservoir	largemouth bass	42.7	0.09	2007
Swimming River Reservoir	largemouth bass	50.1	0.15	2007
Wading River	chain pickerel	36.3	2.60	2007
Wading River	chain pickerel	37.5	2.63	2007
Wading River	chain pickerel	40.7	2.03	2007
Wilson Lake	chain pickerel	34.7	1.58	2007
Wilson Lake	chain pickerel	37	1.36	2007
Wilson Lake	chain pickerel	54.7	2.02	2007
Wilson Lake	largemouth bass	35.4	1.53	2007
Wilson Lake	largemouth bass	38.9	1.63	2007
Wilson Lake	largemouth bass	40.9	3.27	2007
Wilson Lake	yellow perch	28	1.25	2007
Wilson Lake	yellow perch	28	1.46	2007
Wilson Lake	yellow perch	30	0.87	2007

Appendix C

Non-Tidal Surface Water NJPDES Facility List to Quantify Potential Hg Load

NJPDES Permit Number	Facility Name	Permitted Flow	Description
NJ0000876	HERCULES INC - KENVIL	0.7	Industrial
NJ0020036	DEPT OF VETERANS AFFAIRS	0.08	Municipal minor
NJ0020184	NEWTOWN WASTEWATER TREATMENT PLANT	1.4	Municipal major
NJ0020206	ALLENTOWN BORO WWTP	0.238	Municipal minor
NJ0020281	CHATHAM HILL STP	0.03	Municipal minor
NJ0020290	CHATHAM TWP MAIN STP	1	Municipal minor
NJ0020354	BRANCHBURG NESHANIC STP	0.055	Municipal minor
NJ0020389	CLINTON TOWN WWTP	2.03	Municipal major
NJ0020419	LONG POND SCHOOL WTP	0.01	Municipal minor
NJ0020427	CALDWELL WASTEWATER TREATMENT PLANT	4.5	Municipal major
NJ0020532	HARRISON TOWNSHIP TREATMENT PLANT	0.8	Municipal minor
NJ0020605	ALLAMUCHY SEWERAGE TREATMENT PLANT	0.6	Municipal minor
NJ0020711	WARREN CO TECHNICAL SCHOOL STP	0.012	Municipal minor
NJ0021083	VETERANS AFFAIRS NJ HEALTH CARE SYSTEM-LYONS	0.4	Municipal minor
NJ0021091	JEFFERSON TWP HIGH-MIDDLE SCHOOL	0.0275	Municipal minor
NJ0021105	ARTHUR STANLICK SCHOOL	0.013	Municipal minor
NJ0021113	WASHINGTON BORO WWTP	1.5	Municipal major
NJ0021253	INDIAN HILLS HIGH SCHOOL	0.0336	Municipal minor
NJ0021326	MEDFORD LAKES BOROUGH STP	0.55	Municipal minor
NJ0021334	MENDHAM BORO	0.45	Municipal minor
NJ0021342	SKYVIEW/HIBROOK WTP	0.023	Municipal minor
NJ0021369	HACKETTSTOWN MUA	3.48	Municipal major
NJ0021571	SPRINGFIELD TWP ELEM SCH STP	0.0075	Municipal minor
NJ0021636	NEW PROVIDENCE WWTP	1.5	Municipal major
NJ0021717	BUENA BOROUGH MUA	0.4	Municipal major
NJ0021865	FIDDLER'S ELBOW CTRY CLUB WWTP	0.03	Municipal minor
NJ0021890	MILFORD SEWER UTILITY	0.4	Municipal minor
NJ0021954	CLOVERHILL STP	0.5	Municipal minor
NJ0022047	RARITAN TOWNSHIP MUA STP	3.8	Municipal major
NJ0022063	SUSSEX COUNTY HOMESTEAD WTP	0.05	Municipal minor
NJ0022101	BLAIR ACADEMY	0.05	Municipal minor
NJ0022110	EDUCATIONAL TESTING SERVICE	0.08	Municipal minor
NJ0022144	HAGEDORN PSYCHIATRIC HOSPITAL	0.052	Municipal minor
NJ0022250	WOODSTOWN WASTEWATER TREATMENT PLANT	0.53	Municipal minor
NJ0022276	STONYBROOK SCHOOL	0.01	Municipal minor
NJ0022349	ROCKAWAY VALLEY REG SA	12	Municipal major
NJ0022381	NORTHERN BURLINGTON COUNTY	0.0135	Municipal minor
NJ0022390	NPDC SEWAGE TREATMENT PLANT	0.5	Municipal minor
NJ0022438	HELEN A FORT MIDDLE SCHOOL	0.05	Municipal minor

NJ0022489	WARREN TWP SEWERAGE AUTH STAGE I-II STP	0.47	Municipal minor
NJ0022497	WARREN STAGE IV STP	0.8	Municipal minor
NJ0022586	MARLBORO PSYCHIATRIC HOSP STP	1	Municipal major
NJ0022675	ROXBURY TOWNSHIP	2	Municipal major
NJ0022764	RIVER ROAD STP	0.1172	Municipal minor
NJ0022781	POTTERSVILLE STP	0.048	Municipal minor
NJ0022845	HARRISON BROOK STP	2.5	Municipal major
NJ0022918	ROOSEVELT BORO WTP	0.25	Municipal minor
NJ0022985	WRIGHTSTOWN BOROUGH STP	0.337	Municipal minor
NJ0023001	SALVATION ARMY CAMP TECUMSEH	0.018	Municipal minor
NJ0023124	MONTGOMERY HIGH SCHOOL STP	0.035	Municipal minor
NJ0023175	ROUND VALLEY MIDDLE SCHOOL	0.009	Municipal minor
NJ0023311	KINGWOOD TWP SCHOOL	0.0048	Municipal minor
NJ0023493	WASHINGTON TOWNSHIP MUA WTP	0.5	Municipal minor
NJ0023540	NAVAL WEAPONS STATION EARLE	0.37	Municipal minor
NJ0023663	CARRIER FOUNDATION WTP	0.04	Municipal minor
NJ0023698	POMPTON LAKES BORO MUA	1.2	Municipal major
NJ0023728	PINE BROOK STP	8.8	Municipal major
NJ0023736	PINELANDS WASTEWATER COMPANY	0.5	Municipal minor
NJ0023787	EAST WINDSOR WATER POLLUTION CONTROL PLANT	4.5	Municipal major
NJ0023841	LOUNSBERRY HOLLOW MIDDLE SCH STP	0.032	Municipal minor
NJ0023949	LEGENDS RESORT & COUNTRY CLUB	0.35	Municipal minor
NJ0024031	ELMWOOD WTP	2.978	Municipal major
NJ0024040	WOODSTREAM STP	1.7	Municipal major
NJ0024091	UNION TWP ELEMENTARY SCHOOL	0.011	Municipal minor
NJ0024104	UNITED WATER PRINCETON MEADOWS	1.64	Municipal major
NJ0024163	BIG `N` SHOPPING CENTER STP	0.02	Municipal minor
NJ0024414	WEST MILFORD SHOPPING CENTER STP	0.02	Municipal minor
NJ0024457	OUR LADY OF THE MAGNIFICAT	0.0012	Municipal minor
NJ0024465	LONG HILL TOWNSHIP OF STP	0.9	Municipal minor
NJ0024490	VERONA TWP WTP	4.1	Municipal major
NJ0024511	LIVINGSTON WATER POLLUTION CONTROL FACILITY	4.6	Municipal major
NJ0024716	PHILLIPSBURG TOWN STP	3.5	Municipal major
NJ0024759	EWING-LAWRENCE SA WTP	16	Municipal major
NJ0024791	RIDGEWOOD VILLAGE WPC FACILITY	5	Municipal major
NJ0024813	NORTHWEST BERGEN CNTY UA	16.8	Municipal major
NJ0024821	PEMBERTON TOWNSHIP MUA STP	2.5	Municipal major
NJ0024864	SOMERSET RARITAN VALLEY SA	21.3	Municipal major
NJ0024902	HANOVER SEWERAGE AUTHORITY	4.61	Municipal major
NJ0024911	BUTTERWORTH WATER POLLUTION CONTROL UTILITY	3.3	Municipal major
NJ0024929	WOODLAND WATER POLLUTION CONTROL UTILITY(WPCU	2	Municipal major
NJ0024937	MOLITOR WATER POLLUTION CONTROL FACILITY	5	Municipal major
NJ0024970	PARSIPPANY TROY HILLS	16	Municipal major
NJ0025160	HAMMONTON WTPF	1.6	Municipal major
NJ0025330	CEDAR GROVE STP	2	Municipal major

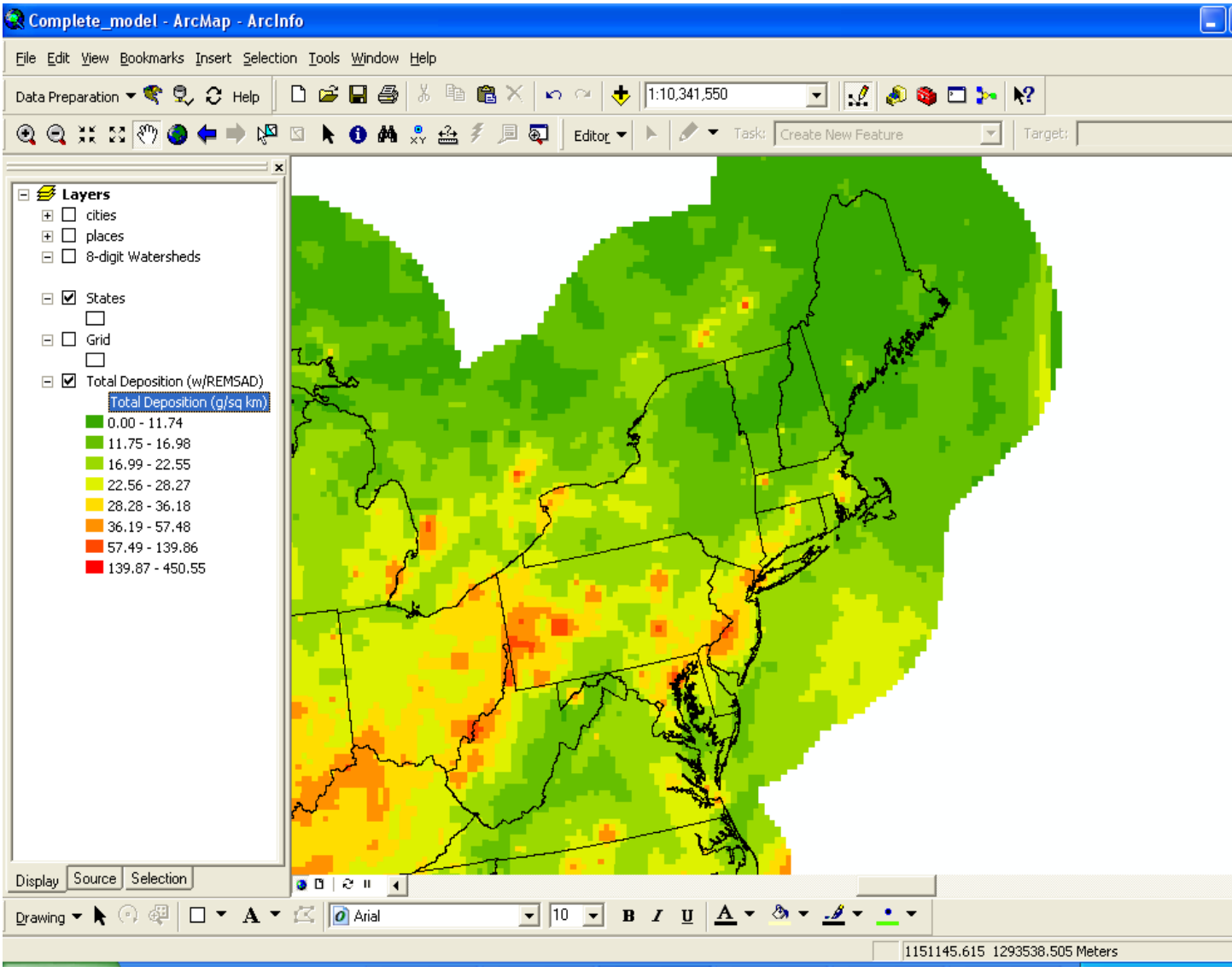
NJ0025496	MORRISTOWN SEWER UTILITY	6.3	Municipal major
NJ0025518	FLORHAM PARK SEWERAGE AUTH	1.4	Municipal major
NJ0026174	CRESCENT PARK STP	0.064	Municipal minor
NJ0026387	BERNARDSVILLE STP	0.8	Municipal minor
NJ0026689	GREYSTONE PARK PSYCH HOSPITAL	0.4	Municipal minor
NJ0026697	READINGTON TWP PUBLIC SCHOOL	0.017	Municipal minor
NJ0026719	ALBERT C WAGNER YOUTH CORRECTIONAL FACILITY	1.3	Municipal minor
NJ0026727	COLORADO CAFE WTP	0.0175	Municipal minor
NJ0026824	CHESTER SHOPPING CENTER	0.011	Municipal minor
NJ0026832	MEDFORD TWP WASTEWATER TREATMENT PLANT	1.75	Municipal major
NJ0026867	WHITE ROCK STP	0.1295	Municipal minor
NJ0026891	BURNT HILL TREATMENT PLANT #1	0.0153	Municipal minor
NJ0026905	STAGE II TREATMENT PLANT	0.48	Municipal minor
NJ0027006	RINGWOOD ACRES TREATMENT PLANT	0.036	Municipal minor
NJ0027031	HOLMDEL BD OF ED VILLAGE SCHOOL STP	0.01	Municipal minor
NJ0027049	POPE JOHN XXIII HIGH SCH WTP	0.022	Municipal minor
NJ0027057	SPARTA PLAZA WTP	0.05	Municipal minor
NJ0027065	SPARTA ALPINE SCHOOL	0.025	Municipal minor
NJ0027227	TRUMP NATIONAL GOLF COURSE	0.0005	Municipal minor
NJ0027464	HANOVER MOBILE VILLAGE ASSOC	0.02	Municipal minor
NJ0027511	CALIFORNIA VILLAGE SEWER PLANT	0.032	Municipal minor
NJ0027529	CAREONE @HOLMDEL	0.025	Municipal minor
NJ0027553	LESTER D. WILSON ELEM SCHOOL	0.0075	Municipal minor
NJ0027561	DELAWARE TOWNSHIP MUA	0.065	Municipal minor
NJ0027596	SPARTAN VILLAGE MOBILE HOME PK	0.038	Municipal minor
NJ0027669	AWOSTING STP	0.045	Municipal minor
NJ0027677	OLDE MILFORD ESTATES STP	0.172	Municipal minor
NJ0027685	HIGHVIEW ACRES STP	0.2	Municipal minor
NJ0027715	MERCER CO CORRECTION CTR STP	0.09	Municipal minor
NJ0027731	PRINCETON HEALTHCARE SYSTEM	0.296	Industrial
NJ0027774	OAKWOOD KNOLLS WWTP	0.035	Municipal minor
NJ0027821	MUSCONETCONG SEWERAGE AUTHORITY	5.79	Municipal major
NJ0027961	BERKELEY HEIGHTS WPCF	3.1	Municipal major
NJ0028002	MOUNTAIN VIEW STP	13.5	Municipal major
NJ0028304	QUALITY INN OF LEDGEWOOD	0.04	Municipal minor
NJ0028436	RARITAN TWP MUA-FLEMINGTON	2.35	Municipal major
NJ0028479	NJ TRAINING SCHOOL FOR BOYS	0.15	Municipal minor
NJ0028487	MOUNTAINVIEW CORRECTIONAL INSTITUTION	0.26	Municipal minor
NJ0028541	BIRCH HILL PARK STP	0.02	Municipal minor
NJ0028665	MOBILE ESTATES OF SOUTHAMPTON INC	0.06	Municipal minor
NJ0028894	KITTATINNY REG HS BD OF ED	0.045	Municipal minor
NJ0029041	REGENCY @ SUSSEX APT	0.08	Municipal minor
NJ0029386	TWO BRIDGES WASTEWATER TREATMENT PLANT	10	Municipal major
NJ0029432	ROBERT ERSKINE SCHOOL STP	0.008	Municipal minor
NJ0029475	HIGHTSTOWN BORO AWWTP	1	Municipal major

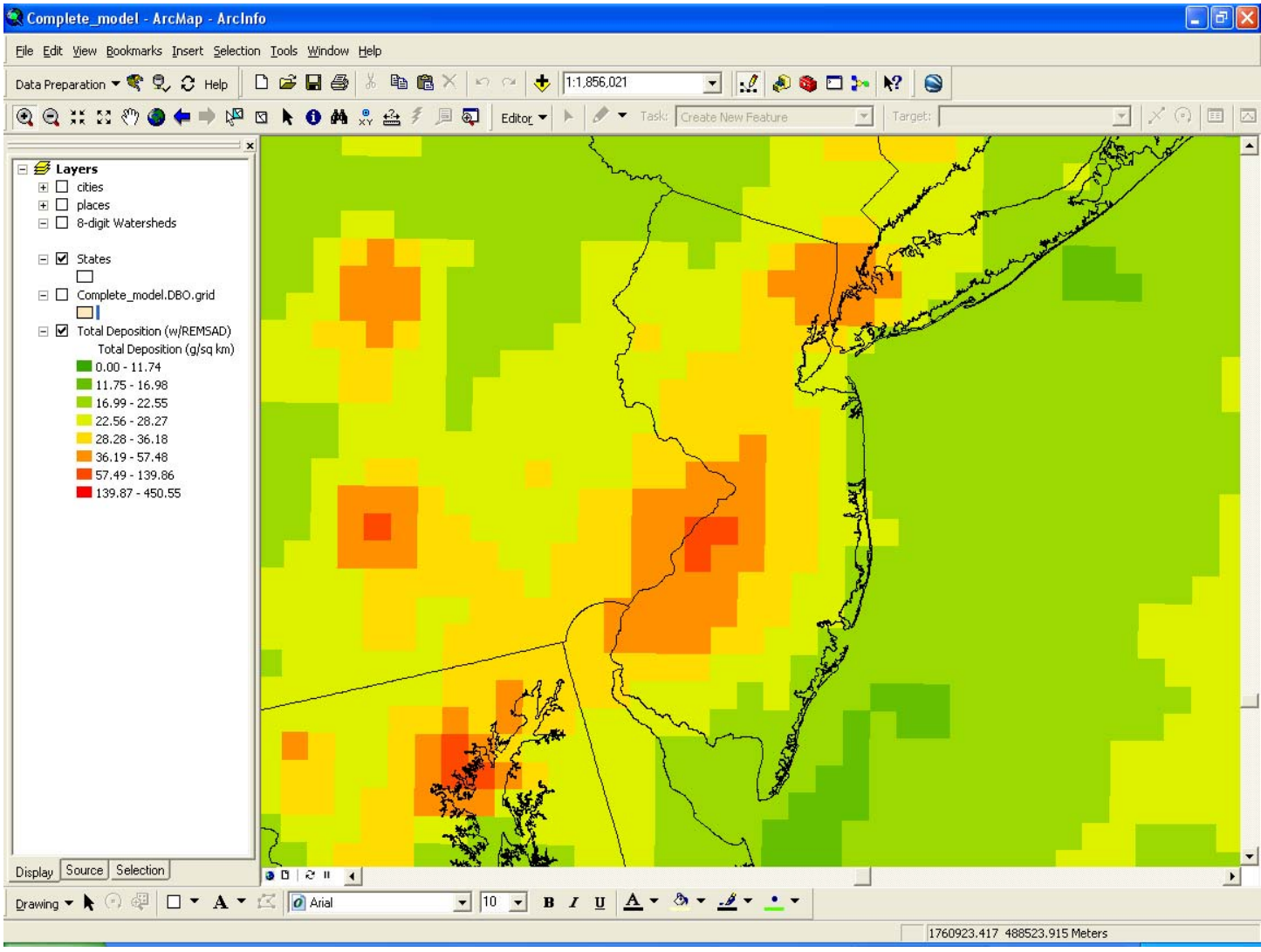
NJ0029831	FRENCHTOWN WASTEWATER TREATMENT PLANT	0.15	Municipal minor
NJ0029858	OAKLAND CARE CENTER INC	0.03	Municipal minor
NJ0031046	NORTH WARREN REG SCH DIST WTF	0.02	Municipal minor
NJ0031119	STONY BROOK RSA- RIVER ROAD STP	13.06	Municipal major
NJ0031585	HIGH POINT REGIONAL HS	0.03	Municipal minor
NJ0031615	CAMDEN COUNTY VOC & TECH SCHOOL	0.058	Municipal minor
NJ0031674	REMINGTON'S RESTAURANT	0.028	Municipal minor
NJ0031771	COLTS NECK INN HOTEL	0.006	Municipal minor
NJ0032395	RINGWOOD PLAZA STP	0.01168	Municipal minor
NJ0033995	ENVIRONMENTAL DISPOSAL CORP	2.1	Municipal major
NJ0035084	EXXONMOBIL RESEARCH & ENGINEERING CO	0.22	Industrial
NJ0035114	BELVIDERE AREA WWTF	0.5	Municipal minor
NJ0035301	STONY BROOK RGNL SEWERAGE AUTH	0.3	Municipal minor
NJ0035319	STONY BROOK RSA	0.3	Municipal minor
NJ0035483	OXFORD AREA WTF	0.5	Municipal minor
NJ0035670	ALEXANDRIA MIDDLE SCHOOL	0.011	Municipal minor
NJ0035718	HOLMDEL WASTEWATER TREATMENT FACILITY	0.04	Municipal minor
NJ0050130	RIVERSIDE FARMS STP	0.145	Municipal minor
NJ0050369	WARREN STAGE V STP	0.38	Municipal minor
NJ0050580	HAMPTON COMMONS WASTEWATER FACILITY	0.05	Municipal minor
NJ0052256	CHATHAM GLEN STP	0.155	Municipal minor
NJ0053112	CHAPEL HILL ESTATES STP	0.01	Municipal minor
NJ0053350	SUSSEX CNTY MUA UPPER WALLKILL FACILITY	3	Municipal major
NJ0053759	WANAQUE VALLEY REGIONAL SEWERAGE AUTHORITY	1.25	Municipal major
NJ0055395	BURLINGTON CNTY RESOURCE RECOVERY COMPLEX	2.075	Industrial
NJ0060038	PIKE BROOK STP	0.67	Municipal minor
NJ0067733	OXBRIDGE WASTEWATER TREATMENT PLANT	0.16	Municipal minor
NJ0069523	CHERRY VALLEY STP	0.286	Municipal minor
NJ0080811	RAMAPO RIVER RESERVE WWTP	0.1137	Municipal minor
NJ0098663	HOMESTEAD TREATMENT UTILITY	0.25	Municipal minor
NJ0098922	READINGTON-LEBANON SA	0.8	Municipal minor
NJ0100528	GLEN MEADOWS/TWIN OAKS STP	0.025	Municipal minor
NJ0102270	EVOINK DEGUSSA CORP	0.015	Industrial
NJ0102563	ROUTE 78 OFFICE AREA WWTF	0.09653	Municipal minor
NJ0109061	LONG VALLEY VILLAGE WTP	0.244	Municipal minor
NJ0136603	MORRIS LAKE WTP	0.2	Municipal minor
NJG0005134	HERCULES GROUNDWATER TREATMT AT GEO SPEC CHEM	0.432	Industrial

Footnote: TMDL Section 4.0 - Source Assessment describes list construction.

Appendix D

Mercury Air Deposition Load for New Jersey (provided by Mr. Dwight Atkinson of EPA)

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Data Preparation
Help
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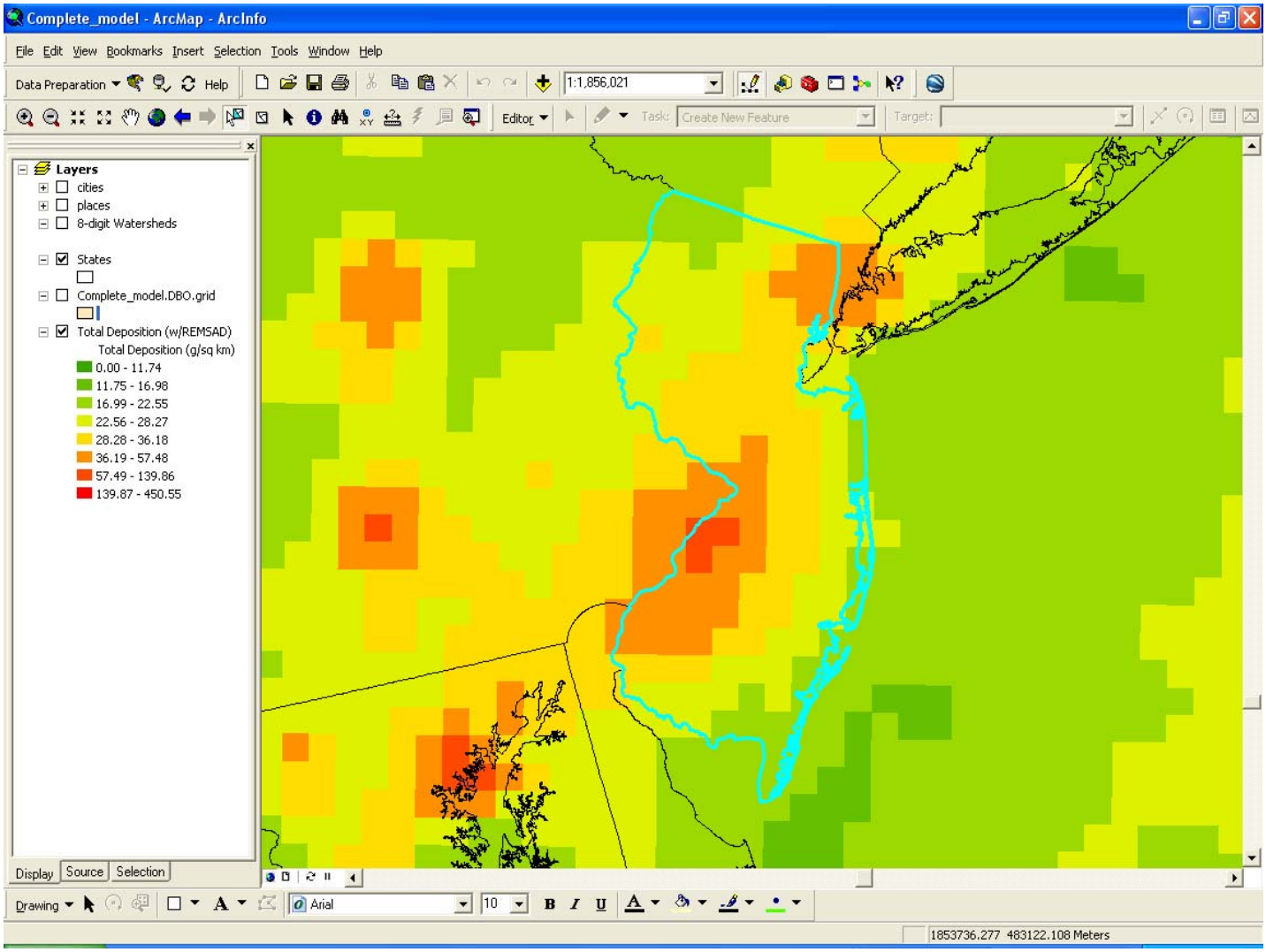
Editor
Task:
Create New Feature
Target:
Layers
cities
places
8-digit Watersheds
States
Complete_model.DBO.grid
Total Deposition (w/REMSAD)
Total Deposition (g/sq km)
0.00 - 11.74
11.75 - 16.98
16.99 - 22.55
22.56 - 28.27
28.28 - 36.18
36.19 - 57.48
57.49 - 139.86
139.87 - 450.55
Display
Source
Selection
Drawing
Arial
10
1760923.417 488523.915 Meters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File Edit View Bookmarks Insert Selection Tools Window Help
Data Preparation
Help
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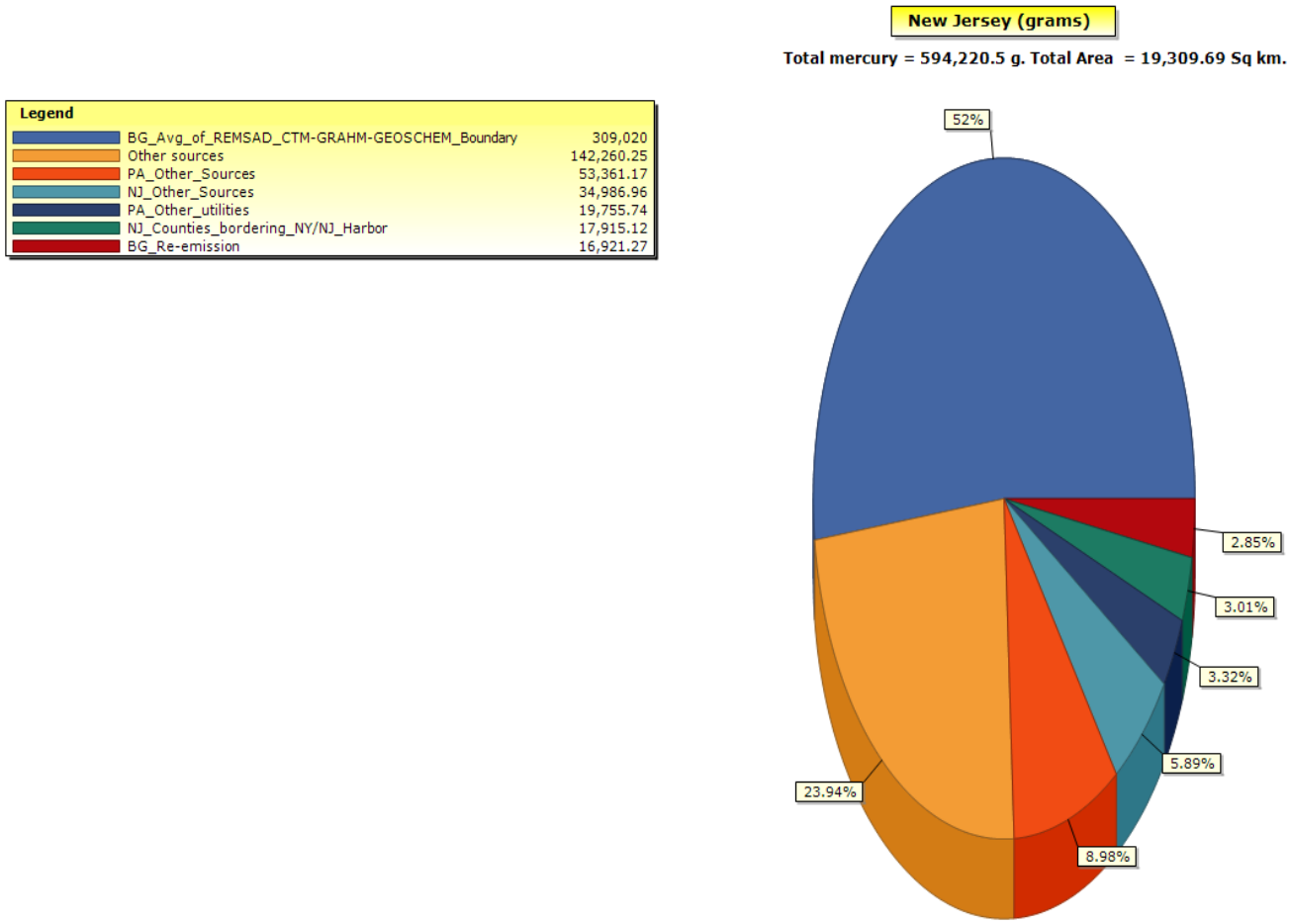
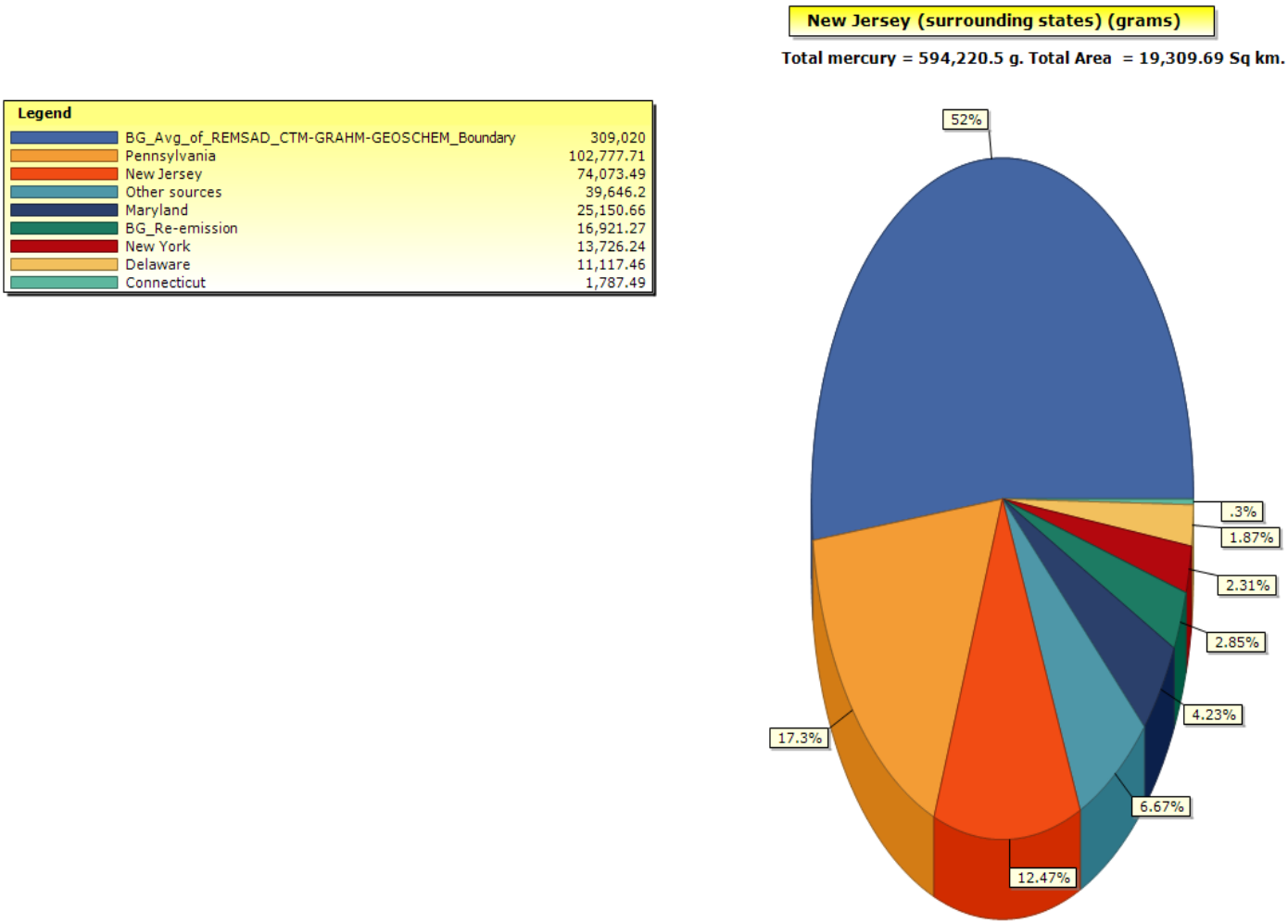
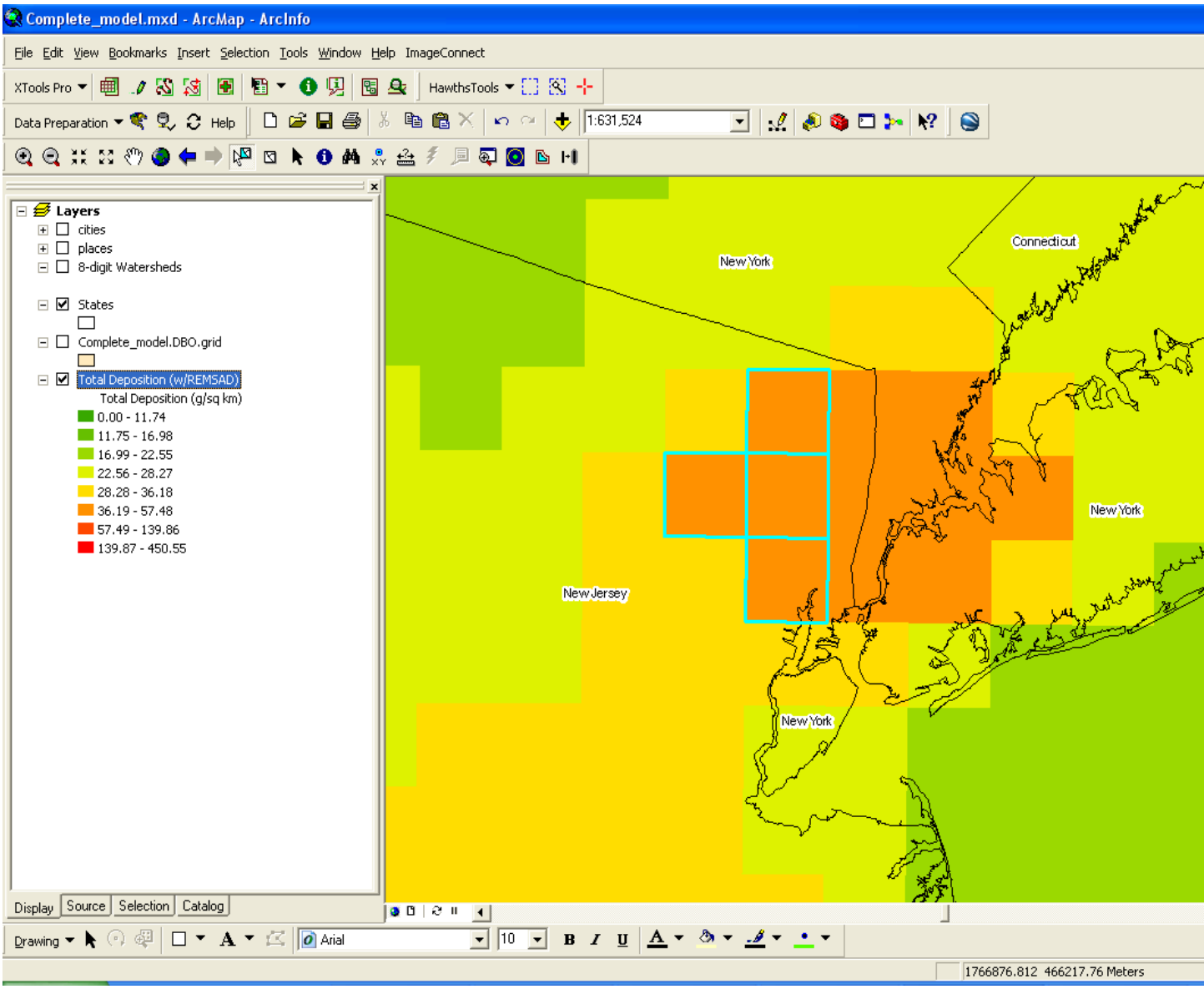
Editor
Task:
Create New Feature
Target:
Layers
cities
places
8-digit Watersheds
States
Complete_model.DBO.grid
Total Deposition (w/REMSAD)
Total Deposition (g/sq km)
0.00 - 11.74
11.75 - 16.98
16.99 - 22.55
22.56 - 28.27
28.28 - 36.18
36.19 - 57.48
57.49 - 139.86
139.87 - 450.55
Display
Source
Selection
Drawing
Arial
10
1853736.277 483122.108 Meters


New Jersey (grams)
Total mercury = 594,220.5 g. Total Area = 19,309.69 Sq km.
Legend
BG_Avg_of_REMSAD_CTM-GRAHM-GEOSCHEM_Boundary 309,020
Other sources 142,260.25
PA_Other_Sources 53,361.17
NJ_Other_Sources 34,986.96
PA_Other_utilities 19,755.74
NJ_Counties_bordering_NY/NJ_Harbor 17,915.12
BG_Re-emission 16,921.27
52%
2.85%
3.01%
3.32%
5.89%
23.94%
8.98%


New Jersey (surrounding states) (grams)
Total mercury = 594,220.5 g. Total Area = 19,309.69 Sq km.
Legend
BG_Avg_of_REMSAD_CTM-GRAHM-GEOSCHEM_Boundary 309,020
Pennsylvania 102,777.71
New Jersey 74,073.49
Other sources 39,646.2
Maryland 25,150.66
BG_Re-emission 16,921.27
New York 13,726.24
Delaware 11,117.46
Connecticut 1,787.49
52%
.3%
1.87%
2.31%
2.85%
4.23%
6.67%
12.47%
17.3%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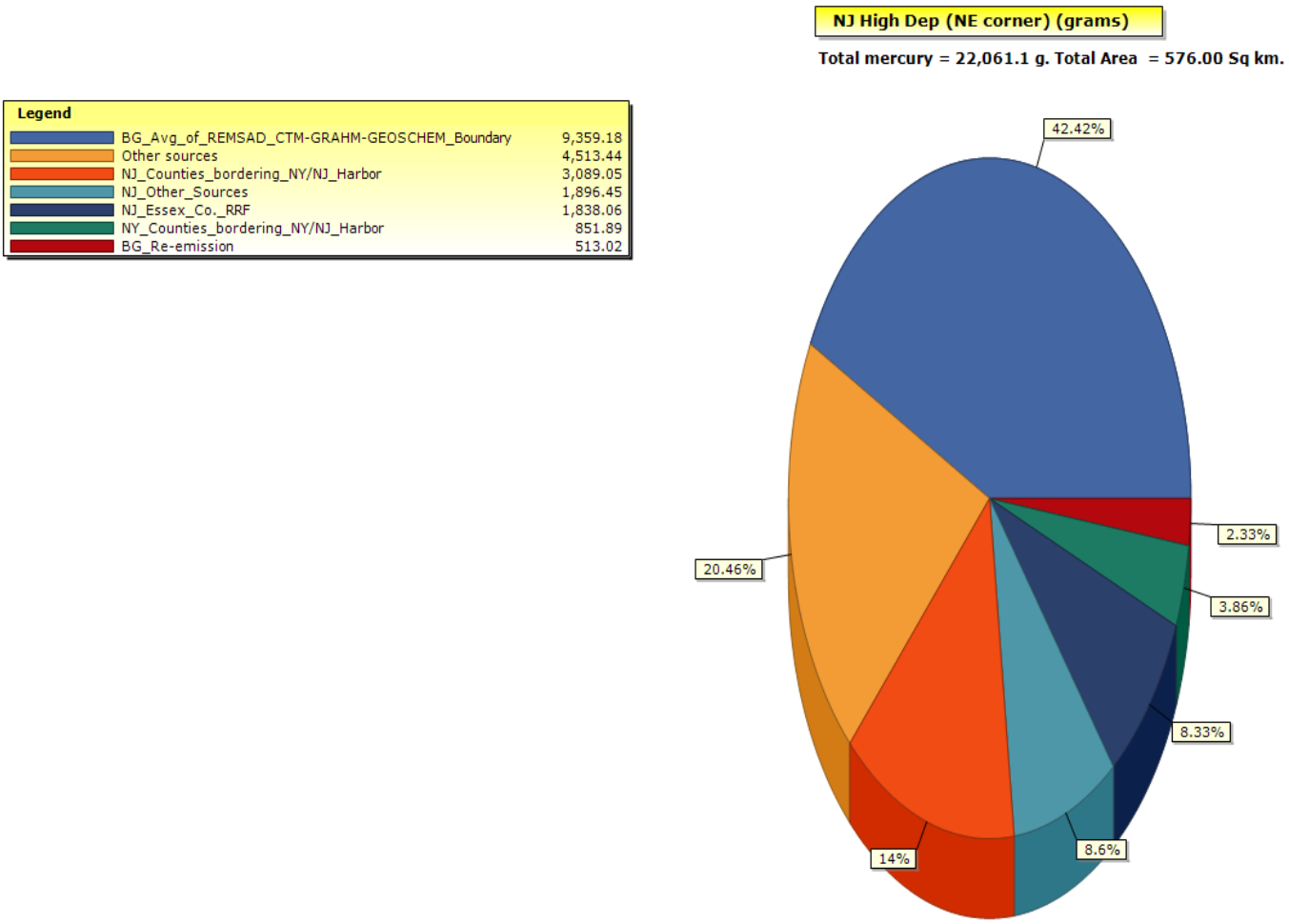
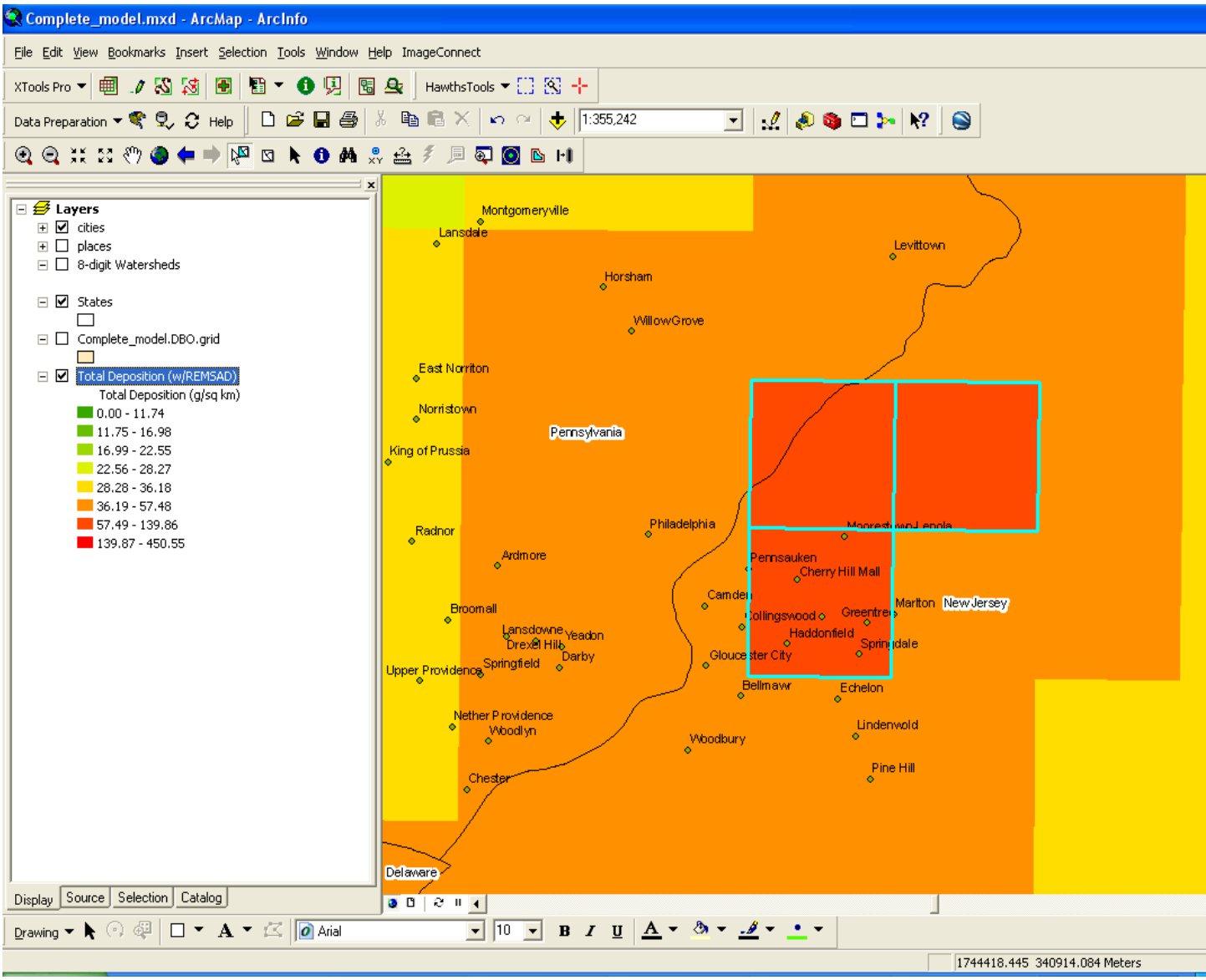
XTools Pro
HawthsTools
Data Preparation
Help
1:631,524
Layers
cities
places
8-digit Watersheds
States
Complete_model.DBO.grid
Total Deposition (w/REMSAD)
Total Deposition (g/sq km)
0.00 - 11.74
11.75 - 16.98
16.99 - 22.55
22.56 - 28.27
28.28 - 36.18
36.19 - 57.48
57.49 - 139.86
139.87 - 450.55
Display
Source
Selection
Catalog
Drawing
Arial
10
New York
Connecticut
New York
New Jersey
New York
1766876.812 466217.76 Meters


NJ High Dep (NE corner) (grams)
Total mercury = 22,061.1 g. Total Area = 576.00 Sq km.
Legend
BG_Avg_of_REMSAD_CTM-GRAHM-GEOSCHEM_Boundary 9,359.18
Other sources 4,513.44
NJ_Counties_bordering_NY/NJ_Harbor 3,089.05
NJ_Other_Sources 1,896.45
NJ_Essex_Co._RRF 1,838.06
NY_Counties_bordering_NY/NJ_Harbor 851.89
BG_Re-emission 513.02
42.42%
2.33%
3.86%
8.33%
8.6%
14%
20.46%


Complete_model.mxd - ArcMap - ArcInfo
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XTools Pro
HawthsTools
Data Preparation
Help
1:355,242
Layers
cities
places
8-digit Watersheds
States
Complete_model.DBO.grid
Total Deposition (w/REMSAD)
Total Deposition (g/sq km)
0.00 - 11.74
11.75 - 16.98
16.99 - 22.55
22.56 - 28.27
28.28 - 36.18
36.19 - 57.48
57.49 - 139.86
139.87 - 450.55
Display
Source
Selection
Catalog
Drawing
Arial
10
Montgomeryville
Lansdale
Levittown
Horsham
WillowGrove
East Norriton
Norristown
Pennsylvania
King of Prussia
Philadelphia
Radnor
Ardmore
Pennsauken
Cherry Hill Mall
Broomall
Lansdowne
Yeadon
Drexel Hill
Darby
Springfield
Upper Providence
Gloucester City
Haddonfield
Marlton
New Jersey
Bellmawr
Echelon
Nether Providence
Woodlyn
Woodbury
Lindenwold
Pine Hill
Chester
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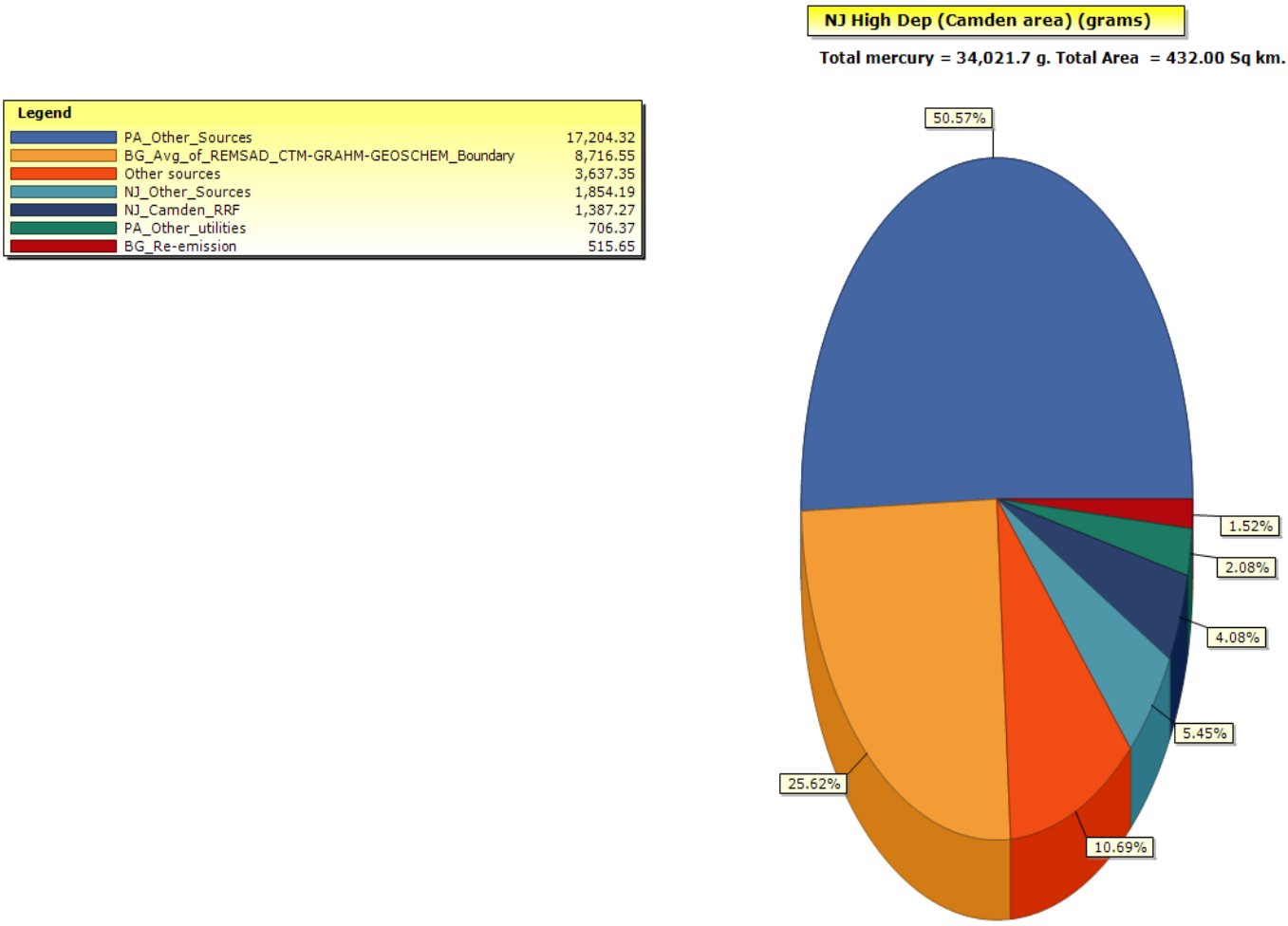
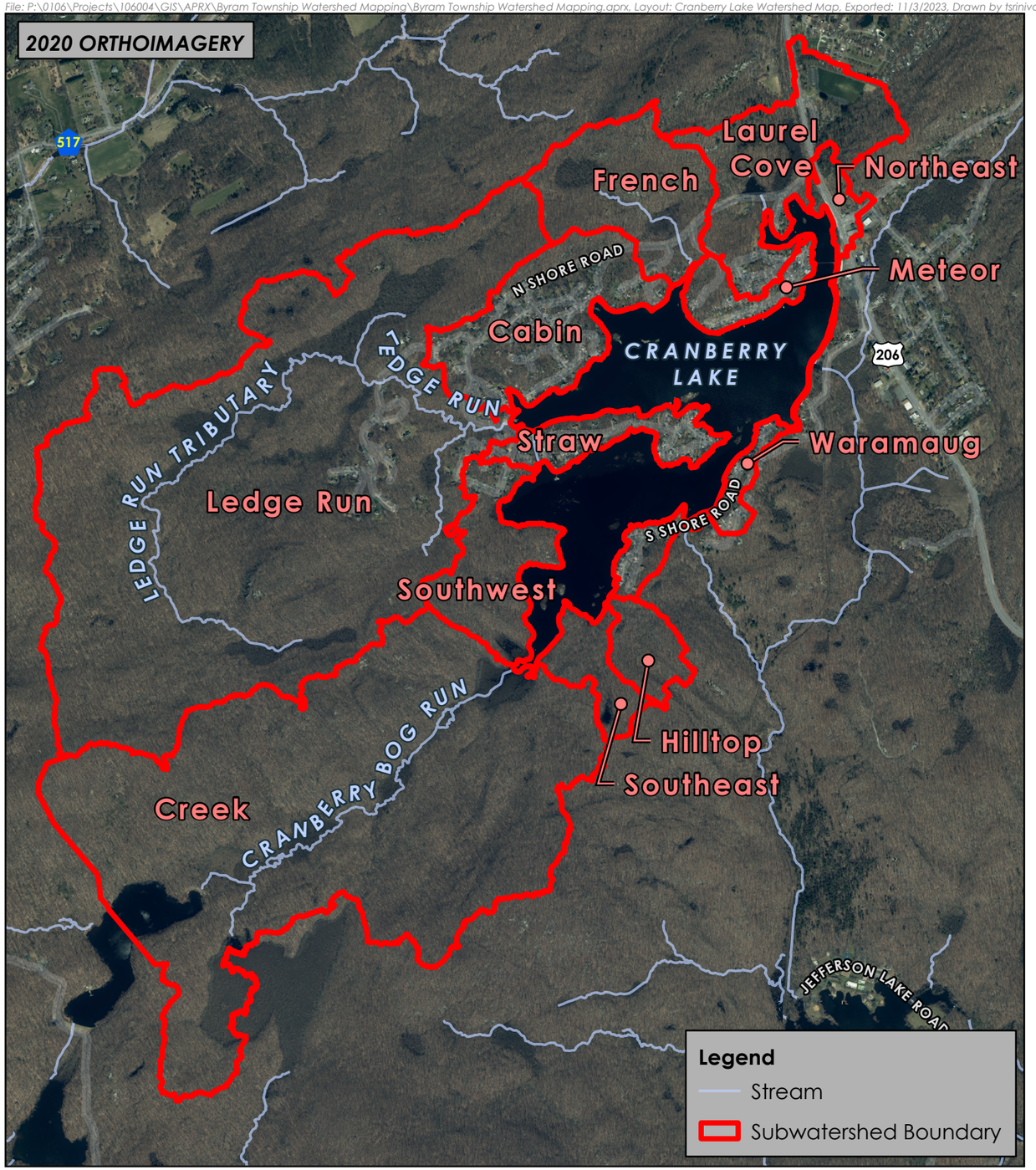
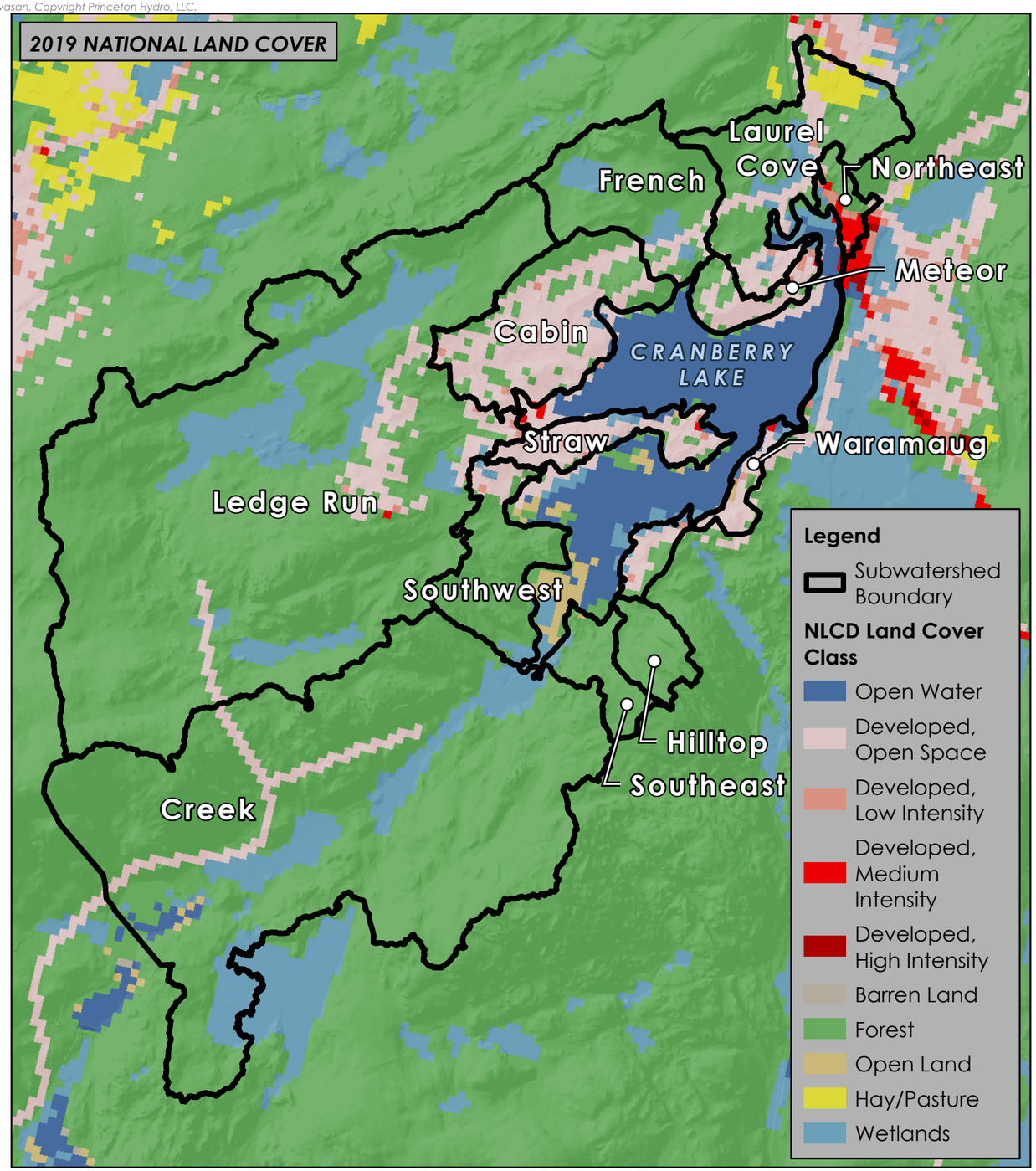
1744418.445 340914.084 Meters


NJ High Dep (Camden area) (grams)
Total mercury = 34,021.7 g. Total Area = 432.00 Sq km.
Legend
PA_Other_Sources 17,204.32
BG_Avg_of_REMSAD_CTM-GRAHM-GEOSCHEM_Boundary 8,716.55
Other sources 3,637.35
NJ_Other_Sources 1,854.19
NJ_Camden_RRF 1,387.27
PA_Other_utilities 706.37
BG_Re-emission 515.65
50.57%
1.52%
2.08%
4.08%
5.45%
25.62%
10.69%

APPENDIX II: WATERSHED/LAND USE MAPS

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Cranberry Lake Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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www.PrincetonHydro.com

NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
2. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
3. 2020 orthoimagery, hillshade DEM, and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal.
4. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

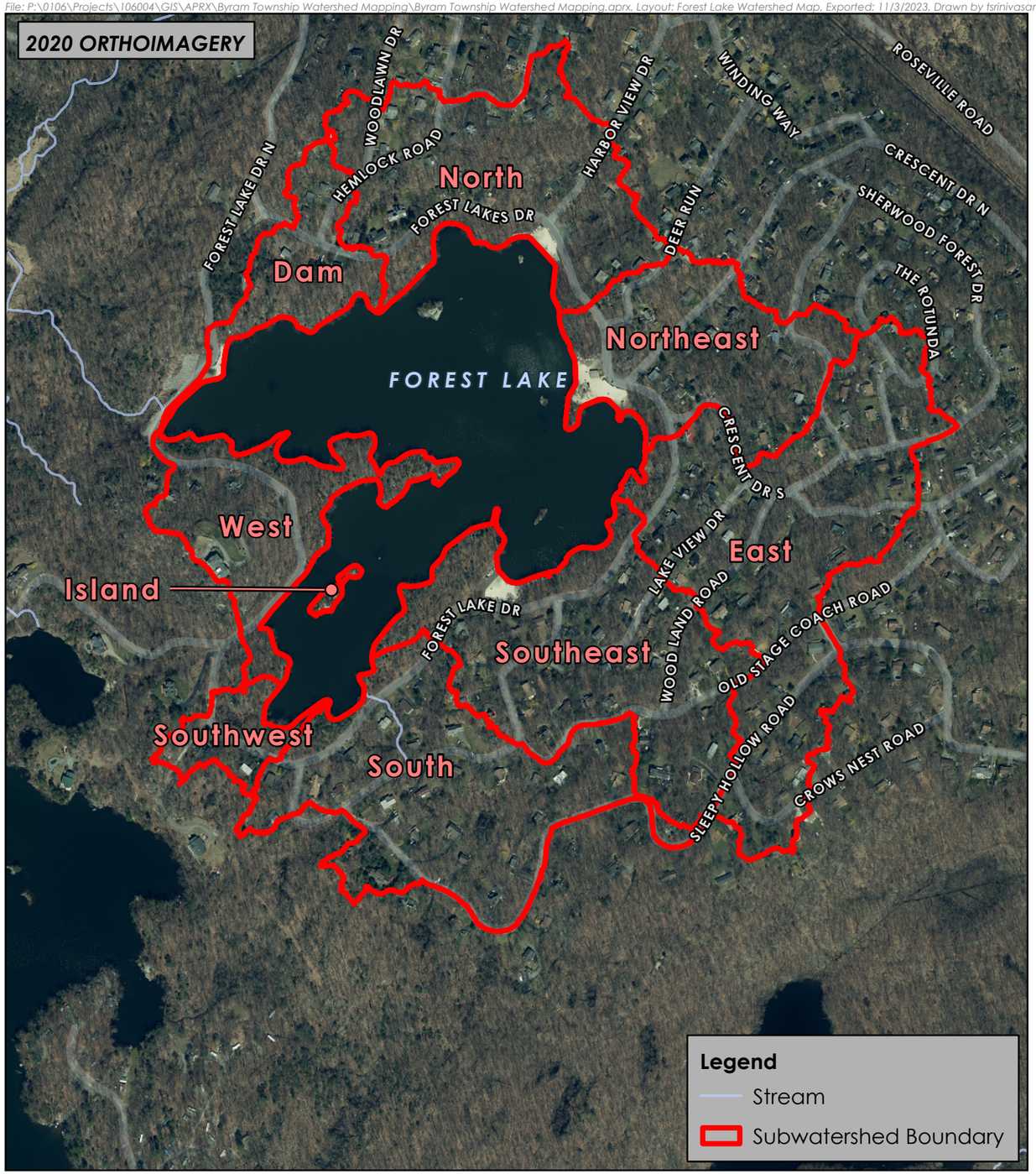
0 800 1,600 Feet

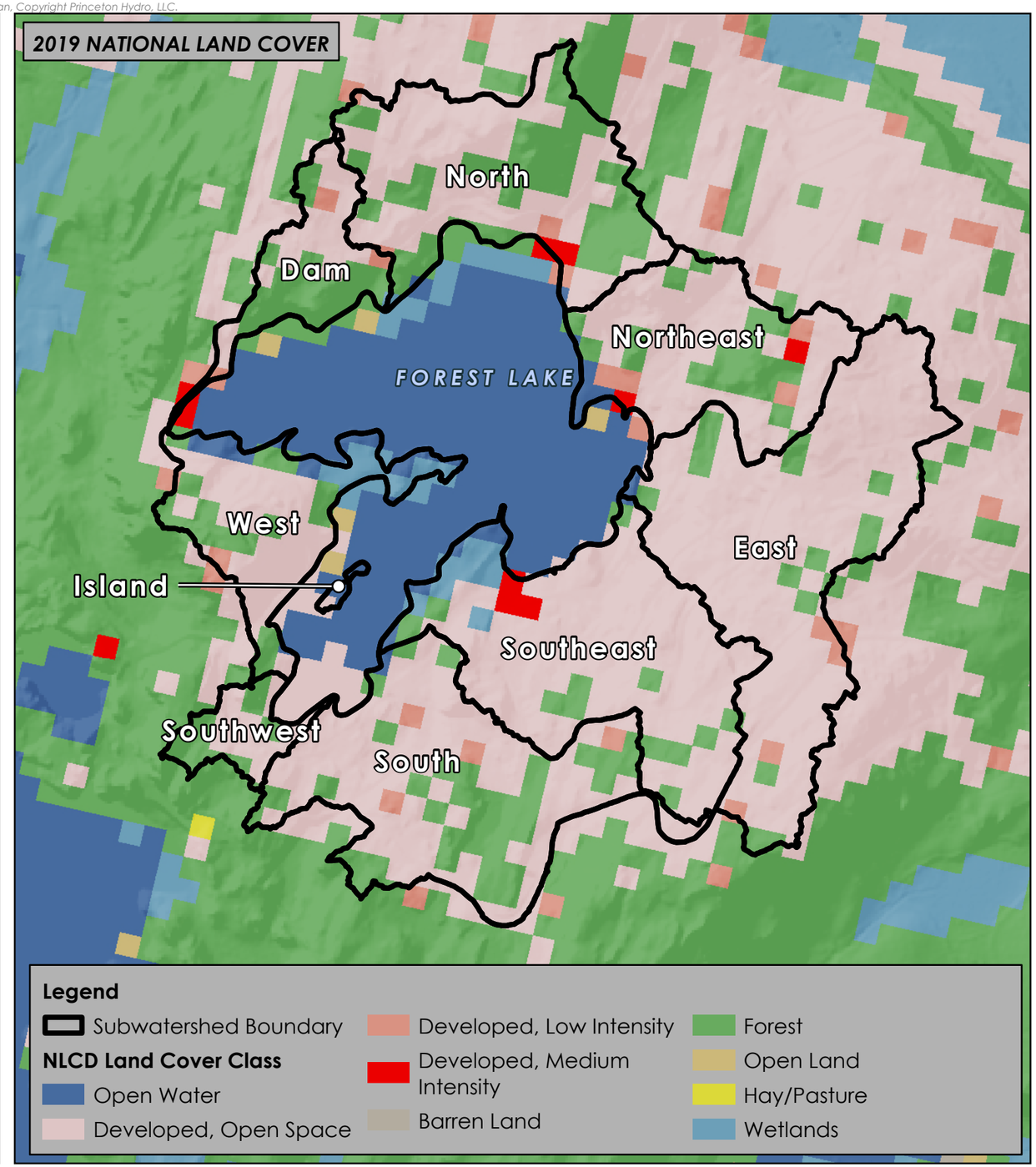
Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

CRANBERRY LAKE WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Forest Lake Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
2. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
3. 2020 orthoimagery, hillshade DEM, and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal.
4. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

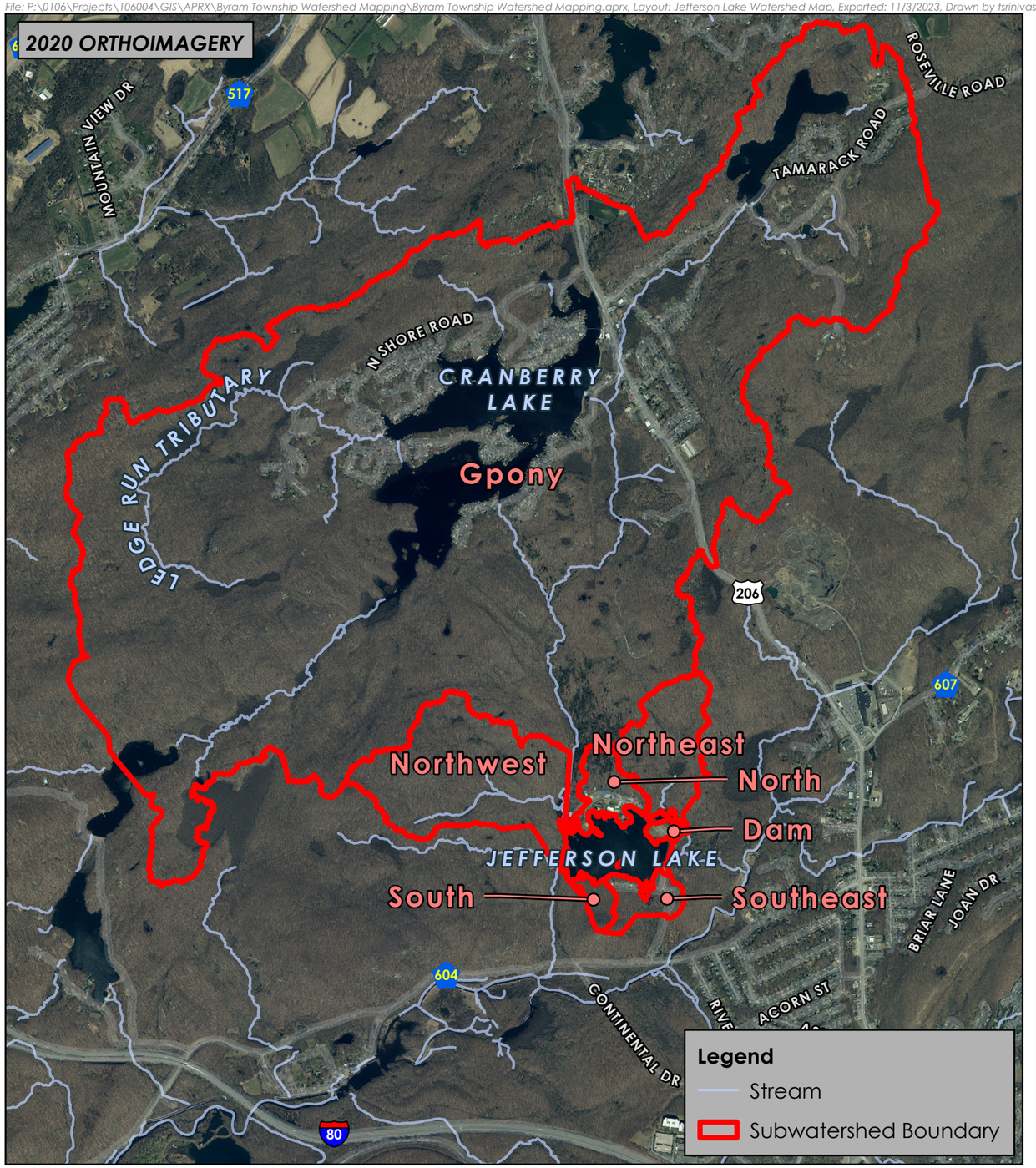
0 280 560 Feet

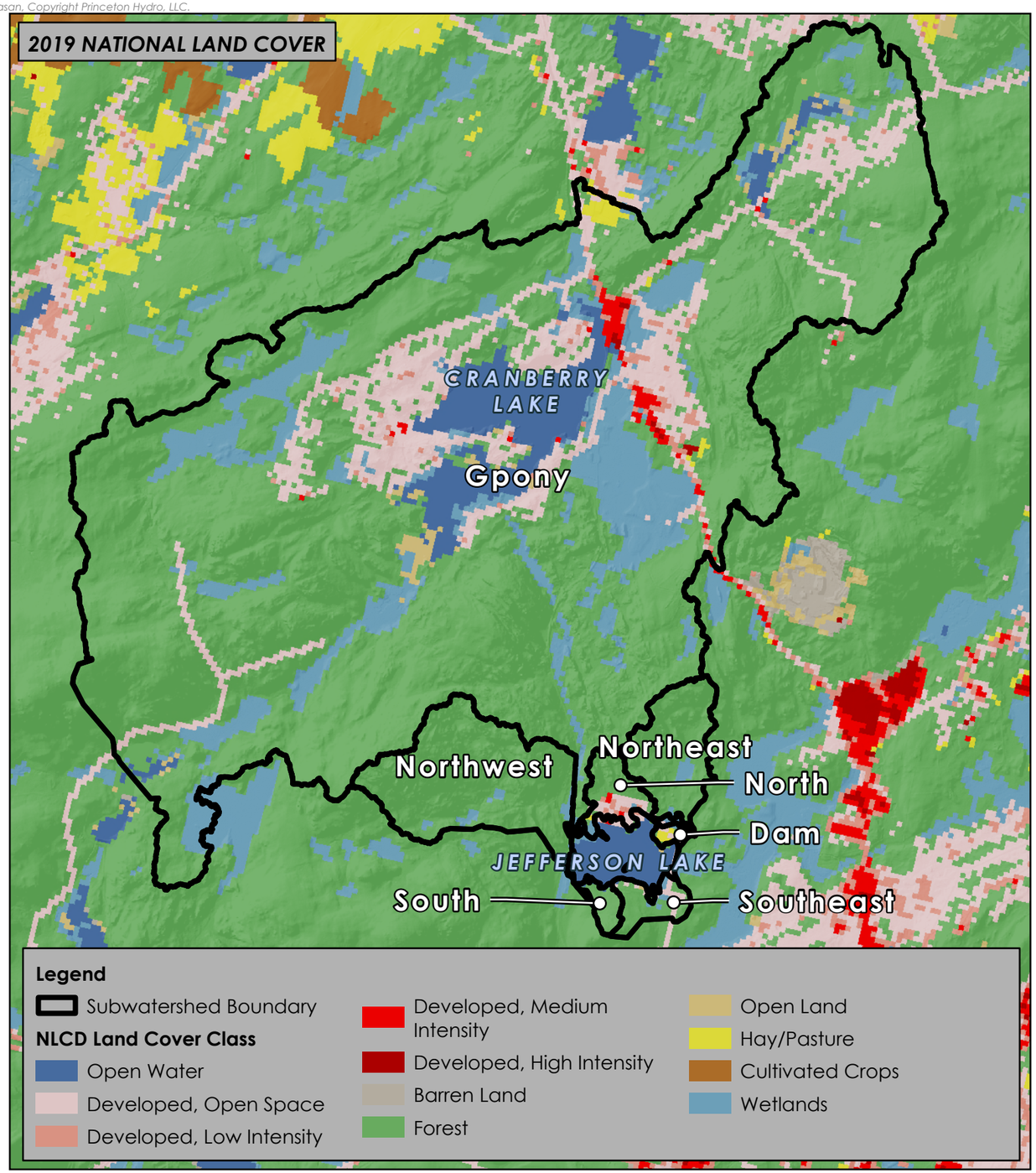
Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

FOREST LAKE WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Jefferson Lake Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
2. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
3. 2020 orthoimagery, hillshade DEM, and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal.
4. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

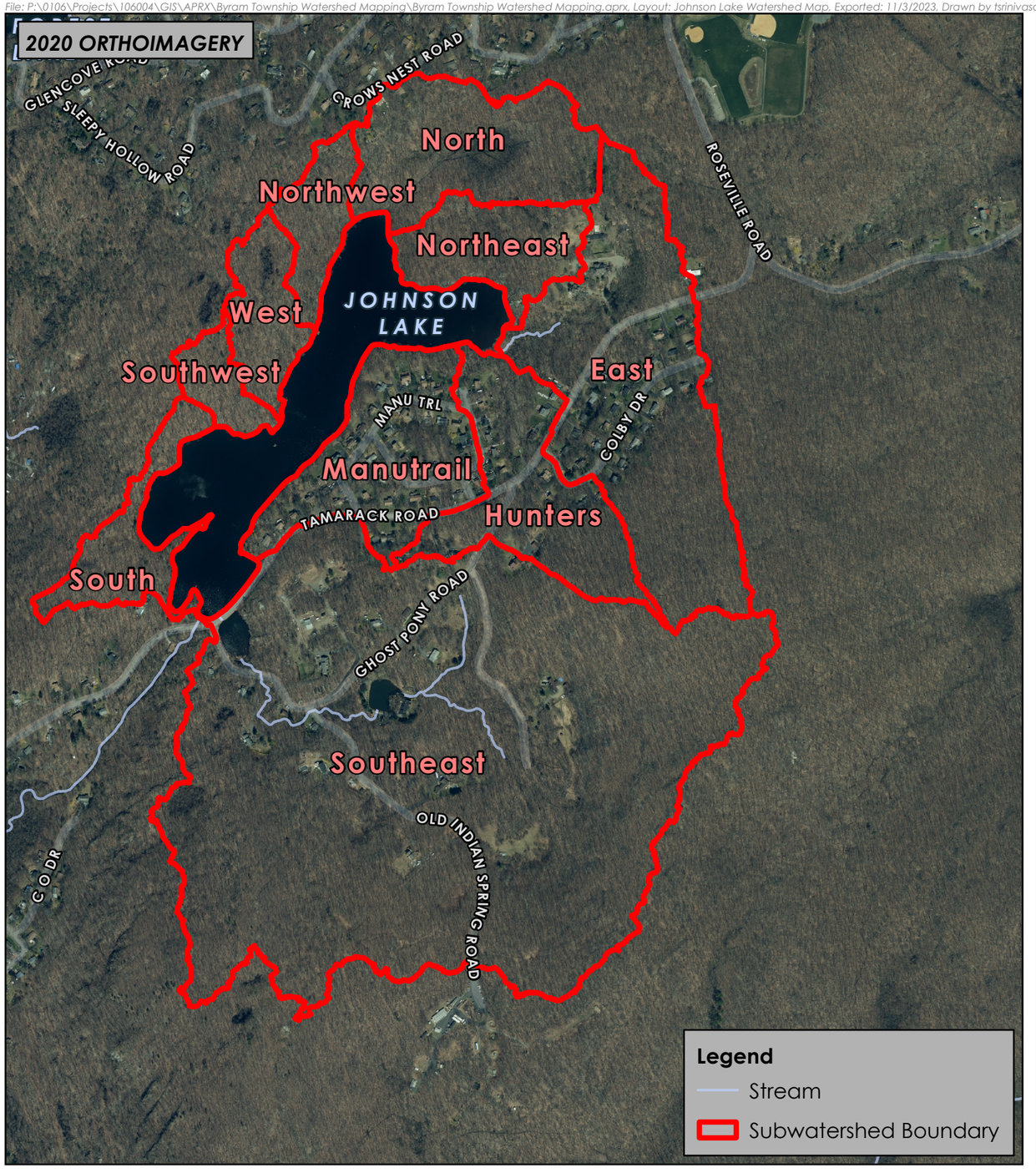
0 1,200 2,400 Feet

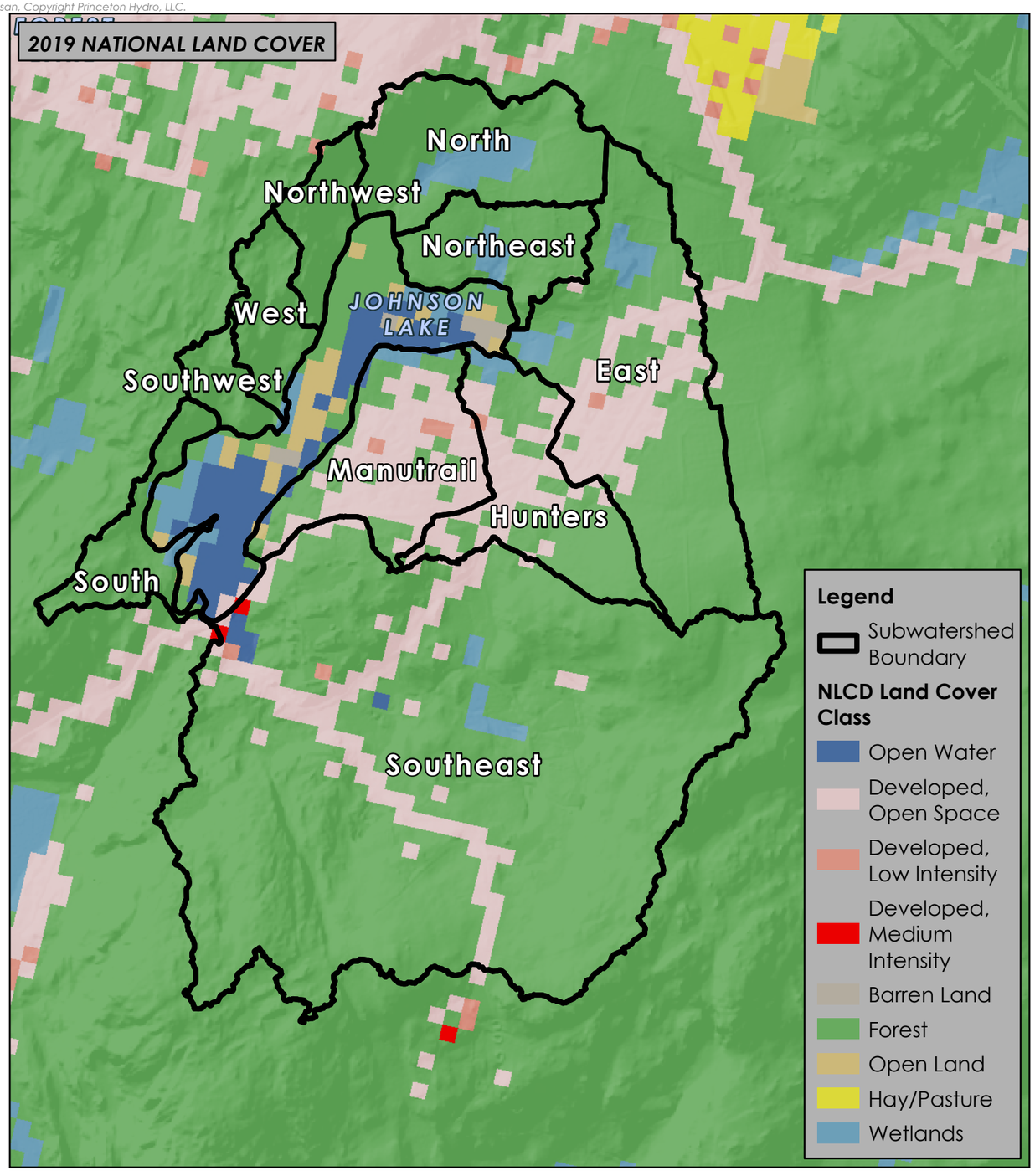
Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

JEFFERSON LAKE WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Johnson Lake Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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SCIENCE DESIGN ENGINEERING
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NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
2. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
3. 2020 orthoimagery, hillshade DEM, and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal.
4. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

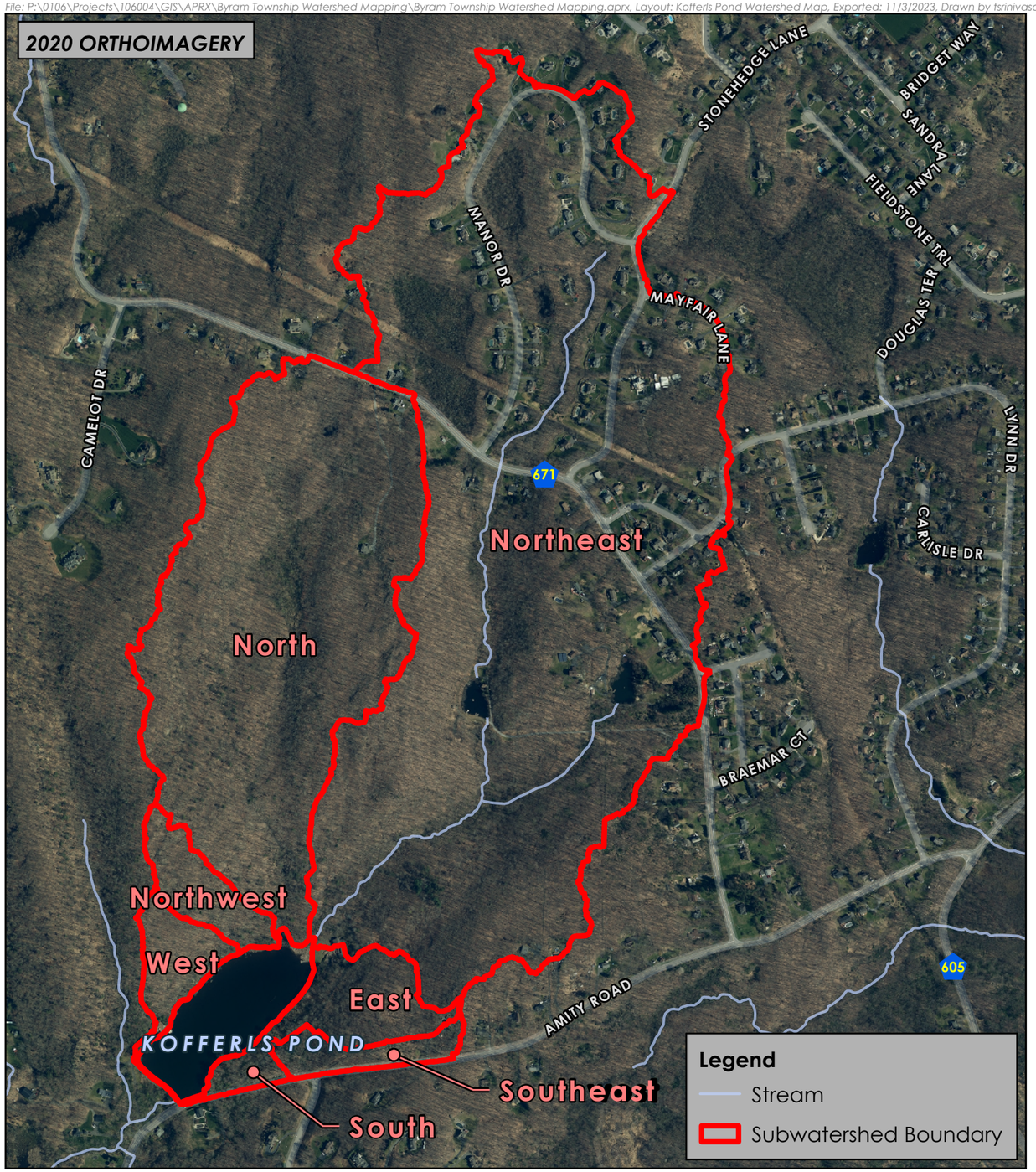
0 400 800 Feet

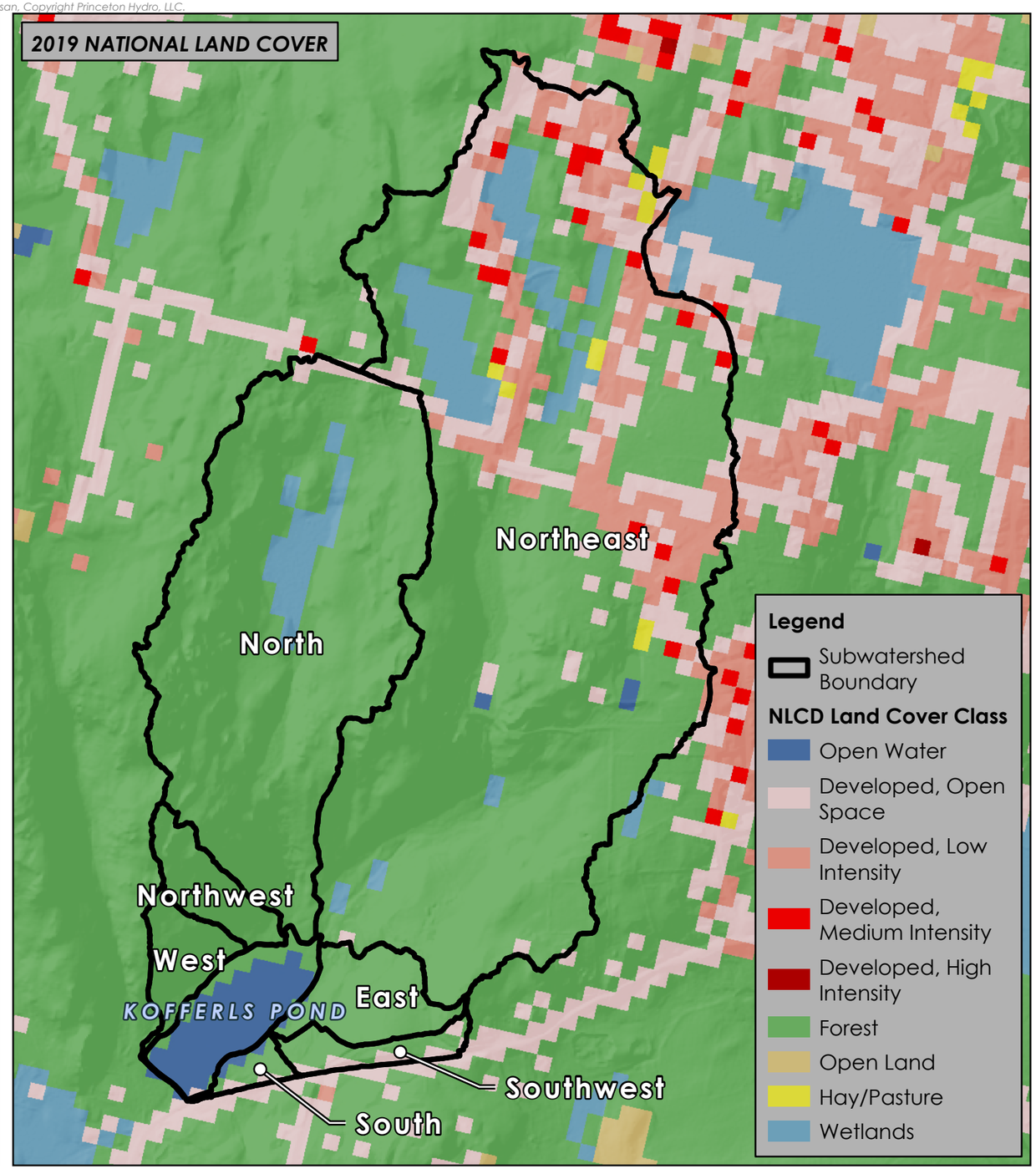
Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

JOHNSON LAKE WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Kofferls Pond Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
2. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
3. 2020 orthoimagery, hillshade DEM, and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal.
4. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

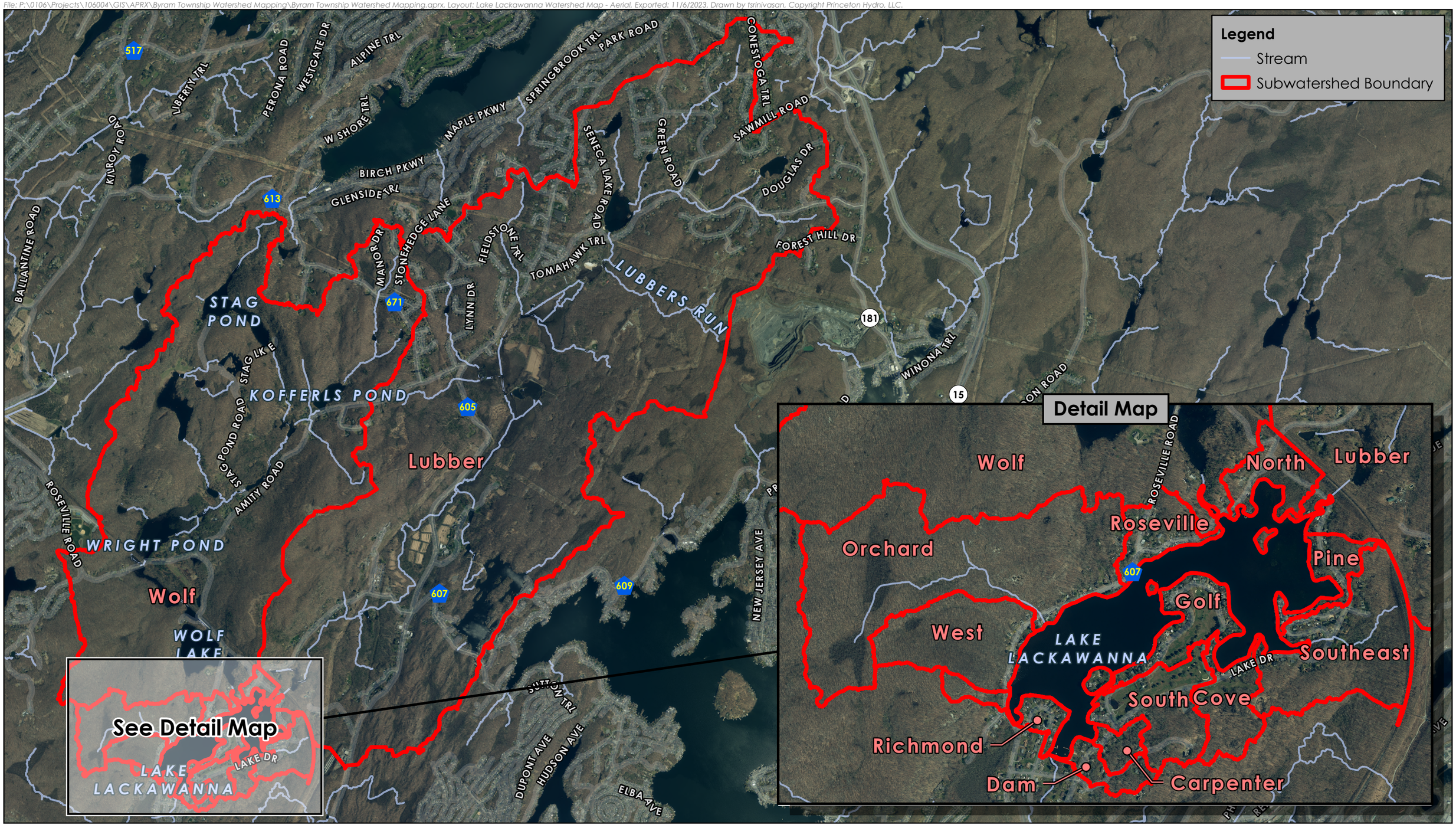
0 400 800 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

KOFFERLS POND WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Lake Lackawanna Watershed Map - Aerial, Exported: 11/6/2023, Drawn by tsrinivasan. Copyright Princeton Hydro, LLC.



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NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
2. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
3. 2020 orthoimagery and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

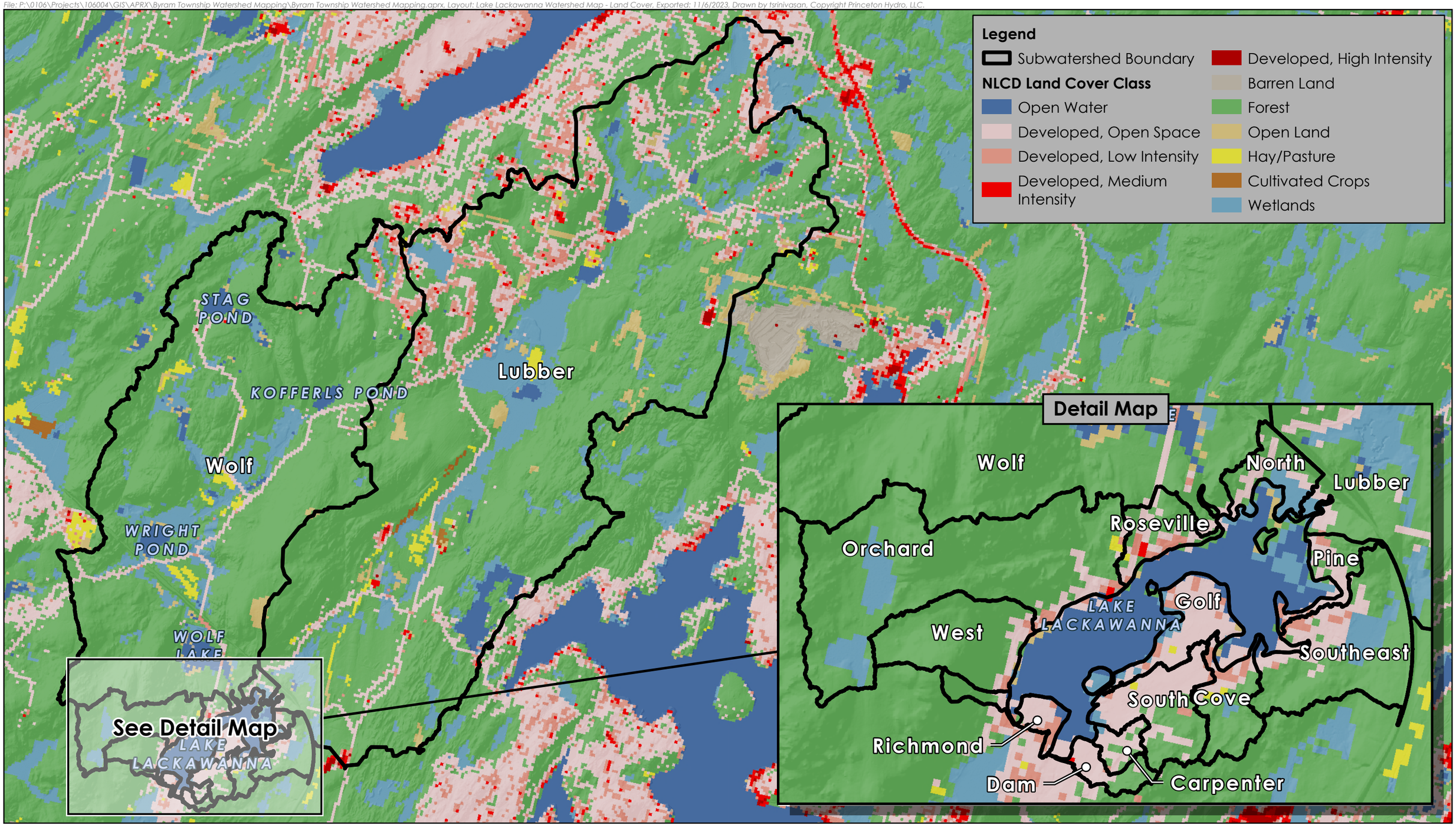
0 1,550 3,100 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

LAKE LACKAWANNA WATERSHED AERIAL MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Lake Lackawanna Watershed Map - Land Cover, Exported: 11/6/2023, Drawn by tsrinivasan. Copyright Princeton Hydro, LLC.



PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING
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NOTES:
1. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
2. Hillshade DEM obtainedd from the NJ Geographic Information Network (NJGIN) Open Data portal.
3. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

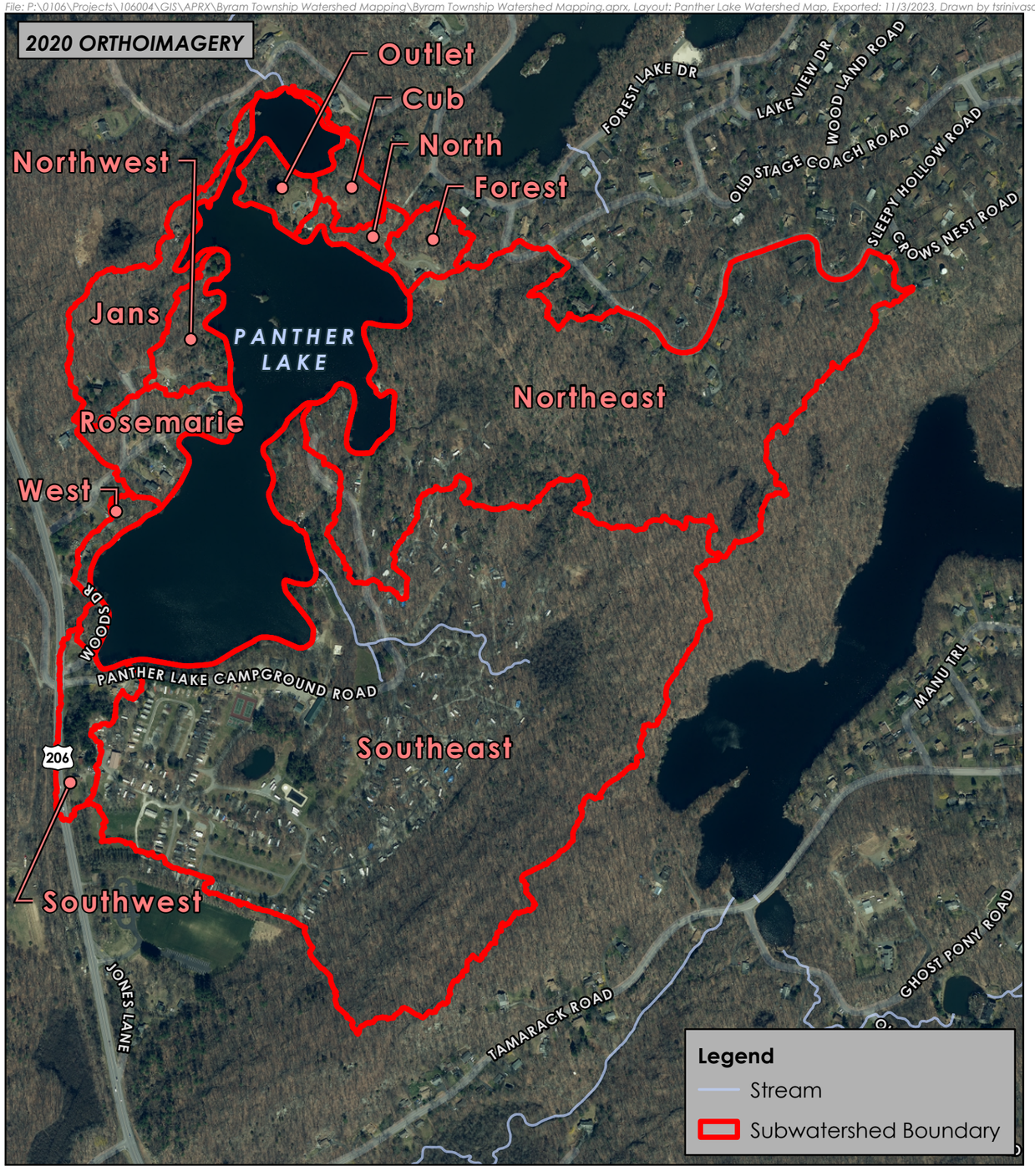
0 1,550 3,100 Feet

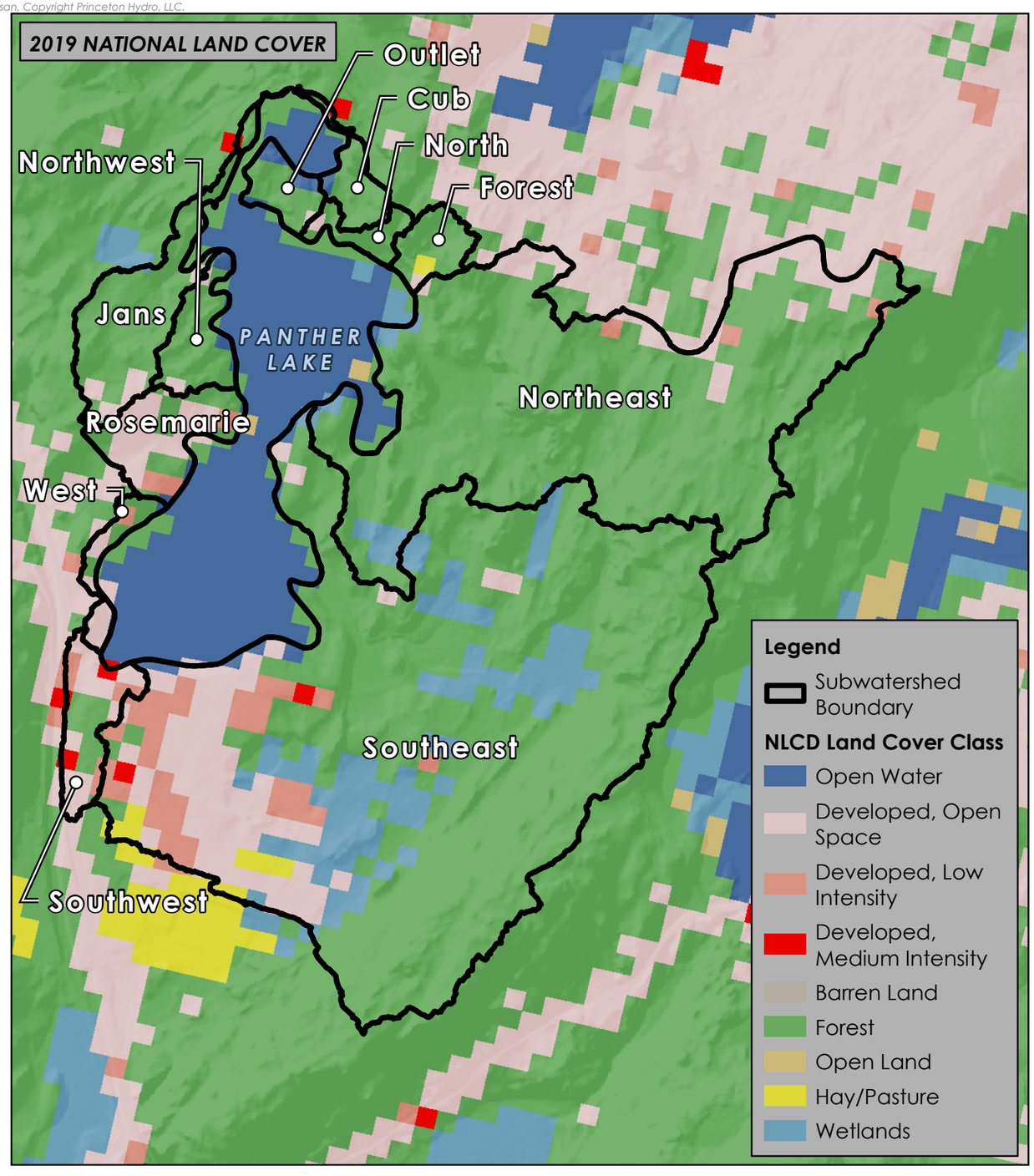
Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

LAKE LACKAWANNA WATERSHED LAND COVER MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Panther Lake Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
2. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
3. 2020 orthoimagery, hillshade DEM, and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal.
4. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

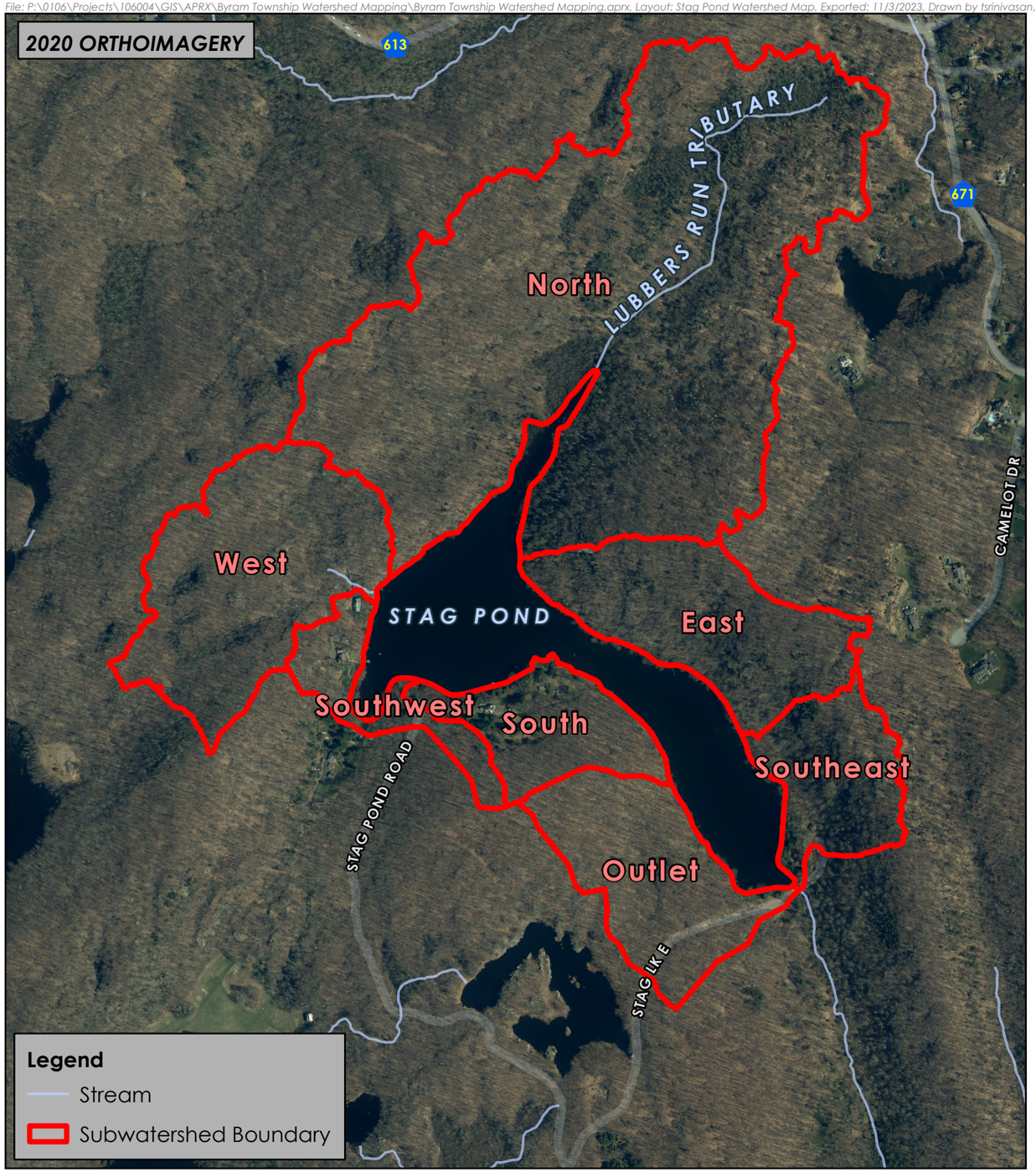
0 320 640 Feet

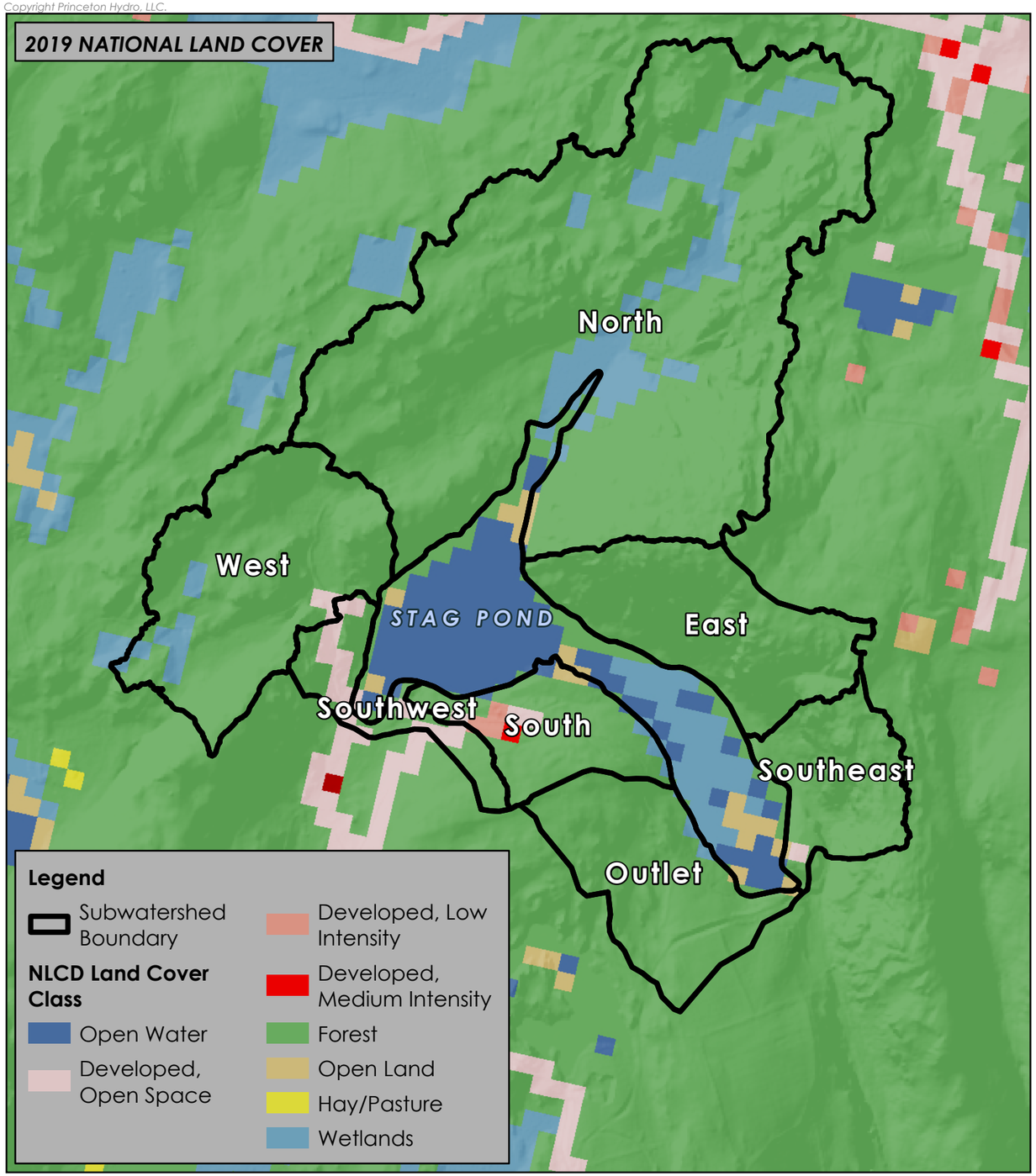
Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

PANTHER LAKE WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Stag Pond Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
2. Watershed delineated by Princeton Hydro, LLC. using 2018 LiDAR data obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/
3. 2020 orthoimagery, hillshade DEM, and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal.
4. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

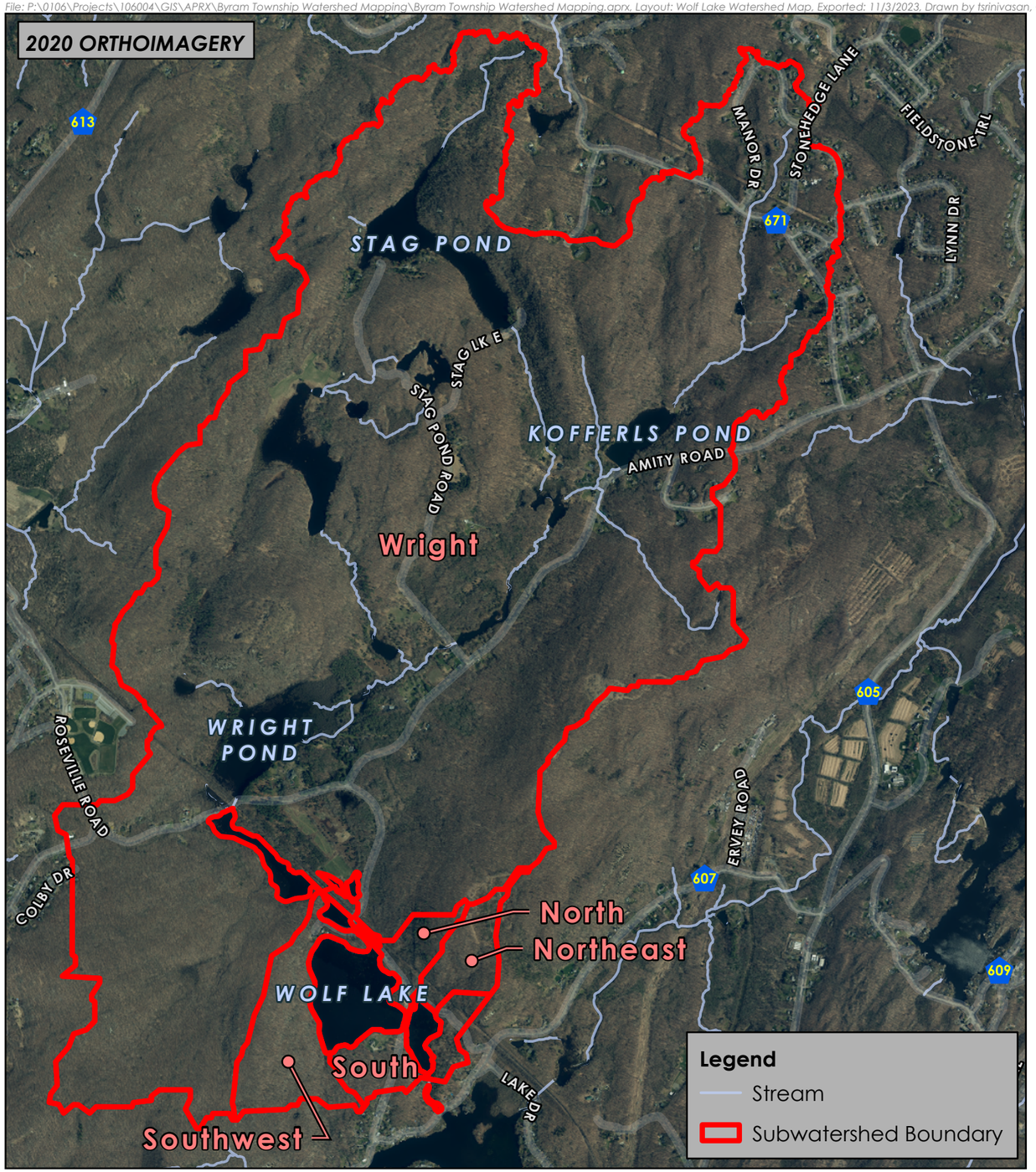
0 400 800 Feet

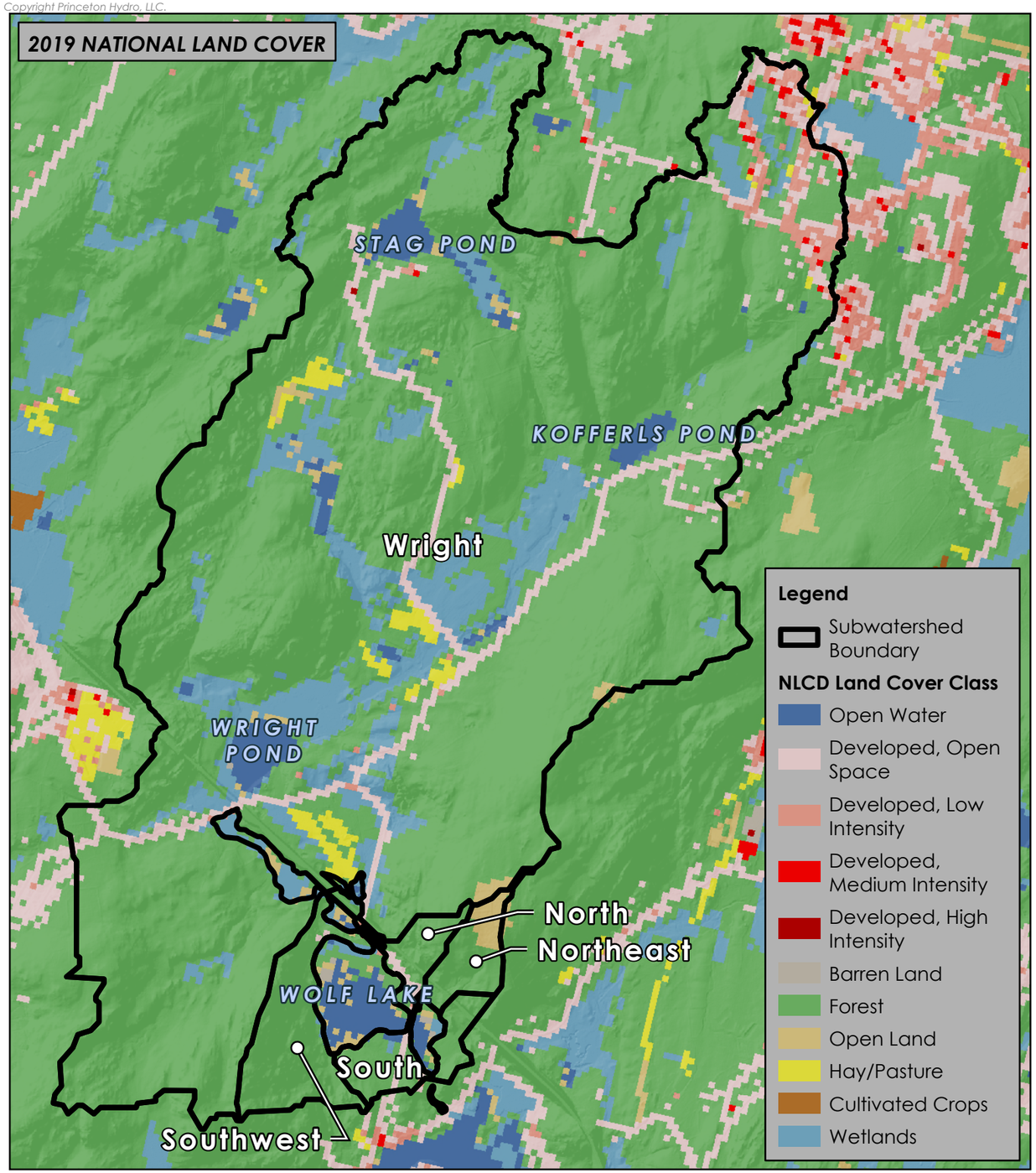
Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

STAG POND WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Wolf Lake Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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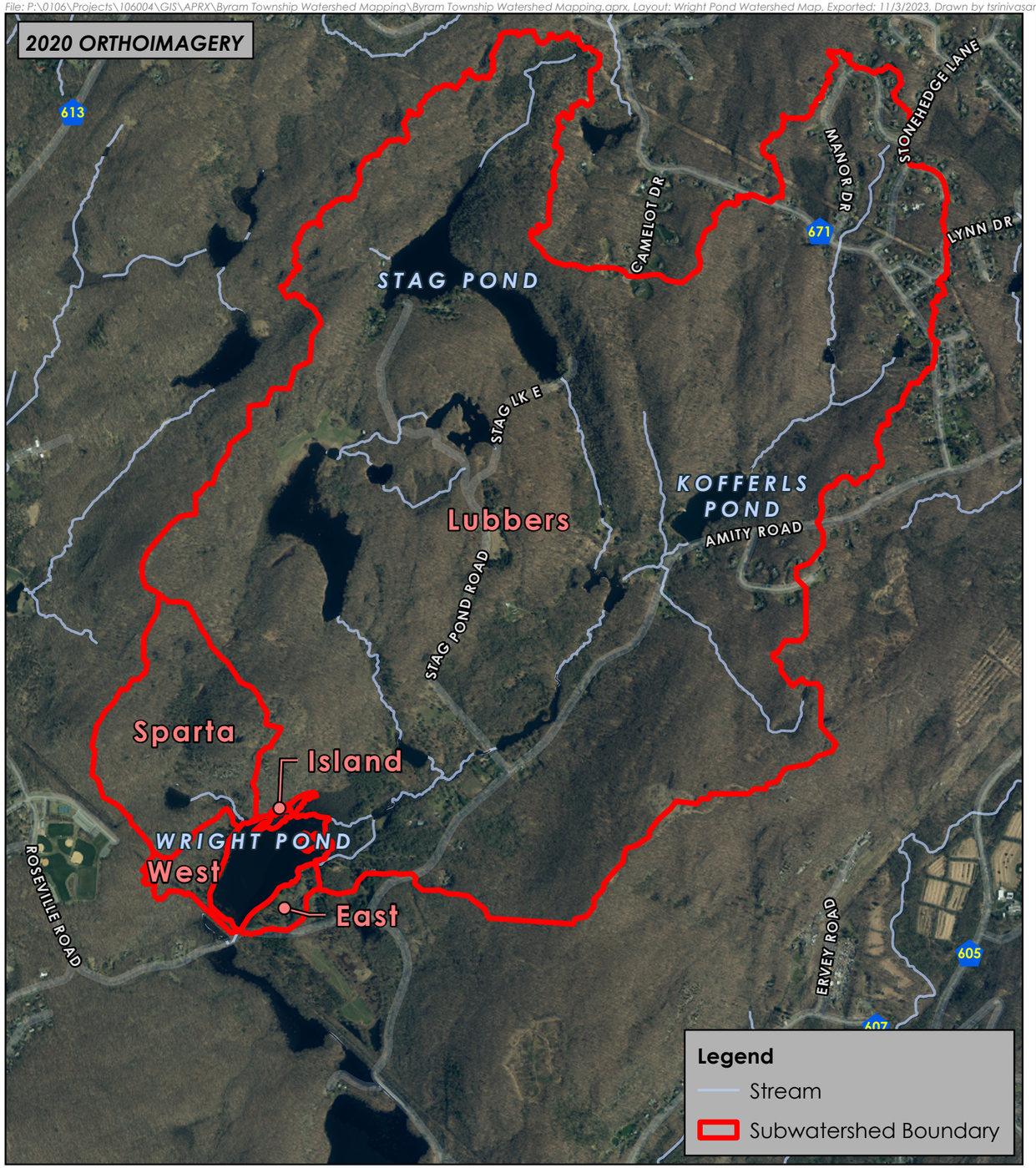
0 1,000 2,000 Feet

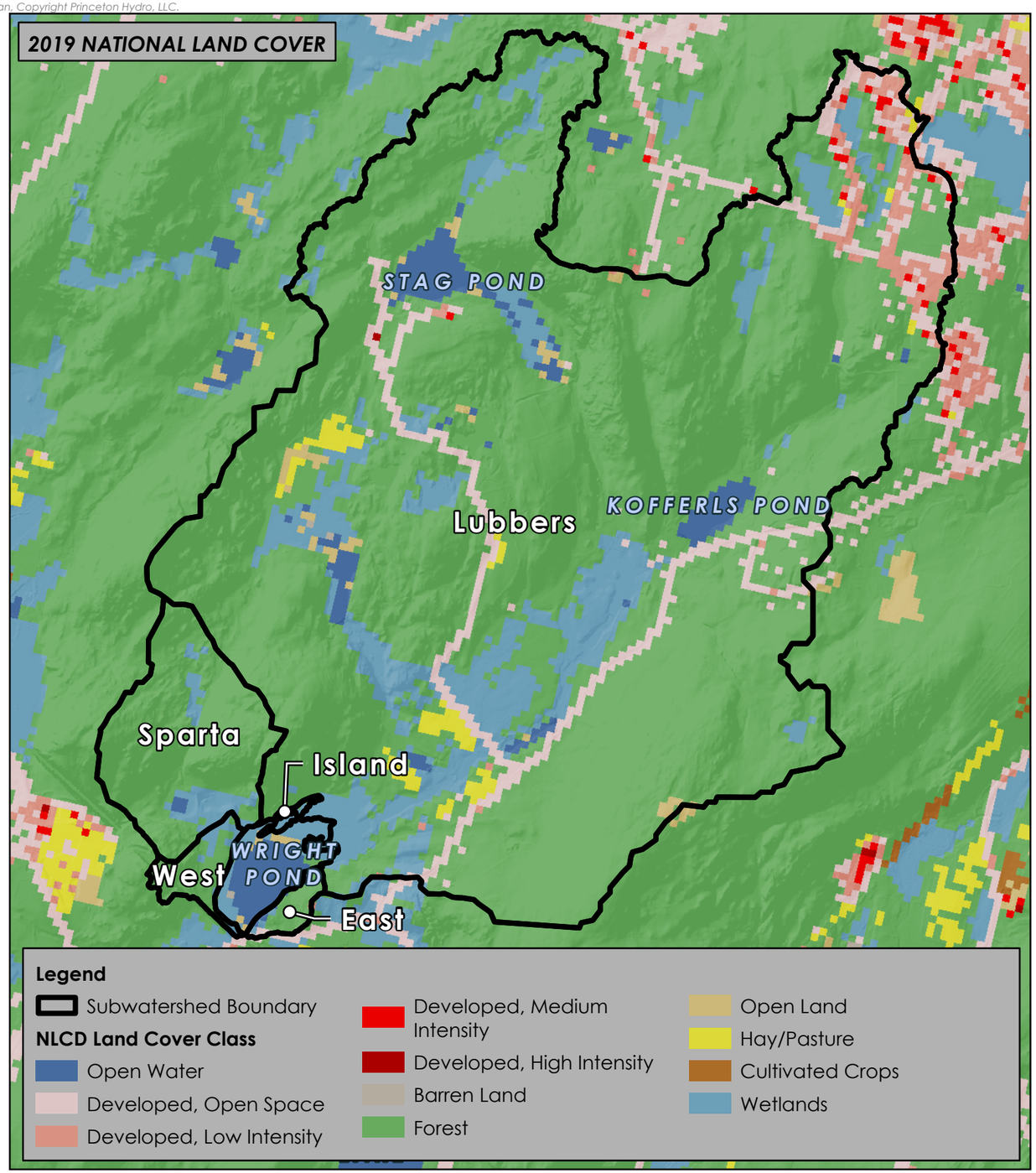
Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

WOLF LAKE WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

File: P:\0106\Projects\106004\GIS\APRX\Byram Township Watershed Mapping\Byram Township Watershed Mapping.aprx, Layout: Wright Pond Watershed Map, Exported: 11/3/2023, Drawn by tsrinivasan, Copyright Princeton Hydro, LLC.





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NOTES:
1. Streams obtained from the United States Geological Survey's (USGS) National Hydrography Dataset (NHD).
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3. 2020 orthoimagery, hillshade DEM, and roads obtained from the NJ Geographic Information Network (NJGIN) Open Data portal.
4. 2019 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

0 850 1,700 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

WRIGHT POND WATERSHED MAP

WATERSHED MANAGEMENT PROGRAM
BYRAM TOWNSHIP
SUSSEX COUNTY, NEW JERSEY

APPENDIX III: WATERSHED NUTRIENT BUDGET LOADING TABLES

Land-use by sub-watershed in the Cranberry Lake watershed

Source	Full Watershed	Cabin Spring	Bog Run	French Grove	Hilltop	Laurel Cove	Ledge Run	Meteor Trail	Northeast	Southeast	Southwest	Strawberry Point	Waramung
							Area (acres)						
Open Water	7.4	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	6.9	0.0	0.0	0.0	0.0	6.9	0.0	0.0	0.0	0	0	0	0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0
Forest	1140.4	29.4	415.4	59.3	21.3	50.9	479.1	6.4	5.9	22	44	2.2	4.7
Wetland	156.7	0.7	54.1	9.1	0.0	9.6	73.4	0.5	0.5	1.2	3.2	2	2.2
Open Land	2.7	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.7	0.5
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	8.4	1.5	0.0	0.0	0.0	0.7	1.5	1.0	2.0	0	0.2	1	1
Medium-Density Mixed	4.7	0.2	0.0	0.0	0.0	0.0	0.2	0.2	3.7	0	0.0	0.2	0.2
High-Density Mixed	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0	0.0	0	0
Low-Density Open Space	183.4	53.9	18.3	4.9	0.0	19.0	31.9	12.1	0.7	0	5.9	22.5	14.1
Total	1510.8	85.7	491.5	73.3	21.3	87.1	586.1	20.2	13.0	23.4	53.3	28.6	22.7

Source	Full Watershed	Cabin Spring	Bog Run	French Grove	Hilltop	Laurel Cove	Ledge Run	Meteor Trail	Northeast	Southeast	Southwest	Strawberry Point	Waramung
							Area (%)						
Open Water	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.5	0.0	0.0	0.0	0.0	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	75.5	34.3	84.5	80.9	100.0	58.4	81.7	31.7	45.4	94.0	82.6	7.7	20.7
Wetland	10.4	0.8	11.0	12.4	0.0	11.0	12.5	2.5	3.8	5.1	6.0	7.0	9.7
Open Land	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	2.4	2.2
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	0.6	1.8	0.0	0.0	0.0	0.8	0.3	5.0	15.4	0.0	0.4	3.5	4.4
Medium-Density Mixed	0.3	0.2	0.0	0.0	0.0	0.0	0.0	1.0	28.5	0.0	0.0	0.7	0.9
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0
Low-Density Open Space	12.1	62.9	3.7	6.7	0.0	21.8	5.4	59.9	5.4	0.0	11.1	78.7	62.1
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Cranberry Lake Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	5.1	0.17
	Cropland	0.0	0.00
	Forest	127.2	4.20
	Wetland	39.1	1.29
	Open Land	1.6	0.05
	Barren Land	0.0	0.00
	Low-Density Mixed	1.0	0.03
	Medium-Density Mixed	3.0	0.10
	High-Density Mixed	0.2	0.01
	Low-Density Open Space	22.6	0.75
Other Sources	Farm Animals and Waterfowl	5.2	0.17
	Stream Bank	20.0	0.66
	Groundwater	839.8	27.72
	Point Sources	0.0	0.00
	Dryfall	274.9	9.08
	Septic Systems	1689.5	55.77
	Total	3029.3	100

Estimated annual loads of phosphorus from various sources in the Cranberry Lake Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	2.02	0.5
	Cropland	0.00	0.0
	Forest	6.58	1.8
	Wetland	2.02	0.5
	Open Land	0.03	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.11	0.0
	Medium-Density Mixed	0.30	0.1
	High-Density Mixed	0.02	0.0
	Low-Density Open Space	2.46	0.7
Other Sources	Farm Animals and Waterfowl	1.80	0.5
	Stream Bank	8.00	2.2
	Groundwater	21.55	5.8
	Point Source	0.00	0.0
	Dryfall	1.37	0.4
	Septic Systems	325.11	87.5
	Total	371.38	100.0

Estimated annual loads of nitrogen by sub-watershed in the Cranberry Lake Watershed

Category	Description	Full Watershed	Cabin Spring	Bog Run	French Grove	Hilltop	Laurel Cove	Ledge Run	Meteor Trail	Northeast	Southeast	Southwest	Strawberry Point	Waramung
		kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	5.1	0.0	0.0	0.0	0.0	4.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	127.2	2.7	37.3	8.3	1.92	7.03	43.30	0.6	0.8	2.0	4.0	0.2	0.4
	Wetland	39.1	0.2	12.0	2.1	0.0	2.1	20.7	0.1	0.1	0.3	0.7	0.6	0.6
	Open Land	1.6	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.3
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	1.0	0.17	0.0	0.0	0.0	0.09	0.2	0.1	0.5	0.0	0.04	0.1	0.1
	Medium-Density Mixed	3.0	0.2	0.0	0.0	0.0	0.0	0.2	0.2	1.9	0.0	0.0	0.2	0.2
	High-Density Mixed	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	Low-Density Open Space	22.6	6.3	2.2	0.57	0.0	2.3	3.8	1.6	0.2	0.0	0.9	2.9	1.8
Other Sources	Farm Animals and Waterfowl	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	20.0	0.0	1.00	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	839.8	49.5	291.9	37.4	14.2	44.5	338.4	11.7	6.9	14.7	34.0	15.4	12.61
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	274.9	.	.	.	.	.	.	.	.	.	.	.	.
	Septic Systems	1689.5	420.5	0.0	9.6	0.0	184.1	211.8	242.1	30.3	0.0	68.5	273.9	251.6
	Total (kg)	3029.3	479.4	345.1	57.8	16.1	244.1	622.3	256.4	40.8	17.0	108.1	293.8	267.7
	kg/acre	2.0	5.6	0.7	0.8	0.8	2.8	1.1	12.7	3.1	0.7	2.0	10.3	11.8

Estimated annual loads of phosphorus by sub-watershed in the Cranberry Lake Watershed

Category	Description	Full Watershed	Cabin Spring	Bog Run	French Grove	Hilltop	Laurel Cove	Ledge Run	Meteor Trail	Northeast	Southeast	Southwest	Strawberry Point	Waramung
		kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	2.02	0.00	0.00	0.00	0.00	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
	Forest	6.58	0.14	1.87	0.43	0.10	0.35	2.28	0.03	0.04	0.09	0.21	0.01	0.02
	Wetland	2.02	0.01	0.60	0.11	0.00	0.10	1.09	0.01	0.01	0.01	0.04	0.03	0.03
	Open Land	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.11	0.02	0.00	0.00	0.00	0.01	0.02	0.01	0.05	0.00	0.00	0.01	0.01
	Medium-Density Mixed	0.30	0.02	0.00	0.00	0.00	0.00	0.02	0.02	0.20	0.00	0.00	0.02	0.02
	High-Density Mixed	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0
	Low-Density Open Space	2.46	0.70	0.24	0.06	0.00	0.23	0.42	0.18	0.02	0.00	0.10	0.32	0.2
Other Sources	Farm Animals and Waterfowl	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	8.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	21.55	1.30	7.27	0.98	0.37	1.07	8.86	0.31	0.18	0.35	0.89	0.40	0.33
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	1.37	.	.	.	.	.	.	.	.	.	.	.	.
	Septic Systems	325.11	47.87	0.00	5.04	0.00	35.92	16.80	65.51	10.08	0.00	1.68	80.63	66.35
	Total (kg)	371.38	50.06	9.99	6.62	0.47	39.66	30.49	66.07	10.59	0.45	2.92	81.43	66.97
	kg/acre	0.25	0.58	0.02	0.09	0.02	0.46	0.05	3.27	0.81	0.02	0.05	2.85	2.95

Estimated annual loads of sediment from various sources in the total Cranberry Lake Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	1.120	3.8
	Cropland	0.000	0.0
	Forest	0.010	0.0
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.050	0.2
	Medium-Density Mixed	0.160	0.5
	High-Density Mixed	0.010	0.0
	Low-Density Open Space	1.090	3.7
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	27.038	91.7
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	29.478	100.0

Estimated annual loads of bacteria from various sources in the total Cranberry Lake Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	2.42E+09	0.5
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	7.23E+10	15.0
	Other Wildlife	4.07E+11	84.5
	Total	4.82E+11	100

Estimated annual loads of sediment by sub-watershed in the Cranberry Lake Watershed

Category	Description	Full Watershed kg x 1000	Cabin Spring kg x 1000	Bog Run kg x 1000	French Grove kg x 1000	Hilltop kg x 1000	Laurel Cove kg x 1000	Ledge Run kg x 1000	Meteor Trail kg x 1000	Northeast kg x 1000	Southeast kg x 1000	Southwest kg x 1000	Strawberry Point kg x 1000	Waramung kg x 1000
Runoff	Hay/Pasture	1.120	0.000	0.000	0.000	0.000	0.990	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.010	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Wetland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.050	0.010	0.000	0.000	0.000	0.000	0.010	0.010	0.020	0.000	0.000	0.010	0.010
	Medium-Density Mixed	0.160	0.010	0.000	0.000	0.000	0.000	0.010	0.010	0.110	0.000	0.000	0.010	0.010
	High-Density Mixed	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000
	Low-Density Open Space	1.090	0.320	0.100	0.030	0.000	0.100	0.190	0.080	0.010	0.000	0.050	0.150	0.090
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	27.038	0.038	1.606	0.003	0.000	0.054	4.258	0.014	0.004	0.000	0.004	0.273	0.015
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	29.478	0.378	1.706	0.033	0.000	1.154	4.468	0.114	0.154	0.000	0.054	0.443	0.125
	kg/acre	19.5	4.4	3.5	0.5	0.0	13.2	7.6	5.6	11.8	0.0	1.0	15.5	5.5

Estimated annual loads of bacteria by sub-watershed in the Cranberry Lake Watershed

Category	Description	Full Watershed %	Cabin Spring %	Bog Run %	French Grove %	Hilltop %	Laurel Cove %	Ledge Run %	Meteor Trail %	Northeast %	Southeast %	Southwest %	Strawberry Point %	Waramung %
Fecal Coliform	Farm Animals and Waterfowl	0.5	0	0	0	0	0	0	0	0	0	0	0	0
	Point Sources	0.0	0	0	0	0	0	0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0	0	0	0	0	0	0
	Urban Areas	15.0	90.6	1.2	4.0	0	10	3	91.8	90.6	0	10.9	98.6	94.7
	Other Wildlife	84.5	9.4	98.8	96.0	100	60	97	8.2	9.4	100	89.1	1.4	5.3
	Total (organisms)	4.80E+11	1.12E+11	1.50E+11	2.20E+10	7.58E+09	3.03E+10	1.76E+11	2.81E+10	2.24E+10	7.84E+09	1.76E+10	5.79E+10	3.18E+10

Land-use by sub-watershed in the Lake Lackawanna watershed

Source	Full Watershed	Carpenter	Cove	Dam	Golf Course	Lubbers Run	North	Orchard St.	Pine Pt.	Richmond	Roseville	South	Southeast	West	Wolf
							Area (acres)								
Open Water	200.2	0.0	0.0	0.0	0.0	103.8	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	91.4
Hay/Pasture	87.7	0.0	0.7	0.0	0.2	52.9	0.0	0.7	0.0	0	0.2	0.2	0	0.0	32.6
Cropland	9.9	0.0	0.0	0.0	0.0	10.1	0.0	0.0	0.0	0	0	0	0	0.0	0.0
Forest	5830.9	2.0	13.8	4.2	0.0	3383.1	9.4	130	5.2	3.7	8.6	11.9	43.5	39.5	2175.3
Wetland	955.8	0.2	1.2	0.0	3.7	640.0	4.7	13.6	0.0	0.0	0.0	1	8.2	0.0	283.4
Open Land	81.1	0.0	0.0	0.0	0.2	52.6	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	28.2
Barren Land	10.1	0.0	0.0	0.0	0.0	7.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Low-Density Mixed	241.4	0.2	2.5	0.0	2.5	192.0	0.0	2.0	1.5	2.2	2.7	1	2.2	1.0	32.1
Medium-Density Mixed	37.3	0.0	0.0	0.2	0.0	32.9	0.0	0.2	0.0	0	0.5	0	0	0.0	3.5
High-Density Mixed	5.4	0.0	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0	0.0	0	0	0.0	0.2
Low-Density Open Space	751.7	5.2	3.7	5.7	16.6	532.0	5.4	5.7	6.2	5.4	5.9	19.3	12.1	3.7	124.3
Total	8211.5	7.6	21.9	10.1	23.2	5012.0	19.5	152.4	12.9	11.3	17.9	33.8	66.0	44.2	2774.0

Source	Full Watershed	Carpenter	Cove	Dam	Golf Course	Lubbers Run	North	Orchard St.	Pine Pt.	Richmond	Roseville	South	Southeast	West	Wolf
							Area (%)								
Open Water	2.4	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	3.3
Hay/Pasture	1.1	0.0	3.2	0.0	0.9	1.1	0.0	0.5	0.0	0.0	1.1	0.6	0.0	0.0	1.2
Cropland	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	71.0	26.3	63.0	41.6	0.0	67.5	48.2	85.3	40.3	32.7	48.0	35.2	65.9	89.4	78.4
Wetland	11.6	2.6	5.5	0.0	15.9	12.8	24.1	8.9	0.0	0.0	0.0	3.0	12.4	0.0	10.2
Open Land	1.0	0.0	0.0	0.0	0.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Barren Land	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Low-Density Mixed	2.9	2.6	11.4	0.0	10.8	3.8	0.0	1.3	11.6	19.5	15.1	3.0	3.3	2.3	1.2
Medium-Density Mixed	0.5	0.0	0.0	2.0	0.0	0.7	0.0	0.1	0.0	0.0	2.8	0.0	0.0	0.0	0.1
High-Density Mixed	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	9.2	68.4	16.9	56.4	71.6	10.6	27.7	3.7	48.1	47.8	33.0	57.0	18.3	8.4	4.5
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Lake Lackawanna Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	28.7	0.24
	Cropland	27.8	0.23
	Forest	409.4	3.45
	Wetland	202.3	1.70
	Open Land	45.5	0.38
	Barren Land	3.4	0.03
	Low-Density Mixed	35.0	0.29
	Medium-Density Mixed	23.9	0.20
	High-Density Mixed	3.5	0.03
	Low-Density Open Space	108.8	0.92
Other Sources	Farm Animals and Waterfowl	31.3	0.26
	Stream Bank	152.0	1.28
	Groundwater	4398.3	37.06
	Point Sources	0.0	0.00
	Dryfall	1347.4	11.35
	Septic Systems	5050.3	42.56
	Total	11867.4	100

Estimated annual loads of phosphorus in the total Lake Lackawanna Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	9.09	1.9
	Cropland	4.53	0.9
	Forest	13.60	2.8
	Wetland	6.76	1.4
	Open Land	0.72	0.1
	Barren Land	0.07	0.0
	Low-Density Mixed	2.39	0.5
	Medium-Density Mixed	1.53	0.3
	High-Density Mixed	0.22	0.0
	Low-Density Open Space	7.45	1.6
Other Sources	Farm Animals and Waterfowl	8.36	1.7
	Stream Bank	68.00	14.2
	Groundwater	116.07	24.2
	Point Source	0.00	0.0
	Dryfall	6.74	1.4
	Septic Systems	234.87	48.9
	Total	480.40	100.0

Estimated annual loads of nitrogen by sub-watershed in the Lake Lackawanna Watershed

Category	Description	Full Watershed kg	Carpenter kg	Cove kg	Dam kg	Golf Course kg	Lubbers Run kg	North kg	Orchard St. kg	Pine Pt. kg	Richmond kg	Roseville kg	South kg	Southeast kg	West kg	Wolf kg
Runoff	Hay/Pasture	28.7	0.0	0.5	0.0	0.1	29.3	0.00	0.4	0.0	0.0	0.1	0.1	0.0	0.0	12.6
	Cropland	27.8	0.0	0.0	0.0	0.0	29.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	409.4	0.2	1.3	0.4	0.00	236.79	0.88	18.1	0.5	0.5	0.8	1.1	2.7	3.6	185.4
	Wetland	202.3	0.1	0.3	0.0	0.5	135.0	1.3	3.1	0.0	0.0	0.0	0.2	1.8	0.0	59.8
	Open Land	45.5	0.0	0.0	0.0	0.1	29.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.8
	Barren Land	3.4	0.0	0.0	0.0	0.0	2.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.0
	Low-Density Mixed	35.0	0.03	0.4	0.0	0.3	28.33	0.0	0.3	0.17	0.4	0.52	0.1	0.3	0.1	4.5
	Medium-Density Mixed	23.9	0.0	0.0	0.2	0.0	21.4	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.0	3.2
	High-Density Mixed	3.5	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	Low-Density Open Space	108.8	0.7	0.6	0.76	2.2	78.49	0.7	0.9	0.7	0.9	1.1	2.4	1.6	0.5	17.4
Other Sources	Farm Animals and Waterfowl	31.3	0.0	0.0	0.0	0.0	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3
	Stream Bank	152.0	0.0	0.00	0.0	0.0	97.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0
	Groundwater	4398.3	4.1	12.4	5.6	11.9	2627.8	0.0	74.7	7.3	6.2	10.3	17.7	39.2	27.6	1444.7
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	1347.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Septic Systems	5050.3	30.3	90.8	43.0	133.8	3688.6	30.3	70.1	130.6	68.5	105.1	60.2	108.3	52.6	473.1
	Total (kg)	11867.4	35.3	106.1	49.9	148.9	7021.3	42.0	167.7	139.2	76.4	118.3	81.9	154.0	84.4	2242.9
	kg/acre	1.4	4.6	4.8	4.9	6.4	1.4	2.2	1.1	10.8	6.8	6.6	2.4	2.3	1.9	0.8

Estimated annual loads of phosphorus by sub-watershed in the Lake Lackawanna Watershed

Category	Description	Full Watershed kg	Carpenter kg	Cove kg	Dam kg	Golf Course kg	Lubbers Run kg	North kg	Orchard St. kg	Pine Pt. kg	Richmond kg	Roseville kg	South kg	Southeast kg	West kg	Wolf kg
Runoff	Hay/Pasture	9.09	0.00	0.22	0.00	0.07	8.17	0.00	0.16	0.00	0.00	0.05	0.06	0.00	0.00	4.38
	Cropland	4.53	0.00	0.00	0.00	0.00	4.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	13.60	0.01	0.07	0.02	0.00	7.59	0.06	0.96	0.03	0.03	0.04	0.05	0.18	0.19	5.92
	Wetland	6.76	0.00	0.01	0.00	0.03	4.32	0.07	0.17	0.00	0.00	0.00	0.01	0.10	0.00	1.94
	Open Land	0.72	0.00	0.00	0.00	0.01	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
	Barren Land	0.07	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
	Low-Density Mixed	2.39	0.00	0.04	0.00	0.04	1.87	0.00	0.03	0.02	0.04	0.06	0.01	0.03	0.02	0.30
	Medium-Density Mixed	1.53	0.00	0.00	0.02	0.00	1.33	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.19
	High-Density Mixed	0.22	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Low-Density Open Space	7.45	0.08	0.06	0.08	0.24	5.18	0.08	0.10	0.08	0.10	0.12	0.26	0.18	0.06	1.15
Other Sources	Farm Animals and Waterfowl	8.36	0.00	0.00	0.00	0.00	3.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.73
	Stream Bank	68.00	0.00	0.00	0.00	0.00	41.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	116.07	0.17	0.50	0.23	0.48	68.08	0.23	1.95	0.19	0.16	0.27	0.69	1.59	0.72	35.60
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	6.74	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Septic Systems	234.87	7.56	34.44	0.84	69.71	90.40	7.56	6.72	28.56	17.64	16.80	5.61	7.56	8.40	13.94
	Total (kg)	480.40	7.82	35.34	1.19	70.58	237.02	8.00	10.11	28.88	17.97	17.37	6.69	9.64	9.39	67.43
	kg/acre	0.06	1.03	1.61	0.12	3.04	0.05	0.41	0.07	2.24	1.59	0.97	0.20	0.15	0.21	0.02

Estimated annual loads of sediment in the Lake Lackawanna Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.720	1.2
	Cropland	0.510	0.9
	Forest	0.010	0.0
	Wetland	0.010	0.0
	Open Land	0.030	0.1
	Barren Land	0.000	0.0
	Low-Density Mixed	0.240	0.4
	Medium-Density Mixed	0.190	0.3
	High-Density Mixed	0.030	0.1
	Low-Density Open Space	0.730	1.3
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	55.271	95.7
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	57.741	100.0

Estimated annual loads of bacteria from various sources in the total Lake Lackawanna

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	6.39E+10	2.5
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	4.13E+11	16.1
	Other Wildlife	2.08E+12	81.3
	Total	2.56E+12	100

Estimated annual loads of sediment by sub-watershed in the Lake Lackawanna Watershed

Category	Description	Full Watershed kg x 1000	Carpenter kg x 1000	Cove kg x 1000	Dam kg x 1000	Golf Course kg x 1000	Lubbers Run kg x 1000	North kg x 1000	Orchard St. kg x 1000	Pine Pt. kg x 1000	Richmond kg x 1000	Roseville kg x 1000	South kg x 1000	Southeast kg x 1000	West kg x 1000	Wolf kg x 1000
Runoff	Hay/Pasture	0.720	0.000	0.050	0.000	0.040	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.340
	Cropland	0.510	0.000	0.000	0.000	0.000	0.380	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.010	0.000	0.000	0.000	0.000	0.000	0.020	0.010	0.000	0.000	0.000	0.000	0.040	0.000	0.000
	Wetland	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.030	0.000	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.240	0.000	0.010	0.000	0.020	0.130	0.000	0.010	0.010	0.020	0.020	0.010	0.010	0.010	0.020
	Medium-Density Mixed	0.190	0.000	0.000	0.010	0.000	0.120	0.000	0.010	0.000	0.000	0.020	0.000	0.000	0.000	0.020
	High-Density Mixed	0.030	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.730	0.040	0.020	0.040	0.100	0.350	0.040	0.040	0.030	0.040	0.050	0.110	0.080	0.020	0.080
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	55.271	0.008	0.006	0.001	0.017	22.909	0.005	0.004	0.009	0.009	0.010	0.014	0.009	0.004	2.948
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	57.741	0.048	0.086	0.051	0.177	24.139	0.065	0.084	0.049	0.069	0.100	0.134	0.139	0.034	3.418
	kg/acre	7.0	6.3	3.9	5.0	7.6	4.8	3.3	0.6	3.8	6.1	5.6	4.0	2.1	0.8	1.2

Estimated annual loads of bacteria by sub-watershed in the Lake Lackawanna Watershed

Category	Description	Full Watershed %	Carpenter %	Cove %	Dam %	Golf Course %	Lubbers Run %	North %	Orchard St. %	Pine Pt. %	Richmond %	Roseville %	South %	Southeast %	West %	Wolf %
Fecal Coliform	Farm Animals and Waterfowl	2.5	0	0	0	0	2	0	0	0	0	0	0	0	0	3.8
	Point Sources	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Urban Areas	16.1	93.9	52	87.2	100	23.2	54.8	2.6	87.9	92.3	83.2	89.1	36.2	9.2	3.4
	Other Wildlife	81.3	6.1	48	12.8	0	74.9	45.2	97.4	12.1	7.7	16.8	10.9	63.8	90.8	92.8
	Total (organisms)	2.56E+12	1.16E+10	1.03E+10	1.17E+10	4.59E+10	1.61E+12	7.40E+09	4.76E+10	1.53E+10	1.72E+10	1.84E+10	3.87E+10	2.43E+10	1.55E+10	8.36E+11

Table 2. Land-use by sub-watershed in the Johnson Lake watershed

Source	Full Watershed	East Inlet	Hunters	Manu Trail	Northeast	North	Northwest	Southeast	South	Southwest	West
						Area (acres)					
Open Water	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
Forest	296.5	37.6	14.1	8.2	12.8	21.5	8.2	169	9.9	5.2	9.9
Wetland	13.1	3.2	1.0	1.0	1.5	4.2	0.0	1.7	0.7	0.2	0.0
Open Land	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	1.5	0.2	0.2	0.7	0.0	0.0	0.0	0.5	0.0	0	0.0
Medium-Density Mixed	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
Low-Density Open Space	56.1	13.1	9.4	15.3	0.0	0.2	0.0	18.0	0.0	0	0
Total	369.0	54.1	24.7	25.4	14.3	25.9	8.2	190.8	10.6	5.4	9.9

Source	Full Watershed	East Inlet	Hunters	Manu Trail	Northeast	North	Northwest	Southeast	South	Southwest	West
						Area (%)					
Open Water	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	80.4	69.5	57.1	32.3	89.5	83.0	100.0	88.6	93.4	96.3	100.0
Wetland	3.6	5.9	4.0	3.9	10.5	16.2	0.0	0.9	6.6	3.7	0.0
Open Land	0.1	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	0.4	0.4	0.8	2.8	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Medium-Density Mixed	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	15.2	24.2	38.1	60.2	0.0	0.8	0.0	9.4	0.0	0.0	0.0
Total	100	100	100	100	100	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Johnson Lake Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	26.2	3.55
	Wetland	2.9	0.39
	Open Land	0.1	0.02
	Barren Land	0.0	0.00
	Low-Density Mixed	0.2	0.02
	Medium-Density Mixed	0.3	0.04
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	6.4	0.87
Other Sources	Farm Animals and Waterfowl	0.3	0.04
	Stream Bank	1.0	0.14
	Groundwater	218.1	29.64
	Point Sources	0.0	0.00
	Dryfall	65.5	8.90
	Septic Systems	415.0	56.39
	Total	736.0	100

Estimated annual loads of phosphorus in the total Johnson Lake Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	1.16	5.1
	Wetland	0.13	0.6
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.02	0.1
	Medium-Density Mixed	0.03	0.1
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.60	2.6
Other Sources	Farm Animals and Waterfowl	0.10	0.4
	Stream Bank	0.00	0.0
	Groundwater	7.44	32.5
	Point Source	0.00	0.0
	Dryfall	0.33	1.4
	Septic Systems	13.09	57.2
	Total	22.89	100.0

Estimated annual loads of nitrogen by sub-watershed in the Johnson Lake Watershed

Category	Description	Full Watershed kg	East Inlet kg	Hunters kg	Manu Trail kg	Northeast kg	North kg	Northwest kg	Southeast kg	South kg	Southwest kg	West kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	26.2	3.4	1.3	0.7	1.16	1.94	0.74	14.4	0.9	0.5	0.9
	Wetland	2.9	0.9	0.3	0.2	0.3	0.9	0.0	0.4	0.2	0.1	0.0
	Open Land	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	0.2	0.03	0.0	0.1	0.0	0.00	0.0	0.1	0.00	0.0	0.00
	Medium-Density Mixed	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	6.4	1.7	1.1	2.04	0.0	0.03	0.0	2.2	0.0	0.0	0.0
Other Sources	Farm Animals and Waterfowl	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	1.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	218.1	30.7	13.8	15.4	8.7	14.9	5.5	111.9	7.1	3.5	6.6
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	65.5	.	.	.	.	.	.	.	.	.	.
	Septic Systems	415.0	113.1	73.3	6.4	0.0	17.5	4.8	73.6	0.0	0.0	0.0
	Total (kg)	736.0	149.7	89.8	25.0	10.2	35.3	11.0	202.8	8.1	4.0	7.5
	kg/acre	2.0	2.8	3.6	1.0	0.7	1.4	1.3	1.1	0.8	0.7	0.8

Estimated annual loads of phosphorus by sub-watershed in the Johnson Lake Watershed

Category	Description	Full Watershed kg	East Inlet kg	Hunters kg	Manu Trail kg	Northeast kg	North kg	Northwest kg	Southeast kg	South kg	Southwest kg	West kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	1.16	0.18	0.07	0.04	0.06	0.10	0.04	0.46	0.05	0.02	0.05
	Wetland	0.13	0.05	0.01	0.01	0.02	0.05	0.00	0.01	0.01	0.00	0.00
	Open Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Medium-Density Mixed	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.60	0.19	0.12	0.23	0.00	0.00	0.00	0.15	0.00	0.00	0.00
Other Sources	Farm Animals and Waterfowl	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	7.44	1.24	0.56	0.62	0.35	0.60	0.22	1.78	0.19	0.14	0.27
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	0.33	.	.	.	.	.	.	.	.	.	.
	Septic Systems	13.09	3.36	1.68	3.36	0.00	0.84	0.00	3.85	0.00	0.00	0.00
	Total (kg)	22.89	5.02	2.44	4.27	0.43	1.59	0.26	6.27	0.25	0.16	0.32
	kg/acre	0.06	0.09	0.10	0.17	0.03	0.06	0.03	0.03	0.02	0.03	0.03

Estimated annual loads of sediment in the Johnson Lake Watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.000	0.0
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.010	0.7
	Medium-Density Mixed	0.010	0.7
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.210	14.3
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	1.237	84.3
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	1.467	100.0

Estimated annual loads of bacteria from various sources in the total Johnson Lake Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.32E+08	0.1
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.49E+10	19.0
	Other Wildlife	1.06E+11	80.9
	Total	1.31E+11	100

Estimated annual loads of sediment by sub-watershed in the Johnson Lake Watershed

Category	Description	Full Watershed kg x 1000	East Inlet kg x 1000	Hunters kg x 1000	Manu Trail kg x 1000	Northeast kg x 1000	North kg x 1000	Northwest kg x 1000	Southeast kg x 1000	South kg x 1000	Southwest kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Wetland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Medium-Density Mixed	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.210	0.090	0.060	0.100	0.000	0.000	0.000	0.010	0.000	0.000	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	1.237	0.126	0.009	0.015	0.000	0.000	0.000	0.072	0.000	0.000	0.000
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	1.467	0.216	0.069	0.115	0.000	0.000	0.000	0.082	0.000	0.000	0.000
	kg/acre	4.0	4.0	2.8	4.5	0.0	0.0	0.0	0.4	0.0	0.0	0.0

Estimated annual loads of bacteria by sub-watershed in the Johnson Lake Watershed

Category	Description	Full Watershed %	East Inlet %	Hunters %	Manu Trail %	Northeast %	North %	Northwest %	Southeast %	South %	Southwest %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.1	0	0	0	0	0	0	0	0	0	0
	Point Sources	0.0	0	0	0	0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0	0	0	0	0
	Urban Areas	19.0	39.8	67.1	90.7	0	0.1	0	8.1	0	0	0
	Other Wildlife	80.9	60.2	32.9	9.3	100	99.9	100	91.9	100	100	100
	Total (organisms)	1.31E+11	2.22E+10	1.53E+10	3.14E+10	4.58E+09	7.67E+09	2.91E+09	6.56E+10	3.53E+09	1.85E+09	3.53E+09

Land-use by sub-watershed in the Forest Lake watershed

Source	Full Watershed	Dam	East	Northeast	North	Southeast	South	Southwest	West
					Area (acres)				
Open Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	35.3	3.2	3.2	4.0	9.1	2.7	7.9	2	3.2
Wetland	3.2	0.0	0.0	0.0	0.0	1.7	0.0	0	1.7
Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	4.0	0.7	1.0	1.0	0.5	0.0	0.7	0.0	0.2
Medium-Density Mixed	1.2	0.0	0.0	0.5	0.2	0.7	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	101.8	3.7	28.7	10.6	12.4	20.8	17.1	2.0	6.4
Total	145.5	7.6	32.9	16.1	22.2	25.9	25.7	4.0	11.5

Source	Full Watershed	Dam	East	Northeast	North	Southeast	South	Southwest	West
					Area (%)				
Open Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	24.3	42.1	9.7	24.8	41.0	10.4	30.7	50.0	27.8
Wetland	2.2	0.0	0.0	0.0	0.0	6.6	0.0	0.0	14.8
Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	2.7	9.2	3.0	6.2	2.3	0.0	2.7	0.0	1.7
Medium-Density Mixed	0.8	0.0	0.0	3.1	0.9	2.7	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	70.0	48.7	87.2	65.8	55.9	80.3	66.5	50.0	55.7
Total	100	100	100	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Forest Lake Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	3.2	0.39
	Wetland	0.7	0.09
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	0.5	0.06
	Medium-Density Mixed	0.4	0.05
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	12.4	1.51
Other Sources	Farm Animals and Waterfowl	2.3	0.29
	Stream Bank	0.0	0.00
	Groundwater	84.2	10.27
	Point Sources	0.0	0.00
	Dryfall	31.2	3.80
	Septic Systems	684.8	83.55
	Total	819.7	100

Estimated annual loads of phosphorus in the total Forest Lake Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.17	0.6
	Wetland	0.04	0.1
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.05	0.2
	Medium-Density Mixed	0.04	0.1
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	1.37	4.8
Other Sources	Farm Animals and Waterfowl	0.82	2.9
	Stream Bank	0.00	0.0
	Groundwater	3.42	11.9
	Point Source	0.00	0.0
	Dryfall	0.16	0.5
	Septic Systems	22.68	78.9
	Total	28.74	100.0

Estimated annual loads of nitrogen by sub-watershed in the Johnson Lake Watershed

Category	Description	Full Watershed kg	Dam kg	East kg	Northeast kg	North kg	Southeast kg	South kg	Southwest kg	West kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	3.2	0.3	0.3	0.4	0.83	0.25	0.71	0.2	0.3
	Wetland	0.7	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4
	Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	0.5	0.09	0.1	0.2	0.1	0.00	0.1	0.0	0.03
	Medium-Density Mixed	0.4	0.0	0.0	0.3	0.2	0.5	0.0	0.0	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	12.4	0.5	3.5	1.61	1.6	2.5	2.2	0.2	0.7
Other Sources	Farm Animals and Waterfowl	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	84.2	4.6	18.4	9.6	13.3	14.3	15.0	2.4	6.6
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	31.2	.	.	.	.	.	.	.	.
	Septic Systems	684.8	30.3	229.3	65.3	95.6	148.1	90.8	8.0	17.5
	Total (kg)	819.7	35.7	251.7	77.3	111.4	166.0	108.7	10.7	25.5
	kg/acre	5.6	4.7	7.6	4.8	5.0	6.4	4.2	2.7	2.2

Estimated annual loads of phosphorus by sub-watershed in the Forest Lake Watershed

Category	Description	Full Watershed kg	Dam kg	East kg	Northeast kg	North kg	Southeast kg	South kg	Southwest kg	West kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	0.17	0.02	0.02	0.02	0.04	0.01	0.04	0.01	0.02
	Wetland	0.04	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02
	Open Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.05	0.01	0.01	0.02	0.01	0.00	0.01	0.00	0.00
	Medium-Density Mixed	0.04	0.00	0.00	0.03	0.02	0.05	0.00	0.00	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	1.37	0.05	0.39	0.18	0.17	0.28	0.24	0.02	0.08
Other Sources	Farm Animals and Waterfowl	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	3.42	0.12	0.75	0.39	0.54	0.58	0.61	0.06	0.17
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	0.16	.	.	.	.	.	.	.	.
	Septic Systems	22.68	0.84	5.88	1.68	2.52	4.20	6.72	0.00	0.84
	Total (kg)	28.74	1.04	7.05	2.32	3.30	5.14	7.62	0.09	1.13
	kg/acre	0.20	0.14	0.21	0.14	0.15	0.20	0.30	0.02	0.10

Estimated annual loads of sediment in the Forest Lake Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.000	0.0
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.020	2.8
	Medium-Density Mixed	0.020	2.8
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.630	86.9
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.055	7.6
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.725	100.0

Estimated annual loads of bacteria from various sources in the total Forest Lake Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.10E+09	0.5
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.27E+11	94.6
	Other Wildlife	1.26E+10	5.3
	Total	2.40E+11	100

Table 5: Estimated annual loads of sediment by sub-watershed in the Forest Lake Watershed

Category	Description	Full Watershed kg x 1000	Dam kg x 1000	East kg x 1000	Northeast kg x 1000	North kg x 1000	Southeast kg x 1000	South kg x 1000	Southwest kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Wetland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.020	0.000	0.010	0.010	0.000	0.000	0.000	0.000	0.000
	Medium-Density Mixed	0.020	0.000	0.000	0.020	0.010	0.030	0.000	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.630	0.020	0.180	0.080	0.080	0.130	0.110	0.010	0.040
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	0.055	0.006	0.025	0.014	0.014	0.021	0.016	0.004	0.008
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.725	0.026	0.215	0.124	0.104	0.181	0.126	0.014	0.048
	kg/acre	5.0	3.4	6.5	7.7	4.7	7.0	4.9	3.5	4.2

Estimated annual loads of bacteria by sub-watershed in the Forest Lake Watershed

Category	Description	Full Watershed %	Dam %	East %	Northeast %	North %	Southeast %	South %	Southwest %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.5	0	0	0	0	0	0	0	0
	Point Sources	0.0	0	0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0	0	0
	Urban Areas	94.6	86.8	98.5	95.2	87.2	98.2	92.5	79.3	90.3
	Other Wildlife	5.3	13.2	1.5	4.8	12.8	1.8	7.5	20.7	9.7
	Total (organisms)	2.40E+11	8.68E+09	7.78E+10	2.95E+10	2.55E+10	5.41E+10	3.75E+10	3.40E+09	1.18E+10

Land-use by sub-watershed in the Panther Lake watershed

Source	Full Watershed	Cub Lake	Forest	Jans Way	Northeast	North	Northwest	Outlet	Rose Marie Ln	Southeast	Southwest	West
						Area (acres)						
Open Water	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	1.3	0.0	0.0
Hay/Pasture	2.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0	0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
Forest	156.4	2.2	2.5	8.2	56.8	1.5	3.5	2	2.2	74.9	1.2	0.7
Wetland	18.3	0.0	0.0	0.0	1.7	0.0	0.0	0	0.0	16.6	0.0	0
Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	9.6	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.7	7.4	0.7	0.2
Medium-Density Mixed	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0
Low-Density Open Space	26.4	0.0	0.0	1.0	4.7	0.2	0.2	0.0	3.0	13.8	2.5	1
Total	215.5	2.2	2.7	9.2	63.9	1.7	3.7	2.4	5.9	116.2	4.9	1.9

Source	Full Watershed	Cub Lake	Forest	Jans Way	Northeast	North	Northwest	Outlet	Rose Marie Ln	Southeast	Southwest	West
						Area (%)						
Open Water	0.8	0.0	0.0	0.0	0.0	0.0	0.0	18.0	0.0	1.1	0.0	0.0
Hay/Pasture	0.9	0.0	7.4	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	72.6	100.0	92.6	89.1	88.9	88.2	94.6	82.0	37.3	64.4	24.5	36.8
Wetland	8.5	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	14.3	0.0	0.0
Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	4.5	0.0	0.0	0.0	1.1	0.0	0.0	0.0	11.9	6.4	14.3	10.5
Medium-Density Mixed	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	10.2	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	12.3	0.0	0.0	10.9	7.4	11.8	5.4	0.0	50.8	11.9	51.0	52.6
Total	100	100	100	100	100	100	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Panther Lake Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	1.1	0.31
	Cropland	0.0	0.00
	Forest	9.5	2.70
	Wetland	4.1	1.16
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	1.5	0.42
	Medium-Density Mixed	0.6	0.18
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	4.0	1.14
Other Sources	Farm Animals and Waterfowl	0.9	0.27
	Stream Bank	0.0	0.00
	Groundwater	136.4	38.94
	Point Sources	0.0	0.00
	Dryfall	42.0	12.00
	Septic Systems	150.2	42.88
	Total	350.2	100

Estimated annual loads of phosphorus in the total Panther Lake Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.55	1.3
	Cropland	0.00	0.0
	Forest	0.49	1.2
	Wetland	0.20	0.5
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.15	0.4
	Medium-Density Mixed	0.06	0.1
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.41	1.0
Other Sources	Farm Animals and Waterfowl	0.33	0.8
	Stream Bank	0.00	0.0
	Groundwater	5.26	12.6
	Point Source	0.00	0.0
	Dryfall	0.21	0.5
	Septic Systems	34.09	81.7
	Total	41.74	100.0

Estimated annual loads of nitrogen by sub-watershed in the Panther Lake Watershed

Category	Description	Full Watershed kg	Cub Lake kg	Forest kg	Jans Way kg	Northeast kg	North kg	Northwest kg	Outlet kg	Rose Marie Ln kg	Southeast kg	Southwest kg	West kg
Runoff	Hay/Pasture	1.1	0.0	0.1	0.0	0.0	0.0	0.00	0.0	0.0	1.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	9.5	0.2	0.2	1.1	5.14	0.13	0.31	0.2	0.2	4.5	0.1	0.1
	Wetland	4.1	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	3.7	0.0	0.0
	Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	1.5	0.00	0.0	0.0	0.1	0.00	0.0	0.0	0.16	1.2	0.15	0.1
	Medium-Density Mixed	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	4.0	0.0	0.0	0.11	0.7	0.03	0.03	0.0	0.7	2.2	0.5	0.1
Other Sources	Farm Animals and Waterfowl	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	136.4	1.6	1.8	5.5	41.1	1.1	2.7	1.6	3.6	69.0	2.7	1.2
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	42.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Septic Systems	150.2	0.0	4.8	17.5	43.0	4.8	17.5	0.0	30.3	0.0	4.8	76.4
	Total (kg)	350.2	1.8	6.9	24.2	90.5	6.1	20.6	1.7	34.9	82.0	8.5	77.9
	kg/acre	1.6	0.8	2.6	2.6	1.4	3.6	5.6	0.7	5.9	0.7	1.7	41.0

Estimated annual loads of phosphorus by sub-watershed in the Panther Lake Watershed

Category	Description	Full Watershed kg	Cub Lake kg	Forest kg	Jans Way kg	Northeast kg	North kg	Northwest kg	Outlet kg	Rose Marie Ln kg	Southeast kg	Southwest kg	West kg
Runoff	Hay/Pasture	0.55	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	0.49	0.01	0.01	0.06	0.27	0.01	0.02	0.01	0.01	0.24	0.00	0.00
	Wetland	0.20	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.19	0.00	0.00
	Open Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.15	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.12	0.02	0.01
	Medium-Density Mixed	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.41	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.07	0.23	0.05	0.01
Other Sources	Farm Animals and Waterfowl	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	5.26	0.04	0.05	0.14	1.67	0.03	0.07	0.04	0.1	2.66	0.07	0.03
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Septic Systems	34.09	0.00	2.52	2.52	0.84	2.52	5.04	0.00	7.56	0.00	2.52	36.11
	Total (kg)	41.74	0.05	2.63	2.73	2.89	2.56	5.13	0.05	7.76	3.99	2.69	36.16
	kg/acre	0.19	0.02	0.97	0.30	0.05	1.51	1.39	0.02	1.32	0.03	0.55	19.03

Estimated annual loads of sediment in the Panther Lake Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.270	50.7
	Cropland	0.000	0.0
	Forest	0.010	1.9
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.060	11.3
	Medium-Density Mixed	0.030	5.6
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.150	28.1
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.013	2.4
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.533	100.0

Estimated annual loads of bacteria from various sources in the total Panther Lake Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	4.35E+08	0.6
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	1.95E+10	25.7
	Other Wildlife	5.58E+10	73.7
	Total	7.57E+10	100

Estimated annual loads of sediment by sub-watershed in the Panther Lake Watershed

Category	Description	Full Watershed kg x 1000	Cub Lake kg x 1000	Forest kg x 1000	Jans Way kg x 1000	Northeast kg x 1000	North kg x 1000	Northwest kg x 1000	Outlet kg x 1000	Rose Marie Ln kg x 1000	Southeast kg x 1000	Southwest kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.270	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.270	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000
	Wetland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.060	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.010	0.040	0.010	0.000
	Medium-Density Mixed	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.020	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.150	0.000	0.000	0.010	0.030	0.000	0.000	0.000	0.030	0.080	0.020	0.010
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	0.013	0.000	0.000	0.001	0.004	0.001	0.001	0.000	0.006	0.010	0.007	0.003
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.533	0.000	0.000	0.011	0.044	0.001	0.001	0.000	0.046	0.430	0.057	0.013
	kg/acre	2.5	0.0	0.0	1.2	0.7	0.6	0.3	0.0	7.8	3.7	11.6	6.8

Estimated annual loads of bacteria by sub-watershed in the Panther Lake Watershed

Category	Description	Full Watershed %	Cub Lake %	Forest %	Jans Way %	Northeast %	North %	Northwest %	Outlet %	Rose Marie Ln %	Southeast %	Southwest %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.6	0	0	0	0	0	0	0	0	0	0	0
	Point Sources	0.0	0	0	0	0	0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0	0	0	0	0	0
	Urban Areas	25.7	0	0	8.9	5.9	15	3.4	0	89.6	32.4	95.8	89.6
	Other Wildlife	73.7	100	100	91.1	94.1	85	96.6	100	10.4	67.6	4.2	10.4
	Total (organisms)	7.57E+10	7.93E+08	8.81E+08	3.19E+09	2.16E+10	6.22E+08	1.28E+09	7.05E+08	7.66E+09	3.95E+10	1.06E+10	2.55E+09

Land-use by sub-watershed in the Wolf Lake watershed

Source	Full Watershed	North	Northeast	South	Southwest	Wright
			Area (acres)			
Open Water	64.2	0.0	0.0	0.0	0.0	64.2
Hay/Pasture	33.1	0.0	0.0	0.0	0.0	33.1
Cropland	0.0	0.0	0.0	0.0	0.0	0.0
Forest	2140.7	22.2	30.6	36.1	73.4	1978.6
Wetland	278.5	0.5	0.0	0.7	1.5	275.8
Open Land	20.8	0.0	2.5	0.2	0.2	17.5
Barren Land	0.7	0.0	0.0	0.0	0.0	0.7
Low-Density Mixed	32.1	1.5	0.0	0.2	0.2	29.9
Medium-Density Mixed	4.0	0.0	0.0	0.0	0.0	4.0
High-Density Mixed	0.2	0.0	0.0	0.0	0.0	0.2
Low-Density Open Space	122.8	3.7	0.0	2.5	0.5	116.1
Total	2697.1	27.9	33.1	39.7	75.8	2520.1

Source	Full Watershed	North	Northeast	South	Southwest	Wright
			Area (%)			
Open Water	2.4	0.0	0.0	0.0	0.0	2.5
Hay/Pasture	1.2	0.0	0.0	0.0	0.0	1.3
Cropland	0.0	0.0	0.0	0.0	0.0	0.0
Forest	79.4	79.6	92.4	90.9	96.8	78.5
Wetland	10.3	1.8	0.0	1.8	2.0	10.9
Open Land	0.8	0.0	7.6	0.5	0.3	0.7
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	1.2	5.4	0.0	0.5	0.3	1.2
Medium-Density Mixed	0.1	0.0	0.0	0.0	0.0	0.2
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	4.6	13.3	0.0	6.3	0.7	4.6
Total	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Wolf Lake Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	12.8	0.48
	Cropland	0.0	0.00
	Forest	183.6	6.93
	Wetland	59.2	2.23
	Open Land	11.7	0.44
	Barren Land	0.3	0.01
	Low-Density Mixed	4.5	0.17
	Medium-Density Mixed	2.1	0.08
	High-Density Mixed	0.1	0.00
	Low-Density Open Space	17.1	0.65
Other Sources	Farm Animals and Waterfowl	14.5	0.55
	Stream Bank	10.0	0.38
	Groundwater	1416.2	53.44
	Point Sources	0.0	0.00
	Dryfall	445.1	16.79
	Septic Systems	473.1	17.85
	Total	2650.1	100

Estimated annual loads of phosphorus in the total Wolf Lake Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	4.77	6.1
	Cropland	0.00	0.0
	Forest	6.29	8.0
	Wetland	2.06	2.6
	Open Land	0.22	0.3
	Barren Land	0.01	0.0
	Low-Density Mixed	0.32	0.4
	Medium-Density Mixed	0.14	0.2
	High-Density Mixed	0.01	0.0
	Low-Density Open Space	1.22	1.6
Other Sources	Farm Animals and Waterfowl	3.80	4.8
	Stream Bank	5.00	6.4
	Groundwater	37.40	47.6
	Point Source	0.00	0.0
	Dryfall	2.23	2.8
	Septic Systems	15.04	19.2
	Total	78.50	100.0

Estimated annual loads of nitrogen by sub-watershed in the Wolf Lake Watershed

Category	Description	Full Watershed kg	North kg	Northeast kg	South kg	Southwest kg	Wright kg
Runoff	Hay/Pasture	12.8	0.0	0.0	0.0	0.0	12.7
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	183.6	3.2	2.8	3.3	10.24	168.06
	Wetland	59.2	0.1	0.0	0.2	0.2	58.0
	Open Land	11.7	0.0	1.5	0.2	0.1	9.8
	Barren Land	0.3	0.0	0.0	0.0	0.0	0.3
	Low-Density Mixed	4.5	0.17	0.0	0.04	0.1	4.15
	Medium-Density Mixed	2.1	0.0	0.0	0.0	0.0	2.0
	High-Density Mixed	0.1	0.0	0.0	0.0	0.0	0.1
	Low-Density Open Space	17.1	0.4	0.0	0.35	0.1	16.11
Other Sources	Farm Animals and Waterfowl	14.5	0.0	0.0	0.0	0.0	14.3
	Stream Bank	10.0	0.0	0.00	0.0	0.0	9.0
	Groundwater	1416.2	15.0	20.4	25.2	42.9	1303.6
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	445.1	0.0	0.0	0.0	0.0	0.0
	Septic Systems	473.1	0.0	0.0	8.0	8.0	452.1
	Total (kg)	2650.1	18.9	24.6	37.2	61.5	2050.3
	kg/acre	1.0	0.7	0.7	0.9	0.8	0.8

Estimated annual loads of phosphorus by sub-watershed in the Wolf Lake Watershed

Category	Description	Full Watershed kg	North kg	Northeast kg	South kg	Southwest kg	Wright kg
Runoff	Hay/Pasture	4.77	0.00	0.00	0.00	0.00	4.26
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	6.29	0.24	0.15	0.17	0.55	5.18
	Wetland	2.06	0.01	0.00	0.01	0.01	1.82
	Open Land	0.22	0.00	0.03	0.00	0.00	0.17
	Barren Land	0.01	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.32	0.02	0.00	0.00	0.01	0.26
	Medium-Density Mixed	0.14	0.00	0.00	0.00	0.00	0.12
	High-Density Mixed	0.01	0.00	0.00	0.00	0.00	0.01
	Low-Density Open Space	1.22	0.04	0.00	0.04	0.01	1.03
Other Sources	Farm Animals and Waterfowl	3.80	0.00	0.00	0.00	0.00	3.73
	Stream Bank	5.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	37.40	0.39	0.53	0.66	1.12	30.96
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	2.23	0.00	0.00	0.00	0.00	0.00
	Septic Systems	15.04	0.00	0.00	0.00	0.00	13.40
	Total (kg)	78.50	0.70	0.71	0.88	1.70	60.94
	kg/acre	0.03	0.03	0.02	0.02	0.02	0.02

Estimated annual loads of sediment in the Wolf Lake Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.670	10.9
	Cropland	0.000	0.0
	Forest	0.000	0.0
	Wetland	0.010	0.2
	Open Land	0.020	0.3
	Barren Land	0.000	0.0
	Low-Density Mixed	0.040	0.6
	Medium-Density Mixed	0.020	0.3
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.160	2.6
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	5.242	85.1
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	6.162	100.0

Estimated annual loads of bacteria from various sources in the total Wolf Lake Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	3.20E+10	3.88
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.85E+10	3.5
	Other Wildlife	7.64E+11	92.7
	Total	8.25E+11	100

Estimated annual loads of sediment by sub-watershed in the Wolf Lake Watershed

Category	Description	Full Watershed kg x 1000	North kg x 1000	Northeast kg x 1000	South kg x 1000	Southwest kg x 1000	Wright kg x 1000
Runoff	Hay/Pasture	0.670	0.000	0.000	0.000	0.000	0.170
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.000	0.070	0.000	0.000	0.010	0.000
	Wetland	0.010	0.000	0.000	0.000	0.000	0.000
	Open Land	0.020	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.040	0.010	0.000	0.000	0.000	0.010
	Medium-Density Mixed	0.020	0.000	0.000	0.000	0.000	0.010
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.160	0.020	0.000	0.020	0.000	0.040
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	5.242	0.005	0.000	0.003	0.001	1.315
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	6.162	0.105	0.000	0.023	0.011	1.545
	kg/acre	2.3	3.8	0.0	0.6	0.1	0.6

Estimated annual loads of bacteria by sub-watershed in the Wolf Lake Watershed

Category	Description	Full Watershed %	North %	Northeast %	South %	Southwest %	Wright %
Fecal Coliform	Farm Animals and Waterfowl	3.9	0	0	0	0	4.2
	Point Sources	0.0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0
	Urban Areas	3.5	26.4	0	3.8	0.1	3.6
	Other Wildlife	92.7	73.6	100	96.2	99.9	92.3
	Total (organisms)	8.25E+11	1.08E+10	1.09E+10	1.34E+10	2.62E+10	7.65E+11

Land-use by sub-watershed in the Wright Pond watershed

Source	Full Watershed	East	Island	Lubbers Run	Sparta Mt.	West
			Area (acres)			
Open Water	42.9	0.0	0.0	42.0	0.9	0.0
Hay/Pasture	8.6	0.0	0.0	21.3	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0
Forest	611.9	7.9	0.0	1385.0	104.3	15.1
Wetland	86.0	1.0	0.4	193.7	12.6	4.0
Open Land	5.3	0.0	0.1	12.8	0.0	0.0
Barren Land	0.2	0.0	0.0	0.5	0.0	0.0
Low-Density Mixed	11.6	0.0	0.0	28.7	0.0	0.0
Medium-Density Mixed	1.6	0.0	0.0	4.0	0.0	0.0
High-Density Mixed	0.1	0.0	0.0	0.2	0.0	0.0
Low-Density Open Space	37.3	0.5	0.0	91.7	0.0	0.0
Total	805.5	9.4	0.5	1779.9	117.8	19.1

Source	Full Watershed	East	Island	Lubbers Run	Sparta Mt.	West
			Area (%)			
Open Water	5.3	0.0	0.0	2.4	0.8	0.0
Hay/Pasture	1.1	0.0	0.0	1.2	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0
Forest	76.0	84.0	0.0	77.8	88.5	79.1
Wetland	10.7	10.6	80.0	10.9	10.7	20.9
Open Land	0.7	0.0	20.0	0.7	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	1.4	0.0	0.0	1.6	0.0	0.0
Medium-Density Mixed	0.2	0.0	0.0	0.2	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	4.6	5.3	0.0	5.2	0.0	0.0
Total	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Wright Pond Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	12.9	0.71
	Cropland	0.0	0.00
	Forest	130.0	7.14
	Wetland	45.2	2.48
	Open Land	7.5	0.41
	Barren Land	0.2	0.01
	Low-Density Mixed	4.1	0.23
	Medium-Density Mixed	2.1	0.11
	High-Density Mixed	0.1	0.01
	Low-Density Open Space	13.3	0.73
Other Sources	Farm Animals and Waterfowl	14.5	0.80
	Stream Bank	7.0	0.38
	Groundwater	1003.2	55.13
	Point Sources	0.0	0.00
	Dryfall	130.6	7.18
	Septic Systems	448.9	24.67
	Total	1819.6	100

Estimated annual loads of phosphorus in the total Wright Pond Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	4.27	7.1
	Cropland	0.00	0.0
	Forest	4.62	7.6
	Wetland	1.59	2.6
	Open Land	0.21	0.3
	Barren Land	0.00	0.0
	Low-Density Mixed	0.29	0.5
	Medium-Density Mixed	0.14	0.2
	High-Density Mixed	0.01	0.0
	Low-Density Open Space	0.94	1.6
Other Sources	Farm Animals and Waterfowl	3.80	6.3
	Stream Bank	4.00	6.6
	Groundwater	26.49	43.8
	Point Source	0.00	0.0
	Dryfall	0.65	1.1
	Septic Systems	13.48	22.3
	Total	60.49	100.0

Estimated annual loads of nitrogen by sub-watershed in the Wright Pond Watershed

Category	Description	Full Watershed kg	East kg	Island kg	Lubbers Run kg	Sparta Mt. kg	West kg
Runoff	Hay/Pasture	12.9	0.0	0.0	12.9	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	130.0	0.7	0.0	118.3	13.75	0.97
	Wetland	45.2	0.1	0.2	40.9	2.7	0.6
	Open Land	7.5	0.0	0.2	7.3	0.0	0.0
	Barren Land	0.2	0.0	0.0	0.2	0.0	0.0
	Low-Density Mixed	4.1	0.00	0.0	4.09	0.0	0.00
	Medium-Density Mixed	2.1	0.0	0.0	2.0	0.0	0.0
	High-Density Mixed	0.1	0.0	0.0	0.1	0.0	0.0
	Low-Density Open Space	13.3	0.1	0.0	13.09	0.0	0.00
Other Sources	Farm Animals and Waterfowl	14.5	13.9	0.0	0.5	0.0	0.0
	Stream Bank	7.0	0.0	0.00	7.0	0.0	0.0
	Groundwater	1003.2	5.9	0.4	919.0	57.0	11.8
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	130.6	0.0	0.0	0.0	0.0	0.0
	Septic Systems	448.9	4.8	0.0	441.5	0.0	0.0
	Total (kg)	1819.6	25.5	0.8	1566.9	73.4	13.3
	kg/acre	2.3	2.7	1.6	0.9	0.6	0.7

Estimated annual loads of phosphorus by sub-watershed in the Wright Lake Watershed

Category	Description	Full Watershed kg	East kg	Island kg	Lubbers Run kg	Sparta Mt. kg	West kg
Runoff	Hay/Pasture	4.27	0.00	0.00	3.97	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	4.62	0.04	0.00	3.91	0.46	0.08
	Wetland	1.59	0.01	0.01	1.34	0.09	0.04
	Open Land	0.21	0.00	0.00	0.19	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.29	0.00	0.00	0.27	0.00	0.00
	Medium-Density Mixed	0.14	0.00	0.00	0.13	0.00	0.00
	High-Density Mixed	0.01	0.00	0.00	0.01	0.00	0.00
	Low-Density Open Space	0.94	0.01	0.00	0.87	0.00	0.00
Other Sources	Farm Animals and Waterfowl	3.80	3.54	0.00	0.19	0.00	0.00
	Stream Bank	4.00	0.00	0.00	3.00	0.00	0.00
	Groundwater	26.49	0.24	0.01	22.64	0.94	0.31
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	0.65	0.00	0.00	0.00	0.00	0.00
	Septic Systems	13.48	0.00	0.00	12.50	0.00	0.00
	Total (kg)	60.49	3.84	0.02	49.02	1.49	0.43
	kg/acre	0.08	0.41	0.04	0.03	0.01	0.02

Estimated annual loads of sediment in the Wright Pond Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.340	7.8
	Cropland	0.000	0.0
	Forest	0.050	1.1
	Wetland	0.010	0.2
	Open Land	0.030	0.7
	Barren Land	0.000	0.0
	Low-Density Mixed	0.040	0.9
	Medium-Density Mixed	0.020	0.5
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.120	2.7
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	3.765	86.1
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	4.375	100.0

Estimated annual loads of bacteria from various sources in the total Wright Pond Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	3.20E+10	5.37
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.51E+10	4.2
	Other Wildlife	5.39E+11	90.4
	Total	5.96E+11	100

Estimated annual loads of sediment by sub-watershed in the Wright Pond Watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	Island kg x 1000	Lubbers Run kg x 1000	Sparta Mt. kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.340	0.000	0.000	0.180	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.050	0.000	0.000	0.020	0.000	0.030
	Wetland	0.010	0.000	0.000	0.000	0.000	0.010
	Open Land	0.030	0.000	0.000	0.010	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.040	0.000	0.000	0.020	0.000	0.000
	Medium-Density Mixed	0.020	0.000	0.000	0.010	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.120	0.000	0.000	0.060	0.000	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	3.765	0.000	0.000	1.842	0.005	0.000
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	4.375	0.000	0.000	2.142	0.005	0.040
	kg/acre	5.4	0.0	0.0	1.2	0.0	2.1

Estimated annual loads of bacteria by sub-watershed in the Wright Pond Watershed

Category	Description	Full Watershed %	East %	Island %	Lubbers Run %	Sparta Mt. %	West %
Fecal Coliform	Farm Animals and Waterfowl	5.4	91.7	0	0	0	0
	Point Sources	0.0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0
	Urban Areas	4.2	0.2	0	5.2	0	0
	Other Wildlife	90.4	8.1	0	94.8	100	100
	Total (organisms)	5.96E+11	3.47E+10	0.00E+00	5.21E+11	3.72E+10	5.38E+09

Land-use by sub-watershed in the Jefferson Lake watershed

Source	Full Watershed	Dam	Ghost Pony	Northeast	North	Northwest	Southeast	South
				Area (acres)				
Open Water	163.1	0.0	163.1	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	10.6	1.2	8.9	0.0	0.5	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	2309.7	2.0	2024.0	69.9	18.3	168.0	16.8	9.9
Wetland	359.8	0.7	345.5	3.5	1.7	6.4	1.7	0.0
Open Land	15.8	0.0	15.6	0.0	0.0	0.0	0.2	0.0
Barren Land	1.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	27.2	0.0	25.5	0.0	1.7	0.0	0.0	0.0
Medium-Density Mixed	19.0	0.0	18.3	0.0	0.7	0.0	0.0	0.0
High-Density Mixed	3.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	336.1	1.5	324.0	0.2	6.2	0.0	4.0	0.0
Total	3245.8	5.4	2929.4	73.6	29.1	174.4	22.7	9.9

Source	Full Watershed	Dam	Ghost Pony	Northeast	North	Northwest	Southeast	South
				Area (%)				
Open Water	5.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.3	22.2	0.3	0.0	1.7	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	71.2	37.0	69.1	95.0	62.9	96.3	74.0	100.0
Wetland	11.1	13.0	11.8	4.8	5.8	3.7	7.5	0.0
Open Land	0.5	0.0	0.5	0.0	0.0	0.0	0.9	0.0
Barren Land	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	0.8	0.0	0.9	0.0	5.8	0.0	0.0	0.0
Medium-Density Mixed	0.6	0.0	0.6	0.0	2.4	0.0	0.0	0.0
High-Density Mixed	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	10.4	27.8	11.1	0.3	21.3	0.0	17.6	0.0
Total	100	100	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Jefferson Lake Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	5.3	0.10
	Cropland	0.0	0.00
	Forest	230.4	4.24
	Wetland	77.1	1.42
	Open Land	8.9	0.16
	Barren Land	0.5	0.01
	Low-Density Mixed	3.3	0.06
	Medium-Density Mixed	12.0	0.22
	High-Density Mixed	1.9	0.03
	Low-Density Open Space	41.1	0.76
Other Sources	Farm Animals and Waterfowl	0.4	0.01
	Stream Bank	74.0	1.36
	Groundwater	1825.5	33.58
	Point Sources	0.0	0.00
	Dryfall	506.9	9.33
	Septic Systems	2648.7	48.73
	Total	5436.0	100

Estimated annual loads of phosphorus in the total Jefferson Lake Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	1.66	0.5
	Cropland	0.00	0.0
	Forest	8.67	2.4
	Wetland	2.90	0.8
	Open Land	0.13	0.0
	Barren Land	0.01	0.0
	Low-Density Mixed	0.26	0.1
	Medium-Density Mixed	0.88	0.2
	High-Density Mixed	0.14	0.0
	Low-Density Open Space	3.25	0.9
Other Sources	Farm Animals and Waterfowl	0.13	0.0
	Stream Bank	25.00	7.0
	Groundwater	52.98	14.8
	Point Source	0.00	0.0
	Dryfall	2.53	0.7
	Septic Systems	258.32	72.4
	Total	356.86	100.0

Estimated annual loads of nitrogen by sub-watershed in the Jefferson Lake Watershed

Category	Description	Full Watershed kg	Dam kg	Ghost Pony kg	Northeast kg	North kg	Northwest kg	Southeast kg	South kg
Runoff	Hay/Pasture	5.3	0.1	4.9	0.0	0.1	0.0	0.00	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	230.4	0.2	174.1	6.3	2.05	15.18	1.50	0.9
	Wetland	77.1	0.2	73.5	0.8	0.1	1.4	0.2	0.0
	Open Land	8.9	0.0	8.7	0.0	0.0	0.0	0.1	0.0
	Barren Land	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	3.3	0.00	3.1	0.0	0.2	0.00	0.0	0.0
	Medium-Density Mixed	12.0	0.0	12.5	0.0	0.5	0.0	0.0	0.0
	High-Density Mixed	1.9	0.0	2.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	41.1	0.1	39.4	0.03	0.7	0.0	0.4	0.0
Other Sources	Farm Animals and Waterfowl	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	74.0	0.0	69.00	0.0	0.0	0.0	0.0	0.0
	Groundwater	1825.5	3.2	1666.6	46.5	17.9	112.7	14.2	7.3
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	506.9	.	.	.	.	.	.	.
	Septic Systems	2648.7	0.0	2597.2	0.0	22.3	0.0	12.5	0.0
	Total (kg)	5436.0	3.9	4651.5	53.6	43.9	129.3	28.9	8.2
	kg/acre	1.7	0.7	1.6	0.7	1.5	0.7	1.3	0.8

Estimated annual loads of phosphorus by sub-watershed in the Jefferson Lake Watershed

Category	Description	Full Watershed kg	Dam kg	Ghost Pony kg	Northeast kg	North kg	Northwest kg	Southeast kg	South kg
Runoff	Hay/Pasture	1.66	0.07	1.42	0.00	0.06	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	8.67	0.01	6.16	0.33	0.11	0.80	0.07	0.05
	Wetland	2.90	0.01	2.60	0.04	0.01	0.08	0.01	0.00
	Open Land	0.13	0.00	0.12	0.00	0.00	0.00	0.00	0.00
	Barren Land	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.26	0.00	0.23	0.00	0.02	0.00	0.00	0.00
	Medium-Density Mixed	0.88	0.00	0.86	0.00	0.05	0.00	0.00	0.00
	High-Density Mixed	0.14	0.00	0.14	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	3.25	0.01	2.93	0.00	0.08	0.00	0.04	0.00
Other Sources	Farm Animals and Waterfowl	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	25.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	52.98	0.08	45.47	1.22	0.47	2.95	0.33	0.19
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	2.53	.	.	.	.	.	.	.
	Septic Systems	258.32	0.00	240.27	0.00	0.84	0.00	0.00	0.00
	Total (kg)	356.86	0.18	321.21	1.59	1.64	3.83	0.45	0.24
	kg/acre	0.11	0.03	0.11	0.02	0.06	0.02	0.02	0.02

Estimated annual loads of sediment in the Jefferson Lake Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.390	0.9
	Cropland	0.000	0.0
	Forest	0.000	0.0
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.060	0.1
	Medium-Density Mixed	0.220	0.5
	High-Density Mixed	0.030	0.1
	Low-Density Open Space	0.710	1.7
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	41.456	96.7
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	42.866	100.0

Estimated annual loads of bacteria from various sources in the total Jefferson Lake Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.70E+08	0.0
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	1.44E+11	14.9
	Other Wildlife	8.24E+11	85.1
	Total	9.68E+11	100

Estimated annual loads of sediment by sub-watershed in the Jefferson Lake Watershed

Category	Description	Full Watershed kg x 1000	Dam kg x 1000	Ghost Pony kg x 1000	Northeast kg x 1000	North kg x 1000	Northwest kg x 1000	Southeast kg x 1000	South kg x 1000
Runoff	Hay/Pasture	0.390	0.040	0.270	0.000	0.010	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Wetland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.060	0.000	0.040	0.000	0.010	0.000	0.000	0.000
	Medium-Density Mixed	0.220	0.000	0.170	0.000	0.030	0.000	0.000	0.000
	High-Density Mixed	0.030	0.000	0.030	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.710	0.010	0.490	0.000	0.030	0.000	0.010	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	41.456	0.000	27.302	0.015	0.008	0.126	0.003	0.000
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	42.866	0.050	28.302	0.015	0.088	0.126	0.013	0.000
	kg/acre	13.2	9.3	9.7	0.2	3.0	0.7	0.6	0.0

Estimated annual loads of bacteria by sub-watershed in the Jefferson Lake Watershed

Category	Description	Full Watershed %	Dam %	Ghost Pony %	Northeast %	North %	Northwest %	Southeast %	South %
Fecal Coliform	Farm Animals and Waterfowl	0.0	0	0	0	0	0	0	0
	Point Sources	0.0	0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0	0
	Urban Areas	14.9	60.6	17.1	0.0	56.4	0	23.4	0
	Other Wildlife	85.1	39.4	82.9	100.0	43.6	100	76.6	100
	Total (organisms)	9.68E+11	1.79E+09	8.71E+11	2.49E+10	1.50E+10	5.99E+10	7.82E+09	3.53E+09

Land-use by sub-watershed in the Stag Pond watershed

Source	Full Watershed	East	North	Outlet	South	Southeast	Southwest	West
				Area (acres)				
Open Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	215.5	24.2	110.7	20.5	10.4	13.6	5.4	30.6
Wetland	17.3	0.0	14.1	0.5	0.7	0.0	0.0	2.0
Open Land	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	0.7	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Medium-Density Mixed	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	3.7	0.0	0.0	0.0	0.7	0.2	2.5	0.5
Total	237.9	24.2	124.8	21.0	13.2	13.8	7.9	33.1

Source	Full Watershed	East	North	Outlet	South	Southeast	Southwest	West
				Area (%)				
Open Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	90.6	100.0	88.7	97.6	78.8	98.6	68.4	92.4
Wetland	7.3	0.0	11.3	2.4	5.3	0.0	0.0	6.0
Open Land	0.2	0.0	0.0	0.0	3.8	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	0.3	0.0	0.0	0.0	5.3	0.0	0.0	0.0
Medium-Density Mixed	0.1	0.0	0.0	0.0	1.5	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	1.6	0.0	0.0	0.0	5.3	1.4	31.6	1.5
Total	100	100	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Stag Pond Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	19.3	8.79
	Wetland	3.8	1.75
	Open Land	0.3	0.13
	Barren Land	0.0	0.00
	Low-Density Mixed	0.1	0.04
	Medium-Density Mixed	0.2	0.07
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	0.5	0.21
Other Sources	Farm Animals and Waterfowl	0.2	0.09
	Stream Bank	0.0	0.00
	Groundwater	138.6	62.98
	Point Sources	0.0	0.00
	Dryfall	44.5	20.21
	Septic Systems	12.6	5.72
	Total	220.0	100

Estimated annual loads of phosphorus in the total Stag Pond Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.98	11.5
	Wetland	0.19	2.2
	Open Land	0.01	0.1
	Barren Land	0.00	0.0
	Low-Density Mixed	0.01	0.1
	Medium-Density Mixed	0.01	0.1
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.05	0.6
Other Sources	Farm Animals and Waterfowl	0.07	0.8
	Stream Bank	0.00	0.0
	Groundwater	3.88	45.5
	Point Source	0.00	0.0
	Dryfall	0.22	2.6
	Septic Systems	3.10	36.4
	Total	8.53	100.0

Estimated annual loads of nitrogen by sub-watershed in the Stag Pond Watershed

Category	Description	Full Watershed kg	East kg	North kg	Outlet kg	South kg	Southeast kg	Southwest kg	West kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	19.3	3.4	10.0	1.9	0.94	1.52	0.49	2.7
	Wetland	3.8	0.0	3.2	0.1	0.2	0.0	0.0	0.6
	Open Land	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	0.1	0.00	0.0	0.0	0.2	0.00	0.0	0.0
	Medium-Density Mixed	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	0.5	0.0	0.0	0.00	0.1	0.03	0.29	0.1
Other Sources	Farm Animals and Waterfowl	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
	Groundwater	138.6	13.5	70.2	13.3	8.0	8.3	4.8	18.9
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	44.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Septic Systems	12.6	0.0	0.0	0.0	5.4	4.8	3.0	0.0
	Total (kg)	220.0	16.9	83.3	15.3	15.2	14.6	8.5	22.2
	kg/acre	0.9	0.7	0.7	0.7	1.2	1.1	1.1	0.7

Estimated annual loads of phosphorus by sub-watershed in the Stag Pond Watershed

Category	Description	Full Watershed kg	East kg	North kg	Outlet kg	South kg	Southeast kg	Southwest kg	West kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	0.98	0.18	0.53	0.10	0.05	0.08	0.03	0.12
	Wetland	0.19	0.00	0.17	0.01	0.01	0.00	0.00	0.02
	Open Land	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00
	Medium-Density Mixed	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.05	0.00	0.00	0.00	0.01	0.00	0.03	0.01
Other Sources	Farm Animals and Waterfowl	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	3.88	0.35	1.84	0.35	0.23	0.22	0.14	0.43
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Septic Systems	3.10	0.00	0.00	0.00	0.26	2.52	0.77	0.00
	Total (kg)	8.53	0.53	2.54	0.46	0.61	2.82	0.97	0.58
	kg/acre	0.04	0.02	0.02	0.02	0.05	0.20	0.12	0.02

Estimated annual loads of sediment in the Stag Pond Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.010	20.0
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.000	0.0
	Medium-Density Mixed	0.010	20.0
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.020	40.0
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.010	20.0
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.050	100.0

Estimated annual loads of bacteria from various sources in the total Stag Pond Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	9.45E+07	0.12
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.80E+08	0.4
	Other Wildlife	7.69E+10	99.5
	Total	7.73E+10	100

Estimated annual loads of sediment by sub-watershed in the Stag Pond Watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	North kg x 1000	Outlet kg x 1000	South kg x 1000	Southeast kg x 1000	Southwest kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Wetland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000
	Medium-Density Mixed	0.010	0.000	0.000	0.000	0.010	0.000	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.020	0.000	0.000	0.000	0.000	0.000	0.020	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	0.010	0.000	0.002	0.000	0.002	0.001	0.003	0.000
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.050	0.000	0.002	0.000	0.022	0.001	0.023	0.000
	kg/acre	0.2	0.0	0.0	0.0	1.7	0.1	2.9	0.0

Estimated annual loads of bacteria by sub-watershed in the Stag Pond Watershed

Category	Description	Full Watershed %	East %	North %	Outlet %	South %	Southeast %	Southwest %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.1	0	0	0	0	0	0	0
	Point Sources	0.0	0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0	0
	Urban Areas	0.4	0	0	0.0	18.5	0.2	51.7	0.2
	Other Wildlife	99.5	100	100	100.0	81.5	99.8	48.3	99.8
	Total (organisms)	7.73E+10	8.64E+09	3.95E+10	7.32E+09	4.54E+09	4.86E+09	4.01E+09	1.09E+10

Land-use by sub-watershed in the Kofferls Pond watershed

Source	Full Watershed	East	Northeast	North	Northwest	Southeast	South	West
				Area (acres)				
Open Water	0.7	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	2.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	272.8	10.9	152.7	90.2	7.4	3.7	1.5	6.7
Wetland	23.5	0.0	17.1	6.4	0.0	0.0	0.0	0.0
Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	26.2	0.0	26.2	0.0	0.0	0.0	0.0	0.0
Medium-Density Mixed	3.7	0.0	3.7	0.0	0.0	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	33.1	0.0	29.7	1.2	0.0	1.5	0.5	0.0
Total	362.0	10.9	232.1	97.8	7.4	5.2	2.0	6.7

Source	Full Watershed	East	Northeast	North	Northwest	Southeast	South	West
				Area (%)				
Open Water	0.2	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.6	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	75.4	100.0	65.8	92.2	100.0	71.2	75.0	100.0
Wetland	6.5	0.0	7.4	6.5	0.0	0.0	0.0	0.0
Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	7.2	0.0	11.3	0.0	0.0	0.0	0.0	0.0
Medium-Density Mixed	1.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	9.1	0.0	12.8	1.2	0.0	28.8	25.0	0.0
Total	100	100	100	100	100	100	100	100

Estimated annual loads of nitrogen in the total Kofferls Pond Watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	1.0	0.15
	Cropland	0.0	0.00
	Forest	24.3	3.69
	Wetland	5.2	0.79
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	4.7	0.72
	Medium-Density Mixed	1.7	0.26
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	6.0	0.91
Other Sources	Farm Animals and Waterfowl	0.6	0.10
	Stream Bank	1.0	0.15
	Groundwater	221.1	33.56
	Point Sources	0.0	0.00
	Dryfall	60.5	9.18
	Septic Systems	332.6	50.49
	Total	658.7	100

Estimated annual loads of phosphorus in the total Kofferls Pond Watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.39	1.6
	Cropland	0.00	0.0
	Forest	1.15	4.7
	Wetland	0.25	1.0
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.46	1.9
	Medium-Density Mixed	0.16	0.7
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.58	2.4
Other Sources	Farm Animals and Waterfowl	0.26	1.0
	Stream Bank	1.00	4.1
	Groundwater	8.09	32.9
	Point Source	0.00	0.0
	Dryfall	0.30	1.2
	Septic Systems	11.93	48.6
	Total	24.56	100.0

Estimated annual loads of nitrogen by sub-watershed in the Kofferls Pond Watershed

Category	Description	Full Watershed	East	Northeast	North	Northwest	Southeast	South	West
		kg	kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	1.0	0.0	1.0	0.0	0.0	0.0	0.00	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	24.3	1.0	13.3	8.2	0.67	0.33	0.13	0.6
	Wetland	5.2	0.0	3.7	1.8	0.0	0.0	0.0	0.0
	Open Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	4.7	0.00	4.6	0.0	0.0	0.00	0.0	0.0
	Medium-Density Mixed	1.7	0.0	1.7	0.0	0.0	0.0	0.0	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	6.0	0.0	5.3	0.07	0.0	0.10	0.1	0.0
Other Sources	Farm Animals and Waterfowl	0.6	0.0	0.5	0.0	0.0	0.0	0.0	0.0
	Stream Bank	1.0	0.0	1.00	0.0	0.0	0.0	0.0	0.0
	Groundwater	221.1	7.0	134.0	58.2	4.8	3.1	1.5	4.4
	Point Sources	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dryfall	60.5	0.0	.	.	.	.	.	.
	Septic Systems	332.6	4.8	304.6	12.7	0.0	0.0	0.0	4.8
	Total (kg)	658.7	12.8	469.5	81.0	5.5	3.6	1.7	9.8
	kg/acre	1.8	1.2	2.0	0.8	0.7	0.7	0.8	1.5

Estimated annual loads of phosphorus by sub-watershed in the Kofferls Pond Watershed

Category	Description	Full Watershed	East	Northeast	North	Northwest	Southeast	South	West
		kg	kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	0.39	0.00	0.31	0.00	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	1.15	0.05	0.51	0.43	0.04	0.02	0.01	0.03
	Wetland	0.25	0.00	0.15	0.10	0.00	0.00	0.00	0.00
	Open Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.46	0.00	0.37	0.00	0.00	0.00	0.00	0.00
	Medium-Density Mixed	0.16	0.00	0.13	0.00	0.00	0.00	0.00	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.58	0.00	0.41	0.01	0.00	0.01	0.01	0.00
Other Sources	Farm Animals and Waterfowl	0.26	0.00	0.19	0.00	0.00	0.00	0.00	0.00
	Stream Bank	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	8.09	0.18	4.00	1.52	0.13	0.08	0.04	0.12
	Point Sources	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dryfall	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Septic Systems	11.93	0.00	7.72	0.00	0.00	0.00	0.00	2.52
	Total (kg)	24.56	0.23	14.79	2.06	0.17	0.11	0.06	2.67
	kg/acre	0.07	0.02	0.06	0.02	0.02	0.02	0.03	0.40

Estimated annual loads of sediment in the Kofferls Pond Watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.000	0.0
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.150	6.0
	Medium-Density Mixed	0.080	3.2
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.180	7.1
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	2.108	83.7
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	2.518	100.0

Estimated annual loads of bacteria from various sources in the total Kofferls Pond Watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	2.11E+08	0.2
	Point Sources	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	3.68E+10	27.4
	Other Wildlife	9.73E+10	72.4
	Total	1.34E+11	100

Estimated annual loads of sediment by sub-watershed in the Kofferls Pond Watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	Northeast kg x 1000	North kg x 1000	Northwest kg x 1000	Southeast kg x 1000	South kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Wetland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.150	0.000	0.070	0.000	0.000	0.000	0.000	0.000
	Medium-Density Mixed	0.080	0.000	0.040	0.000	0.000	0.000	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.180	0.000	0.080	0.000	0.000	0.010	0.000	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	2.108	0.000	1.172	0.001	0.000	0.002	0.001	0.000
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	2.518	0.000	1.362	0.001	0.000	0.012	0.001	0.000
	kg/acre	7.0	0.0	5.9	0.0	0.0	2.3	0.5	0.0

Table 5: Estimated annual loads of bacteria by sub-watershed in the Kofferls Pond Watershed

Category	Description	Full Watershed %	East %	Northeast %	North %	Northwest %	Southeast %	South %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.2	0	0.1	0	0	0	0	0
	Point Sources	0.0	0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0	0
	Urban Areas	27.4	0	48.9	0.1	0	46.2	38.4	0
	Other Wildlife	72.5	100	51	99.9	100	53.8	61.6	100
	Total (organisms)	1.34E+11	3.88E+09	1.07E+11	3.22E+10	2.64E+09	2.46E+09	8.59E+08	2.38E+09

APPENDIX IV: WINTER STREAM IN-SITU DATA

Winter Storm In-Situ Monitoring for Byram Township Inlet Streams 2023

Date	Station	Sample	Temperature	Specific Conductance	Dissolved Oxygen		pH
		m	°C	µS/cm	mg/L	% Sat.	S.U.
1/26/2023	Jefferson Lake	0.0	3.46	207.43	13.30	103.10	7.92
1/26/2023	Cranberry Lake	0.0	3.27	89.70	12.62	97.90	7.27
1/26/2023	Panther Lake	0.0	4.91	78.77	10.90	87.80	7.50
1/26/2023	Johnson Lake	0.0	4.67	372.60	12.73	96.10	7.56
1/26/2023	Forest Lake	0.0	4.32	532.80	12.10	96.90	7.17
1/26/2023	Stag Pond	0.0	6.38	59.90	11.59	97.80	7.56
1/26/2023	Wright Lake	0.0	3.58	372.30	12.27	96.10	7.35
1/26/2023	Kofferls Pond	0.0	4.21	527.70	12.80	102.10	7.86
1/26/2023	Lake Lackawanna	0.0	3.24	260.70	13.25	102.30	7.47

Winter Storm In-Situ Monitoring for Byram Township Inlet Streams 2023

Date	Station	Sample	Temperature	Specific Conductance	Dissolved Oxygen		pH
		m	°C	µS/cm	mg/L	% Sat.	S.U.
2/28/2023	Jefferson Lake	0.0	1.88	288.20	14.45	107.10	7.97
2/28/2023	Cranberry Lake	0.0	0.90	149.40	14.39	104.70	7.77
2/28/2023	Panther Lake	0.0	5.13	234.60	10.22	84.43	7.75
2/28/2023	Johnson Lake	0.0	2.60	314.30	13.36	101.90	7.67
2/28/2023	Forest Lake	0.0	2.43	950.50	11.35	86.10	7.53
2/28/2023	Stag Pond	0.0	5.39	95.59	8.53	98.60	7.15
2/28/2023	Wright Lake	0.0	4.36	301.90	12.22	97.50	7.67
2/28/2023	Kofferls Pond	0.0	2.47	593.60	13.46	101.90	7.83
2/28/2023	Lake Lackawanna	0.0	0.70	484.20	14.15	102.40	7.67

Baseline In-Situ Monitoring for Byram Township Inlet Streams 2023

Date	Station	Sample	Temperature	Specific Conductance	Dissolved Oxygen		pH
		m	°C	µS/cm	mg/L	% Sat.	S.U.
6/22/2023	Jefferson Lake	0.0	14.09	589.00	9.23	89.90	7.86
6/22/2023	Cranberry Lake	0.0	13.68	277.00	11.08	106.70	8.00
6/22/2023	Panther Lake	0.0	12.01	425.00	7.13	66.00	7.58
6/22/2023	Johnson Lake	0.0	13.20	296.00	10.70	101.40	7.88
6/22/2023	Forest Lake	0.0	13.79	125.00	5.03	46.80	7.21
6/22/2023	Stag Pond	0.0	11.60	174.00	10.95	99.70	7.48
6/22/2023	Wright Lake	0.0	12.46	447.00	6.12	55.00	7.33
6/22/2023	Kofferls Pond	0.0	12.79	770.00	10.66	100.70	8.04
6/22/2023	Lake Lackawanna	0.0	15.40	520.00	9.26	92.60	7.79

APPENDIX V: BASELINE STREAM DATA

Baseline In-Situ Monitoring for Byram Township Inlet Streams 2023

Date	Station	Sample	Temperature	Specific Conductance	Dissolved Oxygen		pH
		m	°C	µS/cm	mg/L	% Sat.	S.U.
4/6/2023	Jefferson Lake	0.0	11.27	316.33	10.95	101.96	7.95
4/6/2023	Cranberry Lake	0.0	11.49	160.46	11.26	105.58	7.63
4/6/2023	Panther Lake	0.0	13.19	227.03	7.00	68.19	7.41
4/6/2023	Johnson Lake	0.0	12.75	190.74	10.32	99.25	7.60
4/6/2023	Forest Lake	0.0	12.71	935.55	9.24	89.16	7.43
4/6/2023	Stag Pond	0.0	10.87	57.68	10.63	98.41	7.18
4/6/2023	Wright Lake	0.0	16.40	318.71	8.82	92.32	7.46
4/6/2023	Kofferls Pond	0.0	13.60	608.86	10.15	100.00	7.98
4/6/2023	Lake Lackawanna	0.0	14.04	424.47	10.30	102.03	8.01

Baseline In-Situ Monitoring for Byram Township Inlet Streams 2023

Date	Station	Sample	Temperature	Specific Conductance	Dissolved Oxygen		pH
		m	°C	µS/cm	mg/L	% Sat.	S.U.
6/29/2023	Jefferson Lake	0.0	14.09	589.00	9.23	89.90	7.86
6/29/2023	Cranberry Lake	0.0	13.68	277.00	11.08	106.70	8.00
6/29/2023	Panther Lake	0.0	12.01	425.00	7.13	66.00	7.58
6/29/2023	Johnson Lake	0.0	13.20	296.00	10.70	101.40	7.88
6/29/2023	Forest Lake	0.0	13.79	125.50	5.03	46.80	7.21
6/29/2023	Stag Pond	0.0	11.61	174.00	10.95	99.70	7.48
6/29/2023	Wright Lake	0.0	12.46	447.00	6.12	55.00	7.33
6/29/2023	Kofferls Pond	0.0	12.79	770.00	10.66	100.70	8.04
6/29/2023	Lake Lackawanna	0.0	15.40	520.00	9.26	92.60	7.79

Baseline In-Situ Monitoring for Byram Township Inlet Streams 2023

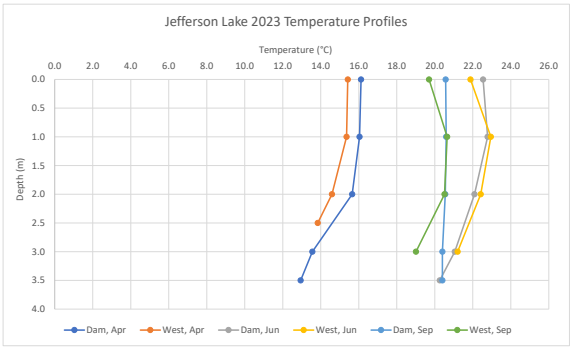
Date	Station	Sample	Temperature	Specific Conductance	Dissolved Oxygen		pH
		m	°C	µS/cm	mg/L	% Sat.	S.U.
9/19/2023	Jefferson Lake	0.0	16.04	279.48	9.50	98.00	7.81
9/19/2023	Cranberry Lake	0.0	20.07	186.37	7.76	87.19	7.43
9/20/2023	Panther Lake	0.0	14.12	223.46	7.67	75.74	7.41
9/20/2023	Johnson Lake	0.0	15.89	170.47	9.78	100.76	7.72
9/20/2023	Forest Lake	0.0	16.76	671.82	7.63	79.68	7.45
9/21/2023	Stag Pond	0.0	13.98	100.94	9.96	98.18	7.82
9/21/2023	Wright Lake	0.0	17.39	163.74	8.48	88.21	7.05
9/21/2023	Kofferls Pond	0.0	14.79	474.37	9.77	97.92	7.96
9/19/2023	Lake Lackawanna	0.0	16.18	349.63	9.48	98.74	7.90

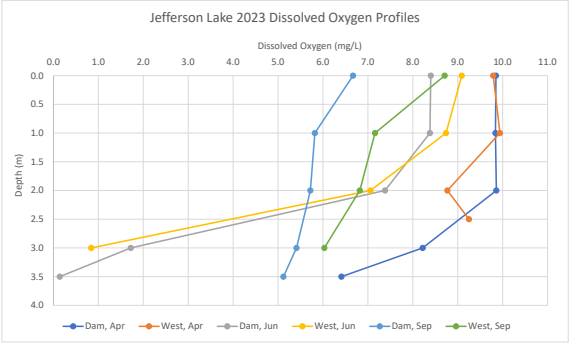
APPENDIX VI: BASELINE LAKE DATA

Discrete Monitoring Data for Byram Lakes - 2023													
Date	Station	Chl A		NH3-N		NO3-N		SRP		TP		TSS	
		S (mg/M3)	D (mg/M3)	S (mg/L)	D (mg/L)	S (mg/L)	D (mg/L)	S (mg/L)	D (mg/L)	S (mg/L)	D (mg/L)	S (mg/L)	D (mg/L)
April-23	Jefferson	3.3	3.7	0.03	0.02	ND <0.03	ND <0.03	ND <0.003	ND <0.003	0.01	0.02	12	13
	Cranberry	6.3	1.7	0.01	0.01	ND <0.03	ND <0.03	ND <0.003	ND <0.003	0.01	0.02	12	9
	Lackawanna	4.5	7.6	0.01	0.02	ND <0.03	0.03	ND <0.003	ND <0.003	0.02	0.03	7	6
	Forest	7.4	30.0	0.02	0.02	0.03	0.10	ND <0.003	ND <0.003	0.02	0.06	2	6
	Panther	8.7	2.7	0.05	0.01	0.03	0.18	ND <0.003	ND <0.003	0.03	0.04	4	6
	Johnson	4.9	5.6	0.02	0.01	0.04	0.07	ND <0.003	ND <0.003	0.02	0.02	3	4
	Stag	3.4	37.0	0.01	0.01	ND <0.03	ND <0.03	ND <0.003	ND <0.003	0.02	0.08	9	15
	Kofferls	2.9	3.9	0.01	0.01	0.03	0.15	ND <0.003	ND <0.003	0.02	0.02	8	4
	Wolf	ACCESS NOT GRANTED											
	Wright	ACCESS NOT GRANTED											
June-23	Jefferson	5.2	7.2	ND <0.01	ND <0.01	0.04	0.08	ND <0.003	ND <0.003	0.02	0.04	ND <2	4
	Cranberry	2.7	7.0	ND <0.01	ND <0.01	0.03	0.07	ND <0.003	ND <0.003	0.01	0.02	ND <2	9
	Lackawanna	3.8	4.0	ND <0.01	ND <0.01	0.03	0.03	ND <0.003	ND <0.003	0.02	0.03	3	5
	Forest	23.0	3.6	ND <0.01	ND <0.01	0.04	0.06	ND <0.003	ND <0.003	0.01	0.03	13	9
	Panther	3.3	3.0	ND <0.01	0.08	ND <0.03	0.16	ND <0.003	0.032	0.02	0.12	10	14
	Johnson	2.2	2.8	ND <0.01	ND <0.01	0.03	0.04	ND <0.003	ND <0.003	0.01	0.01	6	9
	Stag	1.7	35.0	ND <0.01	0.01	ND <0.03	0.04	ND <0.003	0.004	ND <0.01	0.14	ND <2	12
	Kofferls	1.9	1.2	ND <0.01	ND <0.01	0.01	ND <0.03	ND <0.003	ND <0.003	ND <0.01	ND	ND <2	2
	Wolf	ACCESS NOT GRANTED											
	Wright	ACCESS NOT GRANTED											
September-23	Jefferson	18.0	14.0	0.03	0.04	ND <0.07	ND <0.07	0.001	0.002	ND <0.02	0.02	ND <2	ND <2
	Cranberry	5.8	3.2	0.02	0.04	ND <0.07	ND <0.07	0.001	0.001	ND <0.02	ND <0.02	ND <2	ND <2
	Lackawanna	3.5	4.0	0.03	0.04	ND <0.07	ND <0.07	0.001	0.002	ND <0.02	ND <0.02	ND <2	2
	Forest	12.0	14.0	0.09	0.09	ND <0.07	ND <0.07	0.001	0.001	0.03	0.03	5	6
	Panther	3.8	5.0	0.03	0.63	ND <0.07	ND <0.07	0.001	0.028	0.02	0.11	3	6
	Johnson	3.3	5.9	0.03	0.03	0.09	0.10	ND <0.001	0.001	0.02	0.02	3	5
	Stag	18.0	36.0	0.02	0.39	ND <0.07	0.07	0.001	0.056	0.02	0.34	2	9
	Kofferls	2.3	9.6	0.02	0.09	ND <0.07	0.09	ND <0.001	0.002	ND <0.02	0.03	ND <2	8
	Wolf	ACCESS NOT GRANTED											
	Wright	ACCESS NOT GRANTED											

***In-Situ* Monitoring for Jefferson Lake 2023**

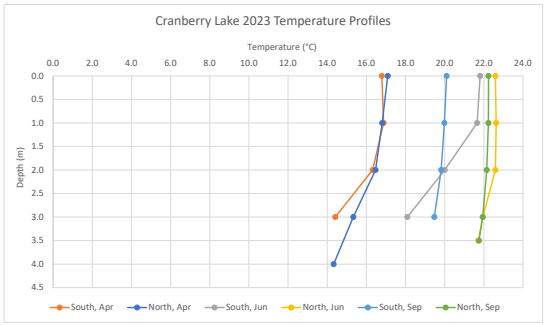
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
4/24/2023	Dam	3.7	2.4	0.0	16.12	232.27	9.85	101.91	8.08
				1.0	16.04	232.45	9.84	101.78	8.03
				2.0	15.65	232.16	9.86	100.74	7.90
				3.0	13.56	235.89	8.22	79.87	7.50
				3.5	12.94	235.60	6.41	59.62	7.26
4/24/2023	West	2.7	2.4	0.0	15.42	214.01	9.79	99.74	7.75
				1.0	15.36	214.35	9.94	101.48	7.79
				2.0	14.59	215.85	8.77	87.79	7.47
				2.5	13.84	213.22	9.25	91.80	7.49
6/21/2023	Dam	3.7	1.8	0.0	22.54	270.06	8.40	98.40	7.96
				1.0	22.78	270.38	8.38	98.68	7.92
				2.0	22.09	270.70	7.38	85.13	7.42
				3.0	21.05	283.60	1.72	18.00	7.36
				3.5	20.26	291.63	0.14	1.52	7.25
6/21/2023	Mid	3.3	1.8	0.0	21.88	270.74	9.09	104.98	8.00
				1.0	22.95	271.16	8.74	103.02	7.98
				2.0	22.42	289.61	7.06	71.43	7.67
				3.0	21.20	300.07	0.84	7.86	7.42
9/19/2023	Dam	3.7	1.2	0.0	20.57	271.53	6.67	73.16	7.55
				1.0	20.60	270.90	5.82	65.81	7.49
				2.0	20.55	270.02	5.72	65.46	7.45
				3.0	20.40	271.71	5.41	60.14	7.39
				3.5	20.40	254.06	5.12	58.02	7.35
9/19/2023	West	3.2	1.5	0.0	19.70	268.87	8.71	90.84	7.72
				1.0	20.65	268.07	7.16	81.54	7.67
				2.0	20.51	267.11	6.82	76.48	7.60
				3.0	19.01	251.59	6.03	66.22	7.51

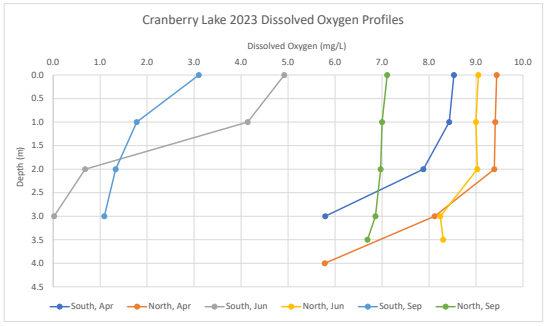




***In-Situ* Monitoring for Cranberry Lake 2023**

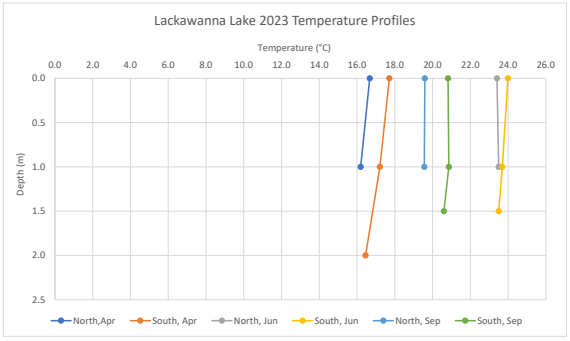
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
4/24/2023	South	3.4	1.6	0.0	16.79	164.68	8.53	89.94	7.52
				1.0	16.88	163.73	8.43	89.11	7.53
				2.0	16.32	150.03	7.88	81.95	7.41
				3.0	14.41	176.50	5.79	57.14	7.16
4/24/2023	North	4.2	2.1	0.0	17.09	238.31	9.44	100.09	7.83
				1.0	16.81	233.98	9.41	99.10	7.82
				2.0	16.47	213.86	9.39	98.43	7.79
				3.0	15.33	214.21	8.12	80.00	7.47
				4.0	14.33	216.47	5.78	56.29	7.18
6/21/2023	South	3.2	1.4	0.0	21.81	162.39	4.92	56.98	7.56
				1.0	21.66	159.50	4.14	47.14	7.34
				2.0	20.00	144.90	0.68	6.01	7.14
				3.0	18.09	156.67	0.02	0.22	6.91
6/21/2023	North	4.0	2.7	0.0	22.59	227.80	9.05	106.18	7.93
				1.0	22.63	227.57	9.00	105.84	8.02
				2.0	22.59	227.14	9.03	106.20	8.03
				3.0	21.95	226.35	8.24	95.24	7.95
				3.5	21.72	225.65	8.30	98.07	7.98
9/19/2023	South	3.5	1.6	0.0	20.10	138.14	3.10	32.00	7.12
				1.0	19.98	138.99	1.78	19.18	6.89
				2.0	19.82	137.43	1.33	14.46	6.76
				3.0	19.47	141.03	1.09	11.73	6.68
9/19/2023	North	4	2.5	0.0	22.24	191.50	7.11	83.51	7.47
				1.0	22.23	191.78	7.00	82.41	7.44
				2.0	22.15	191.30	6.97	82.08	7.46
				3.0	21.94	190.96	6.86	80.11	7.41
				3.5	21.75	190.78	6.69	78.11	7.40

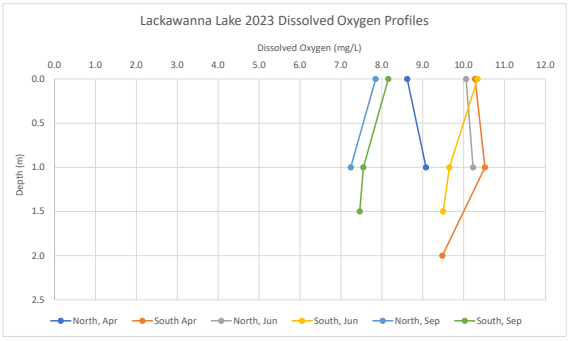




***In-Situ* Monitoring for Lake Lackawanna 2023**

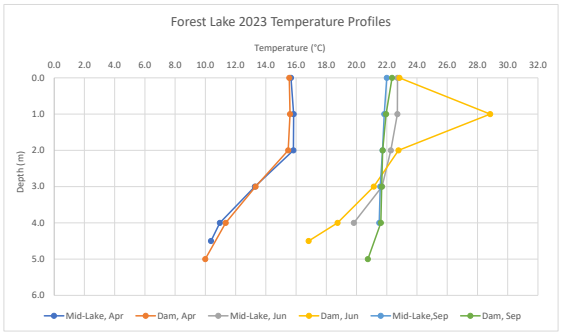
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
4/24/2023	North	1.4	1.4+	0.0	16.67	296.07	8.62	91.03	8.00
				1.0	16.19	310.43	9.08	97.70	8.52
4/24/2023	South	2.4	1.9	0.0	17.71	314.87	10.28	100.29	8.77
				1.0	17.21	311.94	10.52	111.73	8.80
				2.0	16.45	323.57	9.48	98.34	8.30
6/22/2023	North	1.4	1.4	0.0	23.41	382.05	10.06	119.79	8.25
				1.0	23.50	378.41	10.23	122.10	8.31
6/22/2023	South	2.0	2.0	0.0	23.99	366.05	10.34	124.38	8.51
				1.0	23.69	368.79	9.65	115.39	8.34
				1.5	23.50	368.04	9.50	113.75	8.23
9/19/2023	North	1.5	1.5+	0.0	19.59	298.72	7.85	85.97	7.60
				1.0	19.56	314.48	7.24	80.96	7.57
9/19/2023	South	1.8	1.8+	0.0	20.82	290.21	8.16	92.09	7.65
				1.0	20.86	296.74	7.55	86.49	7.65
				1.5	20.60	300.49	7.46	84.54	7.66

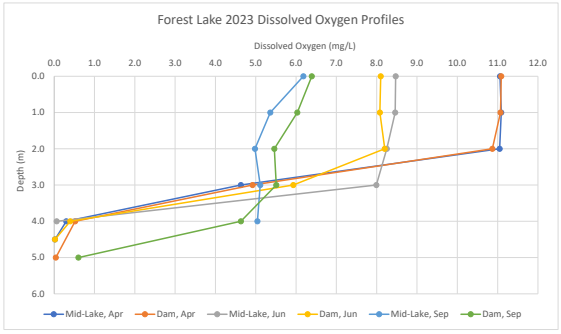




***In-Situ* Monitoring for Forest Lake 2022**

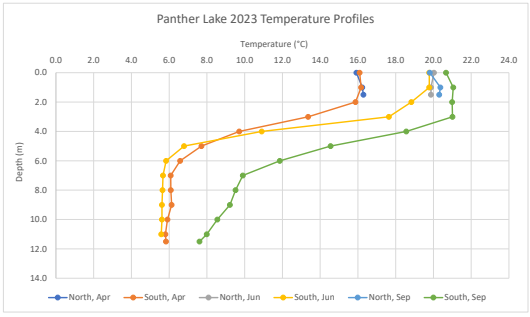
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
4/25/2023	Mid-lake	4.6	2.4	0.0	15.66	813.92	11.06	113.89	8.59
				1.0	15.84	813.23	11.09	114.61	8.62
				2.0	15.82	815.65	11.05	113.78	8.56
				3.0	13.27	831.86	4.63	45.21	7.50
				4.0	10.96	835.91	0.30	2.42	7.14
				4.5	10.37	847.89	0.02	0.17	7.12
4/25/2023	Dam	5.3	2.4	0.0	15.55	816.48	11.09	113.62	8.61
				1.0	15.60	814.03	11.07	113.53	8.62
				2.0	15.48	812.86	10.87	111.38	8.59
				3.0	13.32	829.09	4.92	47.09	7.53
				4.0	11.34	831.86	0.52	4.24	7.28
				5.0	9.99	854.55	0.04	0.43	7.23
6/21/2023	Mid-Lake	4.5	2.7	0.0	22.71	739.27	8.47	99.89	8.26
				1.0	22.70	770.93	8.46	99.46	8.26
				2.0	22.27	766.03	8.25	96.36	8.18
				3.0	21.69	855.13	7.99	92.34	8.12
				4.0	19.82	855.74	0.06	5.88	7.58
6/21/2023	Dam	5.0	2.6	0.0	22.84	877.17	8.10	95.75	8.25
				1.0	28.84	876.89	8.08	95.66	8.26
				2.0	22.77	876.17	8.20	97.08	8.23
				3.0	21.14	870.38	5.93	69.82	7.86
				4.0	18.74	881.77	0.40	3.67	7.47
				4.5	16.83	899.56	0.02	0.17	7.11
9/20/2023	Mid-lake	4.5	1.1	0.0	22.00	733.51	6.18	72.11	7.74
				1.0	21.83	730.03	5.36	61.86	7.62
				2.0	21.72	729.91	4.98	57.71	7.55
				3.0	21.57	729.90	5.11	59.41	7.54
				4.0	21.50	731.53	5.04	58.20	7.53
9/20/2023	Dam	5.2	1.1	0.0	22.35	732.79	6.39	75.15	7.75
				1.0	21.95	729.92	6.03	69.22	7.63
				2.0	21.73	730.88	5.46	63.28	7.57
				3.0	21.66	730.88	5.51	63.85	7.56
				4.0	21.61	733.34	4.63	53.50	7.46
				5.0	20.75	897.10	0.60	6.57	6.97

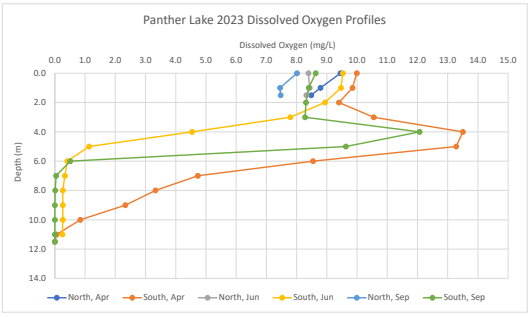




***In-Situ* Monitoring for Panther Lake 2023**

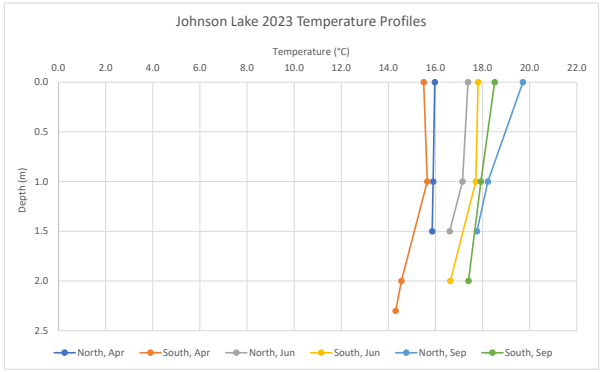
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
4/25/2023	North	2.0	1.3	0.0	15.92	353.45	9.45	97.09	8.34
				1.0	16.23	346.67	8.79	91.08	8.21
				1.5	16.29	348.53	8.48	87.88	8.16
4/25/2023	South	11.6	1.4	0.0	16.09	359.46	9.99	103.34	8.47
				1.0	16.17	358.37	9.85	102.09	8.47
				2.0	15.87	368.81	9.40	95.56	8.28
				3.0	13.36	373.74	10.55	102.60	8.34
				4.0	9.71	378.03	13.50	120.99	8.54
				5.0	7.71	377.83	13.28	112.61	8.33
				6.0	6.58	384.65	8.54	70.42	7.79
				7.0	6.08	402.23	4.73	38.39	7.48
				8.0	6.09	408.05	3.33	27.06	7.40
				9.0	6.13	412.82	2.33	18.83	7.35
				10.0	5.91	408.68	0.84	4.75	7.30
				11.0	5.80	415.12	0.06	0.38	7.25
				11.5	5.83	422.68	0.00	0.00	7.20
6/21/2023	North	1.7	1.7+	0.0	20.03	452.00	8.39	92.30	8.23
				1.0	19.87	460.00	8.43	92.30	8.21
				1.5	19.87	463.00	8.32	88.90	8.14
6/21/2023	South	11.4	1.7	0.0	19.78	464.00	9.53	104.40	8.41
				1.0	19.78	466.00	9.47	103.70	8.36
				2.0	18.83	469.00	8.94	95.40	8.15
				3.0	17.64	477.00	7.79	81.10	7.91
				4.0	10.90	521.00	4.54	38.60	7.42
				5.0	6.79	530.00	1.13	9.30	7.23
				6.0	5.84	534.00	0.41	3.10	6.86
				7.0	5.67	534.00	0.33	2.50	6.83
				8.0	5.65	534.00	0.26	2.10	6.82
				9.0	5.62	532.00	0.26	2.10	6.86
				10.0	5.62	533.00	0.26	2.00	6.86
				11.0	5.58	532.00	0.25	1.90	6.89
9/20/2023	North	1.9	1.9+	0.0	19.81	310.09	8.01	86.46	7.91
				1.0	20.37	306.57	7.45	84.12	7.86
				1.5	20.31	306.85	7.47	84.20	7.83
9/20/2023	South	11.7	2.6	0.0	20.67	328.08	8.63	97.69	8.13
				1.0	21.05	325.66	8.40	96.01	8.10
				2.0	20.99	324.56	8.31	95.02	8.02
				3.0	21.01	323.94	8.28	94.45	7.99
				4.0	18.56	431.01	12.07	133.23	7.80
				5.0	14.55	464.28	9.63	95.89	7.54
				6.0	11.86	478.05	0.51	5.50	7.20
				7.0	9.90	488.97	0.04	0.35	7.18
				8.0	9.52	498.60	0.01	0.06	7.18
				9.0	9.22	496.58	0.00	0.00	7.18
				10.0	8.55	515.67	0.00	0.00	7.09
				11.0	7.99	539.05	0.00	0.00	7.10
				11.5	7.61	569.46	0.00	0.00	6.98

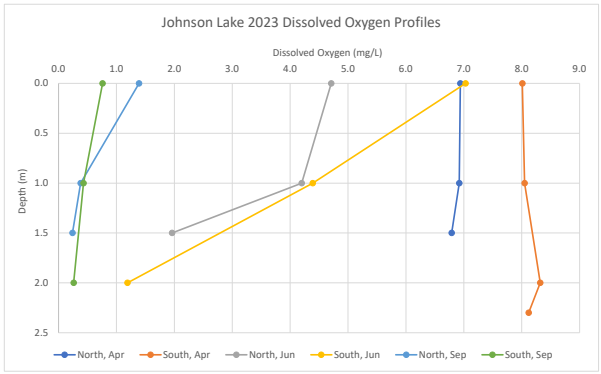




***In-Situ* Monitoring for Post Brooks Johnson Lake 2023**

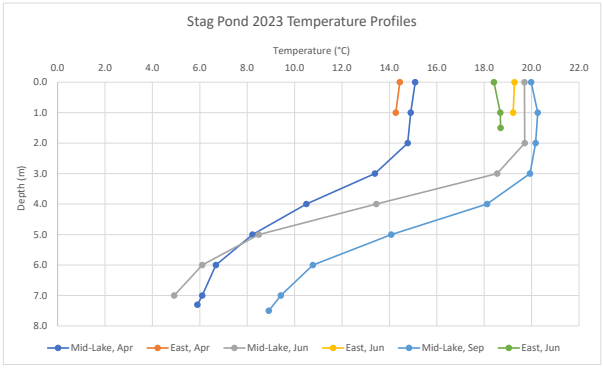
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
4/25/2023	North	1.6	1.6+	0.0	15.97	314.72	6.94	71.86	7.44
				1.0	15.90	324.23	6.92	71.50	7.32
				1.5	15.86	324.44	6.79	69.97	7.28
4/25/2023	South	2.4	2.4+	0.0	15.50	274.20	8.01	82.01	7.37
				1.0	15.65	269.44	8.05	83.09	7.35
				2.0	14.55	222.79	8.32	83.41	7.34
				2.3	14.31	222.80	8.12	81.07	7.19
6/22/2023	North	1.9	1.3	0.0	17.38	366	4.71	48.5	7.2
				1.0	17.15	380	4.2	43.3	7.01
				1.5	16.6	415	1.96	15.5	6.65
6/22/2023	South	2.4	1.6	0.0	17.81	369	7.03	74.1	6.98
				1.0	17.71	376	4.39	44.5	6.83
				2.0	16.63	404	1.19	12.3	6.50
9/20/2023	North	1.9	1.6	0.0	19.71	288.40	1.39	14.62	6.67
				1.0	18.22	285.91	0.38	3.61	6.55
				1.5	17.76	302.35	0.24	2.41	6.51
9/20/2023	South	2.4	1.4	0.0	18.51	264.80	0.76	8.21	6.45
				1.0	17.93	261.18	0.43	2.91	6.42
				2.0	17.40	242.32	0.26	3.65	6.43

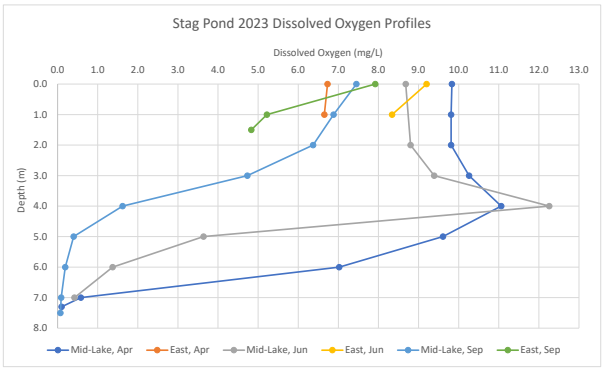




***In-Situ* Monitoring for Stag Pond 2023**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
4/26/2023	Mid-lake	7.4	2.9	0.0	15.09	65.27	9.83	99.39	7.84
				1.0	14.90	65.34	9.81	98.92	7.68
				2.0	14.77	65.19	9.81	98.62	7.62
				3.0	13.39	64.18	10.26	101.51	7.61
				4.0	10.50	62.84	11.06	100.41	7.47
				5.0	8.22	62.84	9.61	81.01	7.29
				6.0	6.68	64.21	7.02	53.65	7.04
				7.0	6.10	75.42	0.58	3.38	6.60
				7.3	5.90	83.04	0.10	0.80	6.53
4/26/2023	East	1.4	1.4+	0.0	14.44	68.48	6.73	67.11	7.12
				1.0	14.27	68.50	6.65	66.05	7.03
6/22/2023	Mid-Lake	7.5	3	0.0	19.70	124.00	8.68	95.00	7.61
				2.0	19.71	128.00	8.80	96.30	7.46
				3.0	18.55	127.00	9.39	101.40	7.33
				4.0	13.45	132.00	12.26	113.20	7.30
				5.0	8.49	145.00	3.64	31.20	5.81
				6.0	6.10	137.00	1.37	9.00	5.50
				7.0	4.92	187.00	0.42	3.10	5.27
6/22/2023	East	1.3	1.3	0.0	19.28	122.00	9.20	101.70	7.40
				1.0	19.22	126.00	8.34	90.30	7.24
9/21/2023	Mid-lake	7.8	2.6	0.0	19.98	51.87	7.45	82.17	7.43
				1.0	20.26	51.72	6.88	76.82	7.34
				2.0	20.17	51.83	6.37	70.63	7.20
				3.0	19.93	52.83	4.73	49.61	6.96
				4.0	18.12	59.60	1.62	14.60	6.74
				5.0	14.08	70.84	0.40	3.99	6.65
				6.0	10.77	81.16	0.19	1.62	6.49
				7.0	9.42	126.77	0.09	0.83	6.36
				7.5	8.91	134.19	0.07	0.58	6.36
9/21/2023	East	1.8	1.8+	0.0	18.41	52.94	7.92	84.36	7.05
				1.0	18.68	52.81	5.22	55.46	6.86
				1.5	18.69	52.75	4.83	52.71	6.80





***In-Situ* Monitoring for Kofferls Pond 2023**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
4/26/2023	Dam	3.0	2.8*	0.0	14.34	372.66	9.79	97.43	8.18
				1.0	14.35	374.30	9.73	95.45	8.14
				2.0	14.11	381.58	10.00	99.66	8.27
				2.5	13.73	386.46	7.36	68.16	7.65
4/26/2023	Inlet	2.0	1.4*	0.0	14.27	352.28	14.50	143.87	9.47
				1.0	13.79	365.33	13.75	134.49	9.28
				1.5	13.50	368.99	11.43	108.76	8.87
6/22/2023	Dam	3	2	0.0	18.73	407	10.83	116.7	9.3
				1.0	18.79	412	11.04	118.5	9.27
				2.0	15.51	434	1.02	4.9	6.77
				2.5	14.21	531	0.30	2.8	6.80
6/22/2023	North	2.5	2.5+	0.0	18.68	425	11.30	121.1	9
				1.0	18.62	431	11.29	121.00	9
				2.0	17.4	487	4.28	40.3	7.7
9/21/2023	Dam	3.0	2.0	0.0	19.22	305.71	3.30	35.32	7.30
				1.0	18.44	300.70	1.79	17.70	7.15
				2.0	18.25	312.37	1.56	17.47	7.15
				2.5	17.84	328.21	1.79	19.17	6.94
9/21/2023	North	2.4	1.9*	0.0	19.11	313.76	6.12	66.76	7.35
				1.0	18.83	314.79	5.44	58.07	7.30
				2.0	18.40	311.95	4.62	48.69	7.22

*Secchi covered by plants