AN ASSESSMENT OF THE LAKES AND WATERSHEDS OF WEST MILFORD TOWNSHIP

TOWNSHIP OF WEST MILFORD, PASSAIC COUNTY, NEW JERSEY

JULY 2023; REVISED JANUARY 2024

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1.0 INTRODUCTION

The Highlands Water Protection and Planning Council (NJHC) is a regional planning agency that works in partnership with municipalities and counties in the Highlands Region to encourage a comprehensive regional approach to implementing the 2004 Highlands Water Protection and Planning Act (the Highlands Act). The Highlands Act established the Highlands Council and charged it with the creation and adoption of a regional master plan to protect and enhance the natural resources within the New Jersey Highlands. The Highlands Regional Master Plan (RMP) was adopted by the Highlands Council on July 17, 2008, and became effective on September 8, 2008.

The Township of West Milford in Passaic County is located entirely within the Preservation Area of the Highlands Region. Home to a population of 24,862 people (US Census, April 2020), the township consists mostly of mountainous forested land and wetlands, with urban areas dotted throughout, largely surrounding some of the various lakes located throughout the township.

In order to take an active role in the management of these natural resources within multiple watersheds, the Township of West Milford is the third municipality in the state of New Jersey to take a regional approach to private lake management through a public-private partnership (PPP) with lake associations. Although almost all of these lakes are private, the township wishes to take an active role in the management of the surrounding watersheds of these lakes, as the private lakes themselves are managed by their respective associations or entities. This regional approach to lake management has recently been informally suggested by staff of both the New Jersey Department of Environmental Protection (NJDEP) and the New Jersey Highlands Council (NJHC).

Given the large number of lakes in the Township, and in an effort to keep this study to a reasonable scope, a selection process occurred with input from the Township Engineering Office, the Township Lakes Committee, Princeton Hydro and the NJHC. Specifically, the NJHC Master Plan states within Policy 1L2: "to establish tiers of lake management appropriate to management strategies that help protect lake water quality and community value from the impacts of present and future development", and within Objective 1L2a: "Lake management programs shall use the following management tiers around all Highlands Region lakes of greater than 10 acres in size: a Shoreline Protection Tier, a Water Quality Management Tier, a Scenic Resources Tier and a Lake Watershed Tier." Given that both the Policy and Objective use the 10-acre size minimum size in the provision of standards for lake protection, it was determined that lakes greater than 10 acres in size would be selected for the study. Additionally, the Highlands Region Land Use Ordinance, which conforming municipalities pass, include this distinction for waterbodies greater than 10 acres, and the Highlands Region ERIs for each town report out on acres of lakes greater than 10 acres in size.

However, lakes greater than 10-acres in size which are permanently preserved, including state-owned lakes, were eliminated from the study, as were other heavily studied lakes, such as Greenwood Lake. Reservoirs owned by private water utilities and lakes present on federal facilities were also not included. Finally, lakes less than 10 acres that may possess a swimming beach WERE included due to the potential impacts of harmful algal blooms (HABs) on the contact recreational use of these lakes. As a result of these criteria, the following list of lakes were selected for this study:

- Algonquin Waters
- Bubbling Springs
- Carpi Lake
- Farm Crest Acres Pond
- Forest Hill Lake
- Gordon Lakes
- High Crest Lake
- Johns Lake
- Kitchell Lake
- Lindy's Lake

- Lake Lookover
- Lower Mount Glen Lake
- Upper Mount Glen Lake
- Mt. Laurel Lake
- Mountain Springs Lake
- Pinecliff Lake
- Post Brook Farms Lake
- Shady Lake
- Upper Greenwood Lake
- Van Nostrand Lake
- Wonder Lake

Most of the above lakes are owned by private lake associations or entities, with only Bubbling Springs being owned by the township. Despite the private status of many of these lakes, the Township has expressed interest in taking an active role in managing the associated waterbody of each lake in order to limit the amount of sediment and nutrients entering each lake. In recent years, several lakes in northern NJ suffered from long-lasting HABs, a phenomenon caused by an overpopulation of cyanobacteria ("blue-green algae") in a waterbody. In addition to impacting the aesthetic condition of a lake, cyanobacteria produce toxins that can cause a host of health issues in humans and animals that come in contact with the water. The Township has therefore expressed interest in implementing watershed management measures in order to reduce the impact of watershed nutrient loading, which can influence cyanobacteria growth. The balance of this report details the results of Princeton Hydro's mapping, modeling and monitoring efforts in each waterbody and its respective watershed, along with recommendations for management implementations that may serve to curb the effects of nutrient and sediment loading, both within the lakes and their respective watersheds.

2.0 HISTORICAL DATA REVIEW

2.1 ALGONQUIN WATERS

The NJDEP and the affiliated Bureau of Freshwater and Biological Monitoring (BFBM) conducted water quality monitoring at two stations in Algonquin Waters Lake in 2009 and 2014. Stations consisted of an Eastern station and a Western station, and sampling included *in-situ* measurements and discrete water sample parameters. The Eastern station consistently had Secchi depths at or just above the bottom of the lake, at an approximate depth of 2.7 m. Dissolved oxygen (DO) levels were consistently at sufficient levels within the water column during all sampling events. Total phosphorus (TP) and inorganic nitrogen (nitrate + nitrite) were also within normal ranges at this station. The Western station had Secchi depths that consistently exceed 3.0 m, and TP concentrations were always < 0.03 mg/L. DO profiles also showed well oxygenated conditions in the upper parts of the water column, with only one instance of anoxia at 3.0 m in August of 2009. Inorganic nitrogen levels were at a concentration of 0.09 mg/L in June of 2009 at the Western station.

2.2 BUBBLING SPRINGS POND

No historical data was located for Bubbling Springs Lake.

2.3 CARPI LAKE

Carpi Lake is located within one of the watersheds included in a NJDEP report titled *Total Maximum Daily Load for Phosphorus to Address Greenwood Lake in the Northeast Water Region* from 2004; however, no specific data from Carpi Lake was included.

2.4 FOREST HILL LAKE

The NJDEP and the affiliated BFBM monitored one Mid-Lake station at Forest Hill Lake in May, August and October of 2007, and in March and July of 2012. Total depth at this station reached 3.6 m, and Secchi depths varied between 1.2 m and 3.0 m, depending on the time of year. Anoxia (DO < 1.0 mg/L) occurred at 3.0 m during the summer months for both years of monitoring. TP concentrations were consistently low and never exceeded 0.03 mg/L. Inorganic nitrogen (nitrate + nitrite) peaked at a concentration of 0.09 mg/L. Additionally, the NJDEP BFBM monitored water quality at the outlet of Forest Hill Lake in October of 2007. DO concentrations were good at 7.59 mg/L and temperature was normal at 21.28 °C. Chlorophyll *a* concentrations were 19.06 µg/L, which suggests a moderately productive lake system. Secchi depths were not recorded. TP and inorganic nitrogen concentrations were low, with concentrations at 0.03 mg/L and 0.02 mg/L, respectively.

2.5 GORDON LAKE

No historical data was located for Gordon Lake.

2.6 HIGH CREST LAKE

The NJDEP and the affiliated BFBM monitored two stations at High Crest Lake in July of 2018, including a Northern station and a deeper Southern station. Secchi depths were 1.5 m at the Northern station and 1.6 m at the Southern station, compared to total depths of 2.9 m and 4.8 m, respectively. During the lone July event, DO concentrations were sufficiently elevated throughout the entire water column, ranging between 9.96 mg/L at 0.4 m to 9.26 mg/L at 2.4 m at the Northern station. DO at the Southern station had similar concentrations in the upper 2.0 m of the water column but became anoxic by 4.0 m. Chlorophyll *a* concentrations were between 24.06 µg/L and 27.91 µg/L which indicates a productive eutrophic lake system. TP and inorganic nitrogen (nitrate + nitrite) levels were within normal ranges at both stations.

2.7 JOHNS LAKE

No historical data was located for Johns Lake.

2.8 KITCHELL LAKE

No historical NJDEP was available for Kitchell Lake. A Total Maximum Daily Load (TMDL) report was put together by NJDEP in 2007 to address fecal coliform in the lake due to the prevalence of septic systems in the surrounding community. Princeton Hydro also collected aqueous samples at six stations within the lake in 2018 for the analysis of percent composition of organics. Percent organics ranged from 7.9% to 18.9% within the collected samples.

2.9 LINDY'S LAKE

The NJDEP and the affiliated BFBM conducted monitoring at Lindy's Lake in July of 2015 at two in-lake stations, including a North and South station. At the South sampling station, the water column was 6.5 m deep and had a Secchi of 1.6 m. Temperature ranged from 23.80 °C at the surface to 6.34 °C at 6.0 m, which indicates thermal stratification was present. As a result, DO concentrations declined rapidly in the water column; surface concentrations were 8.41 mg/L, and anoxic conditions were present at 3.0 m. Despite this, surface concentrations for TP and inorganic nitrogen (nitrate + nitrite) were elevated and each above their respective recommended threshold. TP was measured at 0.08 mg/L and inorganic nitrogen at 0.11 mg/L. The North station was shallower, with a total depth of 1.3 m. Secchi depth was to the bottom of the lake. TP and inorganic nitrogen were both elevated, consistent with the North station.

2.10 LAKE LOOKOVER

The NJDEP and the affiliated BFBM monitored the outlet of Lake Lookover during May and August of 2007. Temperatures during the two events were 18.73 °C in May and 22.82 °C in August. DO, pH and specific conductance values were within normal ranges. TP was also within recommended levels during the May event but was slightly elevated in August at 0.05 mg/L. Inorganic nitrogen (nitrate + nitrite) yielded a concentration of 0.13 mg/L in May, followed by a decrease to 0.03 mg/L by August.

Additionally, three stations were monitored in 2007 and 2012 within Bearfort Waters Lake, which discharges into Lake Lookover. Monitoring occurred at stations between 1.0 m and 1.8 m in depth, with Secchi depths between 0.8 m and 1.8+ m. During the 2007 monitoring events, data was only collected at 0.5 m due to total depth of water being approximately 1.0 m each time. For this reason, it is unknown if thermal stratification or oxygen depletion were preset within the lake at that time. The only profile that had data near the bottom was the November 2012 monitoring event; however, by that time of the year temperatures were even throughout the water column and DO was well mixed throughout. TP levels were consistently within an ideal range, never exceeding 0.02 mg/L. Inorganic nitrogen (nitrate + nitrite) ranged between 0.02 mg/L in October 2007 and 0.09 mg/L in July 2012.

2.11 MOUNT GLEN LAKES

Escherichia coli (*E. coli*) samples were analyzed on 3 September 2020 by Garden State Laboratories (NJDEP Lab Certification #20044). The *E. coli* density was 6.3 organisms / 100 mL which conforms to the State Public

Recreational Bathing Standards.

The NJDEP and the affiliated BFBM monitored Mount Glen Lake in May, August and November of 2011. All samples and *in-situ* data were collected at 0.5 m, with the total depth at the station varying between 0.9 m and 1.0 m. No Secchi depths were collected; however, chlorophyll *a* concentrations did not exceed 12.46 µg/L and turbidity concentrations did not exceed 3.33 NTU; these values are both low and suggest good water clarity. DO was low during the August monitoring event at 2.04 mg/L; this near hypoxic concentration may result in stress to biological organisms as well as lead to internal phosphorus loading. TP concentrations were elevated in May but progressively declined in each subsequent monitoring event, ranging between 0.02 mg/L in November to 0.05 mg/L in May. Likewise, inorganic nitrogen (nitrate + nitrite) concentrations were also elevated, particularly in May and November, at 0.33 mg/L and 0.45 mg/L, respectively.

2.12 MT. LAUREL LAKE

The NJDEP and the affiliated BFBM monitored two stations at Mt. Laurel Lake in July of 2018. At the Southern station, the total depth was 1.4 m, with the Secchi disk being visible to the bottom. DO declined from 8.29 mg/L at the surface to 3.82 mg/L at 0.9 m. TP and inorganic nitrogen (nitrate + nitrite) concentrations were both quite low and neither was above 0.02 mg/L. Similarly, the chlorophyll a concentration was low at 3.11 µg/L, indicating minimal planktonic and algal growth.

The Northern station was slightly deeper at 1.7 m, with a Secchi depth of 1.30 m. Surface DO was ample at 8.52 mg/L, but quickly declined to anoxic conditions by 1.0 m. This was likely the result of established thermal stratification, as temperatures fell from 27.13 at the surface to 24.07 at 1.2 m. TP and inorganic nitrogen were both within their recommended thresholds, consistent with the Southern station.

Additionally, Aquatic Analysts, Inc. conducted routine monitoring at Mt. Laurel from 2016 through the 2022 summer. The reports generally noted Secchi depths at or above 2.0 m, with some planktonic particulate accumulation during the peak of the growing season. Some turbidity in the water was also noted occasionally and influenced reduced Secchi depths. Treatments routinely took place to manage submerged aquatic vegetation (SAV) species and filamentous algae within the lake.

2.13 MOUNTAIN SPRINGS LAKE

No historical data was located for Mountain Springs Lake.

2.14 PINECLIFF LAKE

Pinecliff Lake was monitored monthly by the NJDEP and the affiliated BFBM from February to December in 2019, with the exception of August and November. Water clarity was not measured, but because turbidity concentrations did not exceed 8.72 NTU, it can be concluded that the water was not very turbid. DO during the NJDEP events ranged between 8.54 mg/L 13.61 mg/L. Some of the higher DO concentrations occurred during the winter months, which were likely the result of the increased capacity of cold water to hold more dissolved gas, including oxygen. Concentrations did decline during the warmer months but were still at healthy levels for aquatic organisms in the lake. It is important to note that samples were collected near the surface; thus, it is unclear if anoxia near the bottom was present. TP concentrations ranged between 0.01 mg/L and 0.14 mg/L

during the 2019 monitoring. TP levels were elevated and above the 0.05 mg/L recommended surface threshold during many of the summer months, which would have contributed to any nuisance plant growth or planktonic blooms. Inorganic nitrogen (nitrate + nitrite) was also elevated, with concentrations between 0.52 mg/L and 1.69 mg/L. The elevated nitrogen and phosphorus levels suggest nutrient loading within Pinecliff Lake.

Pinecliff Lake was also included in a United States Environmental Protection Agency (EPA) lead national eutrophication survey in 1976 to acquire more information regarding nutrient sources, concentrations and their impacts on various lakes within northern New Jersey. The study found that the potential for biological productivity within Pinecliff lake was high and that nitrogen was the limiting nutrient within the lake system.

2.15 POST BROOKS FARM LAKE

No historical data was located for Post Brook Farms Lake.

2.16 SHADY LAKE

No historical data was located for Shady Lake.

2.17 UPPER GREENWOOD LAKE

No NJDEP monitoring events were noted at Upper Greenwood Lake; however, Aquatic Analysts, Inc has conducted routine monitoring over the past several summers since at least 2016. Their observations noted Secchi depths between 1.7 m and 2.1 m, indicating good water clarity. The presence of a variety of different SAV species throughout many different regions of the lake was also noted, along with recommendations to treat areas where plant growth had become dense. Particular areas that were repeatedly recommended for treatments were Audubon Cove, Firehouse Cove, Behind Islands, Yardville Cove & Bridge Cove, with various other sites also being listed. The ample plant growth suggests good water clarity, as light can penetrate further into the water column.

2.18 VAN NOSTRAND LAKE

No historical data was located for Van Nostrand Lake.

2.19 WONDER LAKE

The NJDEP and the affiliated BFBM monitored Wonder Lake during May, August and October of 2009 and in June and October in 2014. Monitoring occurred at stations between 0.80 m and 1.3 m in depth, with Secchi depths between 0.8 m and 1.3+ m. All data and water samples were collected at mid-depth in the water column, between 0.4 m to 0.6 m. Due to the lack of deep *in-situ* data, there is uncertainty regarding the presence of thermal stratification or hypolimnetic anoxia. Despite this, there were periods of near hypoxia (DO < 2.0 mg/L), notably in June and October of 2014 where dissolved oxygen was 2.10 mg/L and 2.00 mg/L, respectively. TP levels were consistently within the ideal range, never exceeding 0.03 mg/L. Inorganic nitrogen (nitrate + nitrite) likewise was low, and never exceeded 0.04 mg/L.

Table 1: Acreages of waterbodies and their watersheds

Waterbody Name	Surface Area	Watershed Area	Total Area
	Acres		
Algonquin Waters	22.5	385.0	407.5
Bubbling Springs	2.0	57.2	59.1
Carpi Lake	12.7	177.6	190.3
Farm Crest Acres Pond	3.1	17.8	20.9
Forest Hill Lake	9.2	163.9	173.1
Gordon Lakes	13.8	667.3	681.1
High Crest Lake	39.3	312.4	351.7
Johns Lake	2.3	206.4	208.7
Kitchell Lake	22.7	512.2	534.9
Lindy's Lake	19.3	60.3	79.6
Lake Lookover	15.0	775.4	790.4
Lower Mount Glen Lake	14.8	599.4	614.2
Upper Mount Glen Lake	9.9	512.6	522.5
Mt. Laurel Lake	35.0	1269.2	1304.2
Mountain Spring Lake	2.0	45.2	47.2
Pinecliff Lake	143.6	3800.7	3944.3
Post Brook Farms Lake	7.7	65.5	73.2
Shady Lake	5.2	51.0	56.1
Upper Greenwood Lake	411.7	4229.1	4640.8
Van Nostrand Lake	10.5	46.2	56.7
Wonder Lake	13.7	133.8	147.5

3.0 HYDROLOGIC AND POLLUTANT LOADING ANALYSIS

3.0 METHODS

Watersheds and subwatersheds were delineated for each lake using USGS's Streamstats tool, the Stroud Research Center's Model My Watershed tool, and watershed tools on ERI's ArcMAP 10.8.1. Subwatersheds were edited in ESRI's ArcMAP and QGIS Desktop. Subwatersheds that were too small for proper analysis with GWLF-E were combined with neighboring subwatersheds. For the purposes of this study, watershed areas listed exclude the area of the main waterbody itself. Maps displaying watersheds and subwatersheds for each lake are provided in Appendix I. GIS shapefiles for each subwatershed and total watershed were imported into Model My Watershed, which produced a .gms file containing hydrologic and nutrient data for a 30-year period. This file was subsequently entered into Penn State's Generalized Watershed Loading Functions-Enhanced (GWLF-E) tool.

Edits to the .gms file were made in Model my Watershed prior to export and in GWLF-E. In order to assess septic system loading, all houses within each watershed were counted (excluding sewered locations), with the number of houses within 15 m of a lake or stream were also noted. Populations within 15m of the lake or any inflowing waterways, as well as 5% of the total population, were assumed to "short circuit" or contribute nutrients to waterways and/or groundwater prematurely; these systems usually contribute higher amounts of nutrients than systems with no issues.

Many of the lakes in West Milford are inhabited by a population of Canada goose (*Branta canadensis*) or other waterfowl. While these birds can be a nuisance to lake users for several reasons, their droppings can also negatively impact water quality by adding excess phosphorus and nitrogen. These loads were estimated using GWLF-E's farm animal module, as well as coefficients for each nutrient yielded by each goose each day (Manny et al., 1975). Bacterial loads contributed to Canada geese were modeled using the same estimated loading rate use in the GWLF-E model for turkeys. Each lake was estimated to contain at least two Canada geese and were modeled for larger numbers of birds if field observations indicated a larger population. A migratory population of an estimated three times the resident population. For each lake, an average was calculated of geese numbers, assuming a year-round number for 11 months and a migration population for 1 month. Goose-based nutrient modeling was only applied to full watersheds. It should be noted that the Canada goose population numbers in each scenario are estimates; this model may be fine-tuned in the future using Canada goose and other waterfowl count data collected in West Milford.

GWLF-E was run for a 30-year period following all necessary data edits. The model simulates loading and transport for each day based on actual weather records during the period of record. The data output includes monthly and annual averages.

Dryfall, or atmospheric nitrogen and phosphorus loads, were calculated by multiplying pre-established coefficients by the total area of the watershed and lake. Nitrogen was estimated to occur at a rate of 0.4 kg/ha/yr, while phosphorus was estimated to occur at a rate of 0.002 kg/ha/yr (USEPA, 1980). As with waterfowl loading, dryfall was only calculated for full watersheds.

In addition to watershed-based loading, internal loading of phosphorus in each lake was calculated using a loading coefficient of 6 mg TP/m²/day for loading of phosphorus into the water column from sediments under anoxic conditions, whereas minor loading under oxic conditions during the growing season (May-September, 153 days) is represented by a loading coefficient of 0.6 mg TP/m²/day. The number of days each waterbody was estimated to experience bottom anoxia, as well as the area of each waterbody at which anoxic conditions were estimated to occur, were determined based on dissolved oxygen and temperature data collected in the field during water quality sampling events and bathymetric data, when available. It should be noted that a majority of the lakes in this study did not have readily available bathymetric data; as such, the areas of anoxia in these lakes were estimated. Additionally, this analysis was not run for Carpi Lake, as in-field measurements and observations could not be collected.

3.1 RESULTS

ALGONQUIN WATERS

The full watershed of the waterbody known as Algonquin Waters covers an area of approximately 385 acres, while the waterbody itself is approximately 22.5 acres in surface area. The watershed largely consists of forested land and wetlands, with an area of urbanized land in the northern-most reaches of the watershed. This area also contains Post Brook Farms Lake and its watershed. The waterbody's outlet travels southwest before entering lower Gordon Lake. It should also be noted that, while Algonquin Water's watershed is not modeled to include the waterbody to the immediate north known as Indian Trail Lake, some hydrologic connection to this waterbody may exist. This waterbody largely flows northwards away from Algonquin Waters but may drain to Algonquin Waters during flood events. Descriptions of the waterbody's subwatersheds are as follows:

- **Algonquin Way:** This subwatershed is located in the southeastern portion of the watershed. It contains the development along Algonquin Way and Stanley St., as well as a small area of forested land to the west.
- **Inlet:** As its name suggests, this watershed contains the main inlet stream that feeds Algonquin Waters from the west, as well as the large expanse of forested land that surrounds it. The northern portion of this subwatershed contains an approximately 39-acre area of urbanized land surrounding Post Brook Farms Lake.
- **North:** This subwatershed spans the entire northern edge of the waterbody, containing mostly forested land, as well as a small amount of urbanized area. The subwatershed also contains Pleasant View Drive and small lengths of Lake Isle Drive and Ulster Street.
- **South:** This subwatershed spans approximately one-third of the length of the southern edge of the waterbody. The area consists entirely of forested land.
- **Southeast:** Only a small portion of this watershed abuts the southern edge of the waterbody, however it contains a larger expanse of forested land to the south. This subwatershed is almost entirely forested, with approximately 1.5 acres of wetland.
- **Southwest:** This subwatershed lies to the immediate south of the inlet subwatershed and consists entirely of forested land and wetlands.

Table 2. Land-use by subwatershed in the Algonquin Waters watershed

Source	Full Watershed	Algonquin Way	Inlet	North	South	Southeast	Southwest
	Area (acres)						
Open Water	4.9	0.0	4.9	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	18.3	0.0	0.0	0.0
Forest	290.3	4.0	181.6	1.2	14.3	23.2	47.2
Wetland	49.4	0.0	45.7	0.0	0.0	1.5	2.0
Open Land	1.2	0.0	1.2	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	9.6	0.2	9.1	0.0	0.0	0.0	0.0
Medium-Density Mixed	1.2	0.0	1.2	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
Low-Density Open Space	28.4	2.2	23.7	3.2	0.0	0.0	0.0
Total	385.0	6.4	267.4	22.7	14.3	24.7	49.2

Table 2 continued. Land-use by subwatershed in the Algonquin Waters watershed

Source	Full Watershed	Algonquin Way	Inlet	North	South	Southeast	Southwest
				Area (%)			
Open Water	1.3	0.0	1.8	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	80.6	0.0	0.0	0.0
Forest	75.4	62.5	67.9	5.3	100.0	93.9	95.9
Wetland	12.8	0.0	17.1	0.0	0.0	6.1	4.1
Open Land	0.3	0.0	0.4	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	2.5	3.1	3.4	0.0	0.0	0.0	0.0
Medium-Density Mixed	0.3	0.0	0.4	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
Low-Density Open Space	7.4	34.4	8.9	14.1	0.0	0.0	0.0
Total	100	100	100	100	100	100	100

According to the USDA's Gridded Soil Survey Geographic (gSSURGO) 2016 hydrologic soil groups data, the Algonquin Waters watershed consists largely of the soil type "C – slow infiltration", approximately 15.3% of the area featuring soil type "D – very slow infiltration". These soils allow for relatively low infiltration of rainwater into the water table, generating relatively high runoff during rain events and thus increased erosion. The Inlet subwatershed features the highest percentage (20.6%) of soil type D.

Variations in elevation change in a watershed can determine the impact water runoff has on soil erosion, with steeper slopes causing higher erosion rates, especially if little vegetation is present. While the percent slope in the full watershed averages approximately 8.5%, the maximum percent slope is approximately 36.4%, which occurs in the inlet subwatershed. The Algonquin Way subwatershed featured the highest average percent slope, at approximately 15%.

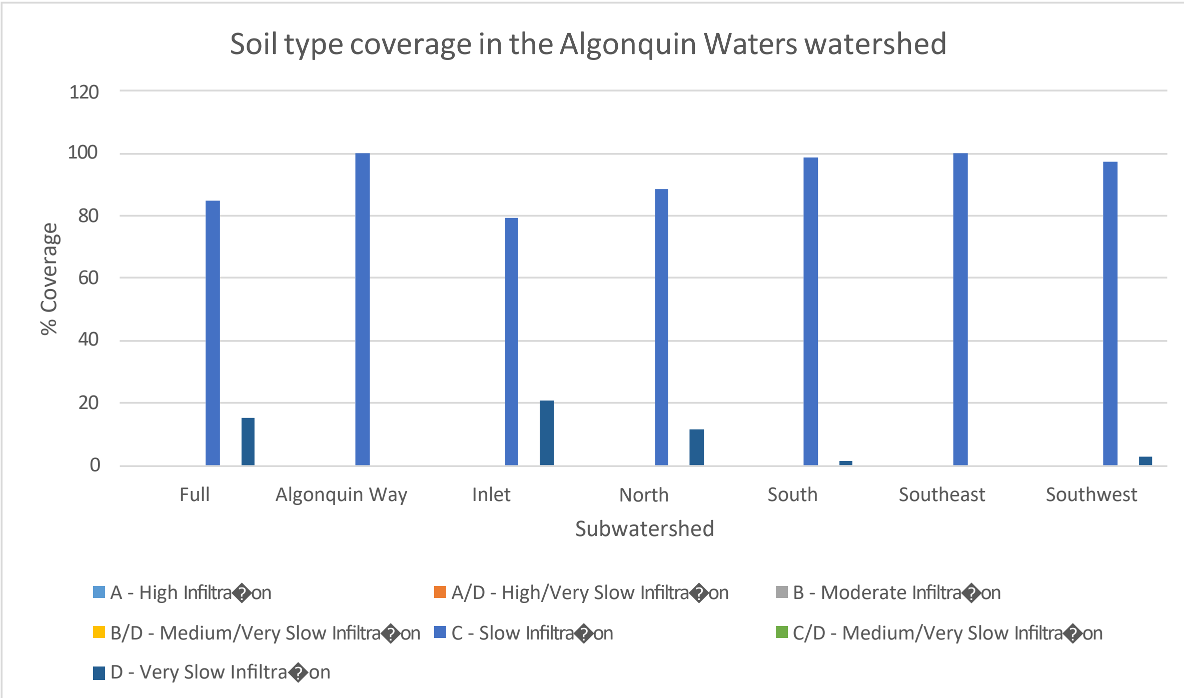


Figure 1. Percent coverage of Algonquin Waters watershed and subwatersheds by different hydrologic soil groups.

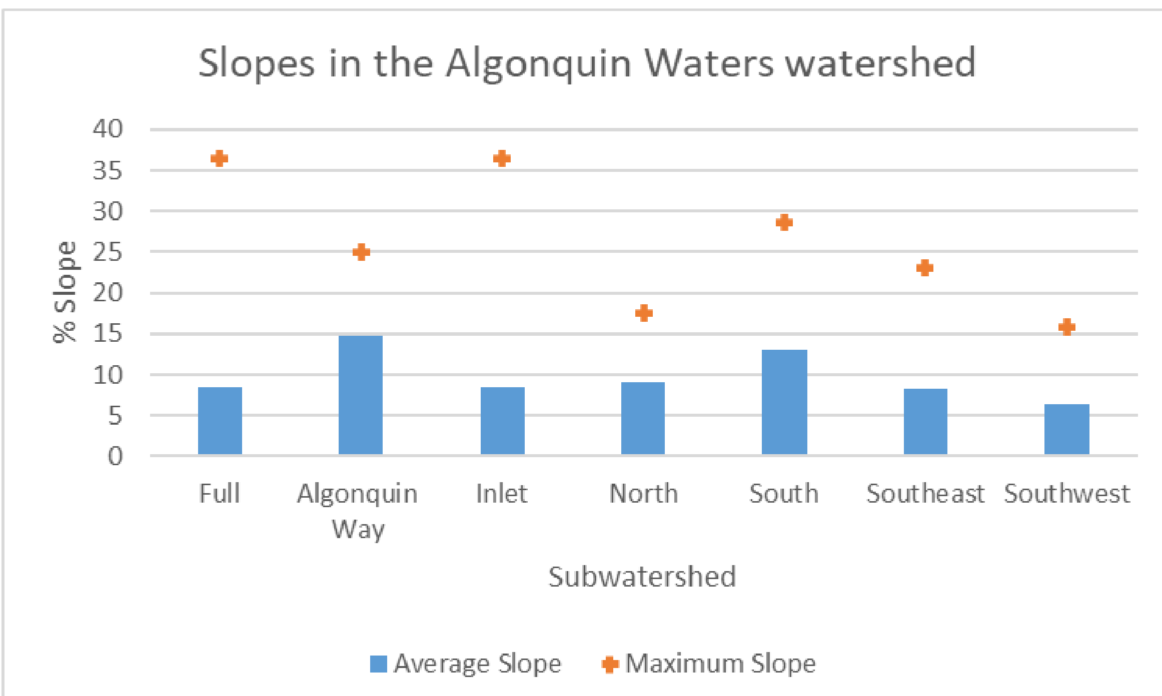


Figure 2. Variation in average and maximum percent slope between subwatersheds in the Algonquin Waters watershed.

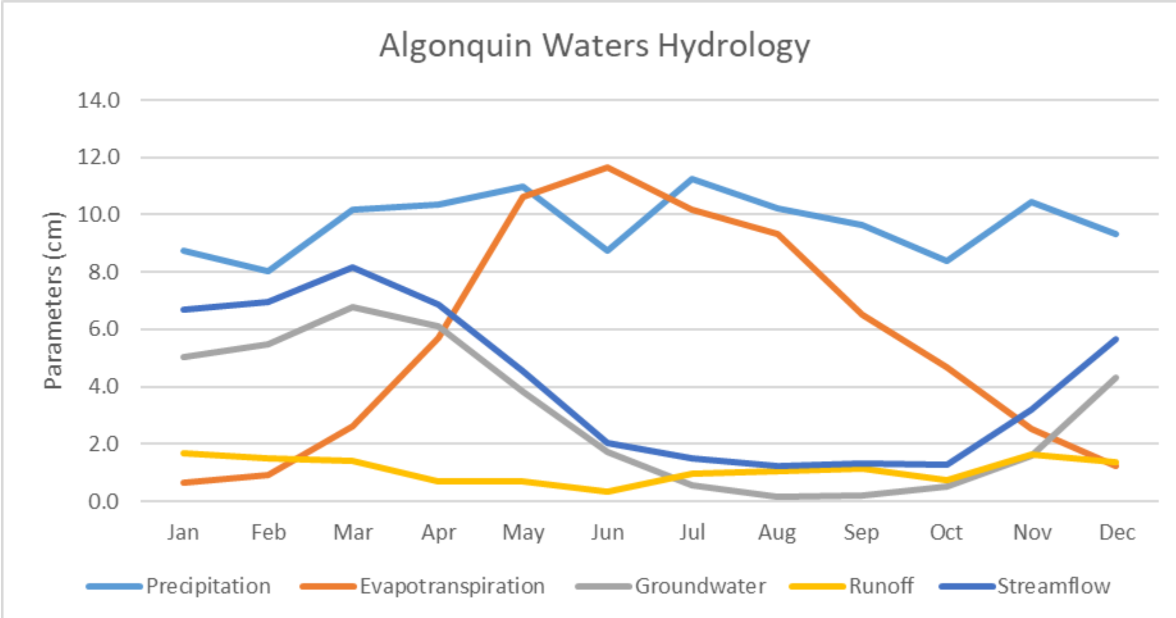


Figure 3. Estimated seasonal changes in hydrology in the Algonquin Waters Watershed

Table 3. Total hydrological parameters in the Algonquin Waters watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.1	1.7	6.7	1.4
Feb	8.0	0.9	5.5	1.5	7.0	1.6
Mar	10.2	2.6	6.8	1.4	8.2	1.7
Apr	10.4	5.7	6.1	0.7	6.9	1.5
May	11.0	10.6	3.8	0.7	4.5	0.9
Jun	8.8	11.7	1.7	0.3	2.1	0.4
Jul	11.2	10.2	0.6	1.0	1.5	0.3
Aug	10.2	9.3	0.2	1.1	1.2	0.3
Sep	9.7	6.5	0.2	1.1	1.3	0.3
Oct	8.4	4.7	0.5	0.8	1.3	0.3
Nov	10.4	2.5	1.6	1.6	3.2	0.7
Dec	9.3	1.2	4.3	1.4	5.7	1.2
Total	116.4	66.7	36.3	13.3	49.5	0.9

Runoff varied relatively little between the different subwatersheds, with the exception of the inlet watershed. This subwatershed consistently featured the highest runoff throughout the year, likely due to its relatively high acreage of impervious landcover and very slow-infiltration soil.

As displayed in Table 3, most hydrologic data is presented in the one-dimensional unit of centimeters, in order to relate these metrics back to precipitation, the base of a watershed's hydrology. This allows for a simpler comparison between watersheds. The total amount of water in m³ each of these values represents can be calculated by multiplying the value by 0.01 (in order to convert the unit to m²) and multiplying this product by the total watershed area in m². As displayed above, streamflow is also reported as cubic feet per second (cfs), a common measurement of waterflow. The streamflow component is the sum of the groundwater and runoff components, which themselves are influenced by modeled evapotranspiration, precipitation, groundwater intrusion, and other factors.

When direct precipitation and evapotranspiration to and from the waterbody itself are factored in, Algonquin Waters is estimated to receive approximately 817,653 m³ or 216 million gallons of water a year.

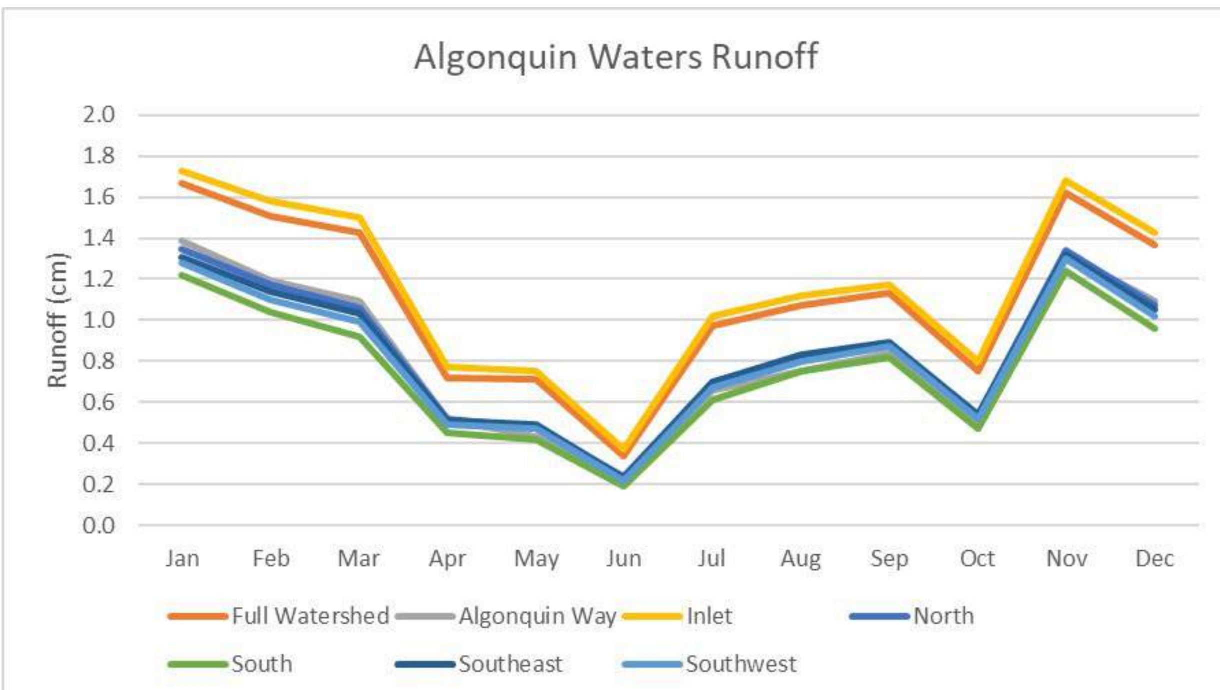


Figure 4. Average monthly runoff occurring by subwatershed in the Algonquin Waters watershed

No bathymetry data was found to exist for Algonquin Waters; as such, the lake's volume is an estimate based on depths of the sample sites. The lake is estimated to contain approximately 229,030 m³ or 60.5 million gallons of water. By using the above estimated annual hydraulic load, the flushing rate and retention period can be estimated. These parameters are important at determining, among other things, how long nutrients and algae populations will remain in the lake after entering from the watershed.

Based on its modeled hydraulic load and lake volume, Algonquin Waters is estimated to flush approximately 3.6 times a year. Accordingly, the hydraulic retention time, or how long water takes to move through the lake, is estimated to be approximately 102.3 days.

Due to variations in monthly precipitation, the annual flushing rate and retention times can be further broken down into monthly annualized estimates. Figure 5 displays this variation over the course of a hypothetical year. It can be observed that the annualized flushing rate typically decreases during the summer months, allowing water, nutrients, and algae to remain within the lake for even longer. While this pattern is typical, it helps to explain increases in trophic productivity during the growing season and is also useful in understanding how a large rainstorm may affect smaller lakes during the summer months.

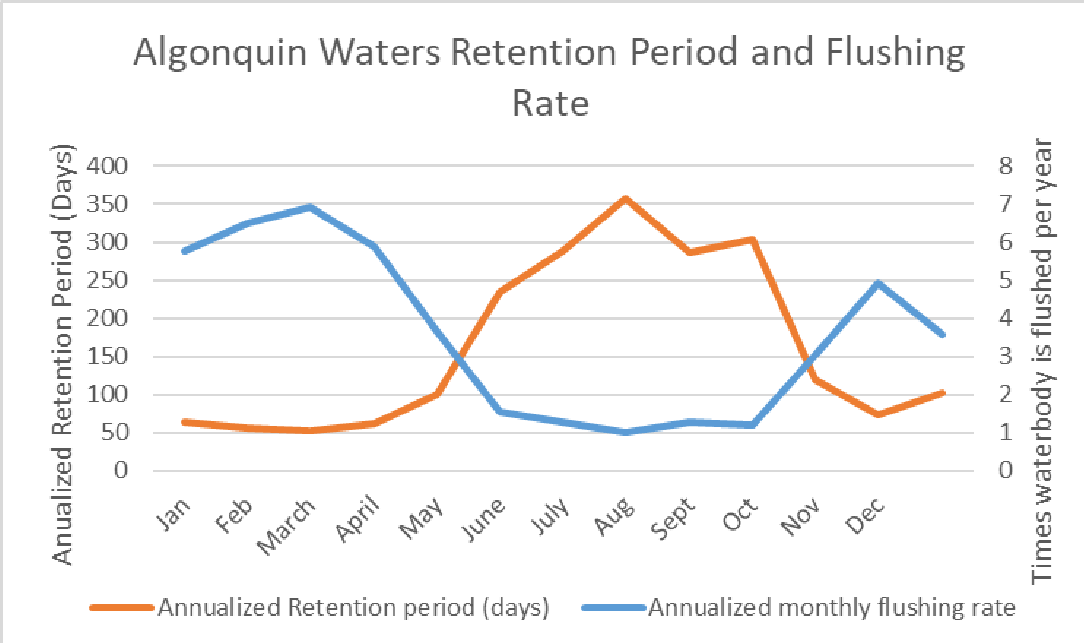


Figure 5. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Algonquin Waters, based on variations in hydraulic loads.

Table 4: Estimated annual loads of nitrogen in the total Algonquin Waters watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	25.6	3.91
	Wetland	9.2	1.40
	Open Land	0.7	0.11
	Barren Land	0.0	0.00
	Low-Density Mixed	1.2	0.19
	Medium-Density Mixed	0.3	0.05
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	3.6	0.55
Other Sources	Farm Animals and Waterfowl	0.2	0.03
	Stream Bank	0.0	0.00
	Groundwater	188.7	28.80
	Dryfall	66.3	10.12
	Septic Systems	359.4	54.85
	Total	655.2	100

Table 5: Estimated annual loads of nitrogen by subwatershed in the Algonquin Waters watershed

Category	Description	Full Watershed kg	Algonquin Way kg	Inlet kg	North kg	South kg	Southeast kg	Southwest kg
Runoff	Hay/Pasture	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
	Forest	25.6	0.3	0.0	1.3	1.0	1.7	3.4
	Wetland	9.2	0.0	15.9	0.2	0.0	0.3	0.4
	Open Land	0.7	0.0	8.4	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.7	0.0	0.0	0.0	0.0
	Low-Density Mixed	1.2	0.03	1.2	0.0	0.0	0.0	0.0
	Medium-Density Mixed	0.3	0.0	0.3	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
	Low-Density Open Space	3.6	0.3	3.0	0.4	0.0	0.0	0.0
Other Sources	Farm Animals and Waterfowl	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	188.7	3.8	124.5	12.4	8.4	13.4	27.0
	Dryfall	66.3	.	.	.	.	.	.
	Septic Systems	359.4	242.1	312.2	12.7	0.0	0.0	0.0
	Total (kg)	655.2	246.4	466.2	27.0	9.5	15.4	30.7
	kg/acre	1.7	38.5	1.7	1.2	0.7	0.6	0.6

The annual estimated nitrogen load for Algonquin waters is estimated to occur largely from septic systems in the watershed. In particular, the Inlet subwatershed contributed to a majority of this load. Groundwater-based nitrogen loading was the second-highest contributor to the over nitrogen load, with this source dominating the nitrogen loads in areas where no septic systems were present, such as the Southwestern subwatershed. It should be noted that groundwater typically contains naturally higher concentrations of nitrogen than most surface waters, due to the high solubility of nitrogen in water. Septic leachate also usually enters into the groundwater when present, further influencing this, as can be observed in the results from the watersheds with more houses. Atmospheric nitrogen deposition (dryfall) also contributed significantly to the overall nitrogen load, due to the relatively large, combined area of the waterbody and watershed. Runoff from forested areas contributed a significant amount of nitrogen to the overall estimated annual load, however this is likely a product of the largely forested nature of this watershed; per unit area, forests have low nitrogen loading rates. When examined on a per-acre basis, the Algonquin Way subwatershed yielded the highest estimated annual nitrogen load, as this subwatershed contains a high density of septic systems in a relatively small area. The full watershed is estimated to yield approximately 1.7 kg/acre of nitrogen.

Influences from septic systems and groundwater are estimated to contribute to almost 80% of the estimated annual phosphorus load in the Algonquin Waters watershed. Forested areas yielded the highest runoff-based phosphorus load; however this was due to this being the dominant land-use type in the watershed. As with nitrogen, the Algonquin Way subwatershed yielded both the highest estimated load of phosphorus per acre and the highest overall estimated annual load. The total rate of yearly phosphorus loading for the watershed as a whole is approximately 0.13 kg/acre.

Table 6: Estimated annual loads of phosphorus from various sources in the Algonquin Waters watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	1.51	3.0
	Wetland	0.50	1.0
	Open Land	0.03	0.1
	Barren Land	0.00	0.0
	Low-Density Mixed	0.13	0.3
	Medium-Density Mixed	0.03	0.1
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.37	0.7
Other Sources	Farm Animals and Waterfowl	0.08	0.2
	Stream Bank	0.00	0.0
	Groundwater	7.36	14.8
	Dryfall	0.33	0.7
	Septic Systems	39.30	79.2
	Total	49.64	100.0

Table 7: Estimated annual loads of phosphorus by subwatershed in the Algonquin Waters watershed

Category	Description	Full Watershed	Algonquin Way	Inlet	North	South	Southeast	Southwest
		kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	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
	Forest	1.51	0.02	0.86	0.10	0.11	0.14	0.28
	Wetland	0.50	0.00	0.42	0.01	0.00	0.02	0.02
	Open Land	0.03	0.00	0.03	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.13	0.00	0.11	0.00	0.00	0.00	0.00
	Medium-Density Mixed	0.03	0.00	0.03	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
	Low-Density Open Space	0.37	0.03	0.29	0.05	0.00	0.00	0.00
Other Sources	Farm Animals and Waterfowl	0.08	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
	Groundwater	7.36	0.10	4.55	0.36	0.22	0.35	0.71
	Dryfall	0.33	.	.	.	.	.	.
	Septic Systems	39.30	121.78	24.60	2.52	0.00	0.00	0.00
	Total (kg)	49.64	121.93	30.89	3.04	0.33	0.51	1.01
	kg/acre	0.13	19.05	0.12	0.13	0.02	0.02	0.02

While tables 6 and 7 describe external (watershed-based) loading of phosphorus into a lake, a waterbody can also receive internal phosphorus loading. One of the major sources for this in many deeper northeastern lakes is the release of phosphorus from sediment under anoxic conditions. For most of the year when water above the bottom sediments of a lake contains dissolved oxygen, phosphorus is bound to metals in sediment in a form that that does not easily dissolve into water. However, during periods of anoxia in the warmer summer months, the lack of dissolved oxygen in the water results in a redox reaction causing phosphorus to become soluble in water. On a large scale, this can result in measurably higher concentrations in the deeper waters of a lake than those obtained at the surface. When mixed towards the top of the water column, this increased phosphorus load can trigger blooms of algae and cyanobacteria. This internal load can be modeled using water quality data obtained in the field, which provides an approximate depth at which anoxia occurs and concentrations of phosphorus at the surface and at depth. A deep phosphorus concentration that is notably higher than those obtained from the surface paired with the presence of anoxia at the bottom of the water column can suggest that increased internal phosphorus loading may be occurring.

During the course of the 2022 sampling season, Algonquin Waters was observed to feature anoxia (dissolved oxygen <1.0 mg/L) at 3 meters and deeper during the summer event. These conditions were accompanied by a slightly higher concentration of phosphorus near the lake bottom when compared to that collected at the surface. While the lack of dissolved oxygen detected at the bottom of the water column suggests that conditions for internal loading may had been present, the lack of a severe disparity between the surface and deep phosphorus concentrations suggests that, if internal loading was occurring, it was not likely to be severe.

Based on these field results, modeling of the internal loading of phosphorus in Algonquin Waters was conducted using an estimation of increased internal loading occurring in the water body approximately one (1) month during the year. The area of the lake at which this occurs was estimated to be equivalent to 20% of the lake's surface area, or approximately 18,210 m². Using the loading rate estimate of 6 mg of phosphorus/m²/day for anoxic areas and an estimate of 0.6 mg of phosphorus/m²/day for areas with oxygen over the course of a 153-day growing season, internal loading was calculated to result in approximately 11.4 kg of phosphorus per year being added to the water column. If a year without any bottom anoxia were to occur, Algonquin Waters would receive an oxic loading-based internal load of approximately 8.4 kg/year. Table 8 below compares Algonquin Waters' yearly estimated phosphorus loads from external and internal sources, totaling approximately 61.1 kg/year.

Table 8: Total estimated annual phosphorus loads for Algonquin Waters from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	49.6
Internal	11.4
Total	**61.1**

Over 67% of the estimated annual load of sediment is modeled to originate from streambank erosion. Runoff from forested and urbanized areas are also estimated to contribute notable annual loads. As mentioned above, the soils in Algonquin Waters' watershed only allow for slow infiltration of water, causing runoff to occur at a relatively high rate, carrying higher amounts of sediment and other material. While the inlet subwatershed yielded a higher estimated sediment load (1.018 kg/yr) than the other subwatersheds did, the southwest subwatershed yielded the highest load of sediment on a per-acre basis, at 20.5 kg/acre each year. The overall watershed was estimated to yield approximately 1,337 kg of sediment, or approximately 3.5 kg/acre.

Table 9: Estimated annual loads of sediment from various sources in the total Algonquin Waters watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.180	13.5
	Wetland	0.030	2.2
	Open Land	0.010	0.7
	Barren Land	0.000	0.0
	Low-Density Mixed	0.050	3.7
	Medium-Density Mixed	0.020	1.5
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.140	10.5
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.907	67.8
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	1.337	100.0

Table 10: Estimated annual loads of sediment by subwatershed in the Algonquin Waters watershed

Category	Description	Full Watershed kg x 1000	Algonquin Way kg x 1000	Inlet kg x 1000	North kg x 1000	South kg x 1000	Southeast kg x 1000	Southwest kg x 1000
Runoff	Hay/Pasture	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
	Forest	0.180	0.010	0.090	0.030	0.050	0.050	0.280
	Wetland	0.030	0.000	0.020	0.000	0.000	0.000	0.020
	Open Land	0.010	0.000	0.010	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.050	0.000	0.040	0.000	0.000	0.000	0.000
	Medium-Density Mixed	0.020	0.000	0.020	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
	Low-Density Open Space	0.140	0.010	0.100	0.020	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
	Stream Bank	0.907	0.000	0.738	0.002	0.000	0.001	0.000
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.710
	Septic Systems	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	1.337	0.020	1.018	0.052	0.050	0.051	1.010
	kg/acre	3.5	3.1	3.8	2.3	3.5	2.1	20.5

Due to the largely forested nature of Algonquin Waters' watershed, a majority of bacteria originates from wildlife, while approximately 8.5% is generated from urban area runoff and a fraction of a percent is estimated to be contributed by waterfowl (Tables 11 and 12). The Inlet subwatershed was estimated to yield the highest estimated annual load of bacteria, likely as a product of its large area and relatively high area of urbanized landcover.

Table 11: Estimated annual loads of bacteria from various sources in the total Algonquin Waters watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.08E+08	0.1
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	9.69E+09	8.5
	Other Wildlife	1.04E+11	91.4
	Total	1.14E+11	100

Table 12: Estimated annual loads of bacteria by subwatershed in the Algonquin Waters watershed

Category	Description	Full Watershed %	Algonquin Way %	Inlet %	North %	South %	Southeast %	Southwest %
Fecal Coliform	Farm Animals and Waterfowl	0.1	0	0	0	0	0	0
	WWTP	0.0	0	0	0	0	0	0
	Septic Systems	0.0	0	0	0	0	0	0
	Urban Areas	8.5	60.1	14.3	12.6	0	0	0
	Other Wildlife	91.4	39.9	85.7	87.4	100	100	100
	Total (organisms)	1.14E+11	3.53E+09	7.56E+10	7.46E+09	5.11E+09	8.28E+09	1.68E+10

BUBBLING SPRINGS POND

Bubbling Springs Pond is the only waterbody in the study entirely on township-owned land. The Bubbling Springs system features an upper swimming lake that is fed by spring and raised and lowered for maintenance, while the lower pond is a year-round 2-acre waterbody that is used mainly for recreational fishing. This Watershed Management Plan focuses on the lower pond, however results for the two southern subwatersheds may largely apply also to the swimming lake, and some in-watershed recommendations may provide benefit to both waterbodies. The Bubbling Springs watershed covers an area of approximately 57 acres, which is largely forested and features peripheral urbanized land. The Bubbling Springs Park features open sports field areas and a paved parking lot. The pond's subwatersheds are as follows:

- **Northeast:** This 16-acre subwatershed is largely forested, with a smaller amount of low- and medium-density mixed residential areas and low-density open space also present. These residential areas are likely in part contributed to by the park's parking lot located in the southern portion of the subwatershed.
- **Northwest:** This 8.8-acre subwatershed contains approximately 3.2 acres of forested land, 3.2 acres of hay/pastureland-use, and approximately 2.2 acres of urbanized land area.
- **Southeast:** This 13.3-acre subwatershed contains half of the Bubbling Springs Swimming Lake, as well as approximately 11.4 acres of forested land and a small amount of urbanized land cover.
- **Southwest:** This 8.4-acre subwatershed contains half of the swimming lake and is largely dominated by forested and urbanized land.

Table 13. Land-use by subwatershed in the Bubbling Springs watershed.

Source	Full Watershed	Northeast	Northwest	Southeast	Southwest
			Area (acres)		
Open Water	1.5	0.0	0.0	0.7	0.7
Hay/Pasture	7.4	0.0	3.2	0.0	1.8
Cropland	0.0	0.0	0.0	0.0	0.0
Forest	35.8	13.6	3.2	11.4	2.9
Wetland	1.2	1.2	0.2	0.0	0.0
Open Land	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	3.5	0.5	0.0	0.2	1.1
Medium-Density Mixed	1.7	0.2	0.5	0.0	0.5
High-Density Mixed	1.7	0.0	0.0	0.5	0.6
Low-Density Open Space	4.4	0.5	1.7	0.5	0.8
Total	57.2	16.0	8.8	13.3	8.4

Table 13 continued. Land-use by subwatershed in the Bubbling Springs watershed.

Source	Full Watershed	Northeast	Northwest	Southeast	Southwest
			Area (%)		
Open Water	2.5	0.0	0.0	5.5	8.7
Hay/Pasture	12.9	0.0	36.4	0.0	21.4
Cropland	0.0	0.0	0.0	0.0	0.0
Forest	62.6	85.0	36.4	85.5	34.4
Wetland	2.1	7.5	2.3	0.0	0.0
Open Land	0.0	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	6.1	3.1	0.0	1.5	13.0
Medium-Density Mixed	3.0	1.3	5.7	0.0	5.9
High-Density Mixed	3.0	0.0	0.0	3.8	7.1
Low-Density Open Space	7.7	3.1	19.3	3.8	9.5
Total	100	100	100	100	100

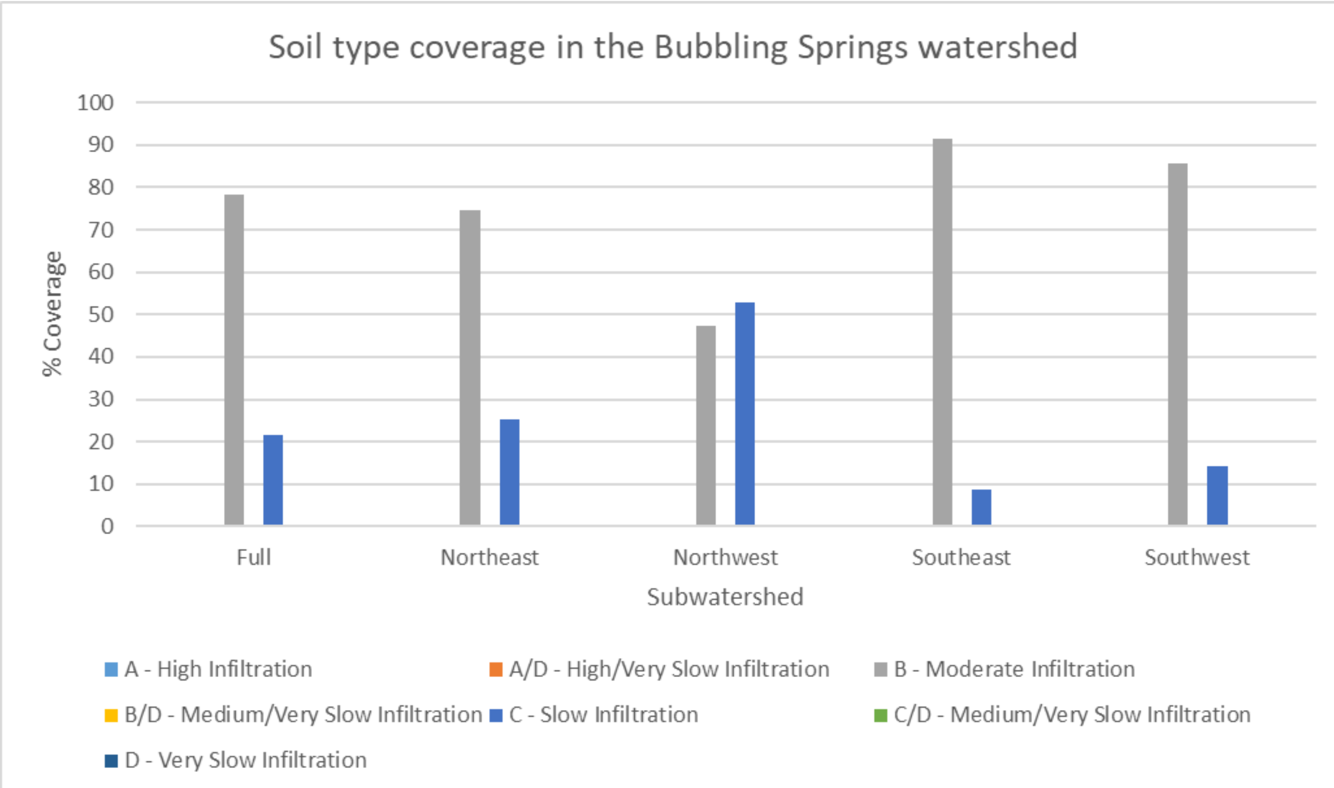


Figure 6. Percent coverage of Bubbling Springs Pond's Watershed and subwatersheds by different hydrologic soil groups

Bubbling Springs Pond's watershed was modeled to largely contain soil group "B – Moderate Infiltration", with approximately 20% of the area containing soil group "C – Slow Infiltration". The Northwest subwatershed contained more than 50% coverage of soil group C. Areas with higher percentages of slower-infiltrating soil groups will generate greater amounts of runoff and erosion.

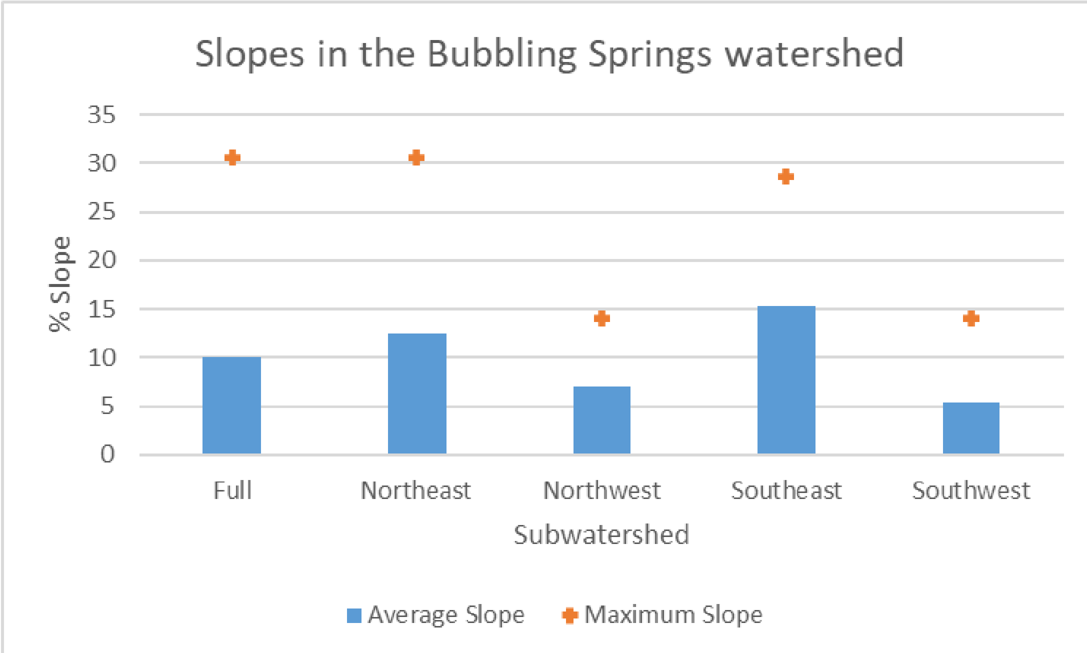


Figure 7. Variation in average and maximum percent slope between subwatersheds in the Bubbling Springs Pond Watershed.

Slopes in the full Bubbling Springs watershed averaged approximately 10%, with a maximum slope of approximately 30%, which occurred in the Northeast subwatershed. The Southeast subwatershed featured the highest average slope at approximately 15%.

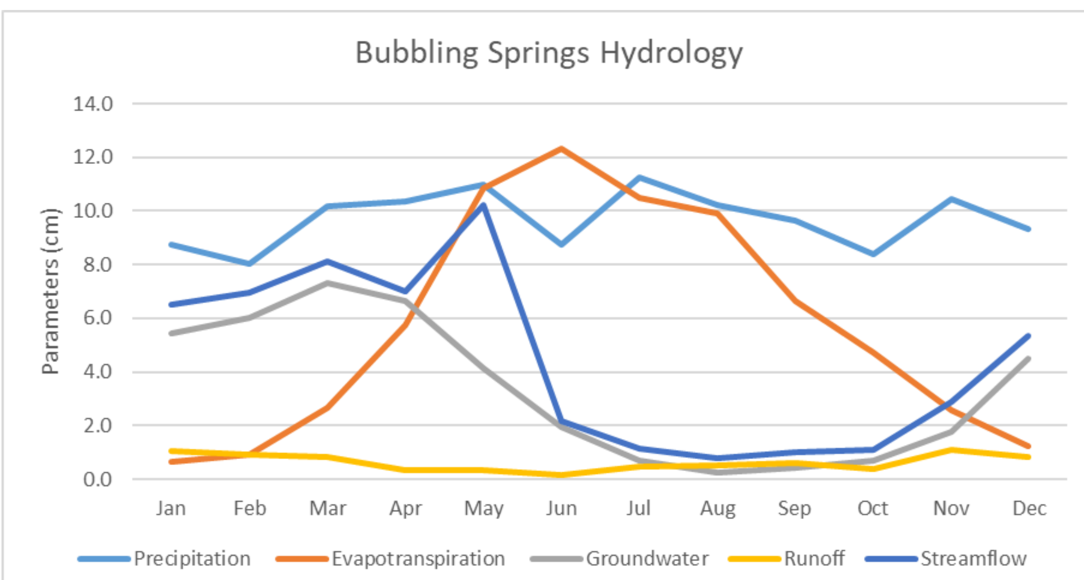


Figure 8. Estimated seasonal changes in hydrology in the Bubbling Springs watershed

Table 14: Total hydrological parameters in the full Bubbling Springs watershed over the course of a simulated year

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.4	1.1	6.5	0.2
Feb	8.0	0.9	6.0	0.9	6.9	0.2
Mar	10.2	2.7	7.3	0.8	8.1	0.2
Apr	10.4	5.8	6.7	0.4	7.0	0.2
May	11.0	10.9	4.1	0.3	10.2	0.3
Jun	8.8	12.3	2.0	0.2	2.2	0.1
Jul	11.2	10.5	0.7	0.5	1.2	0.0
Aug	10.2	9.9	0.2	0.5	0.8	0.0
Sep	9.7	6.7	0.4	0.6	1.0	0.0
Oct	8.4	4.7	0.7	0.4	1.1	0.0
Nov	10.4	2.6	1.8	1.1	2.9	0.1
Dec	9.3	1.2	4.5	0.8	5.3	0.2
Total	116.4	68.8	39.8	7.6	53.2	0.1

Runoff was modeled to be the highest in the Northwest and Southwest subwatersheds, likely due to their higher urbanized land cover and land classified as hay/pasture. In the Northwest subwatershed, larger amounts of lower-infiltration soil groups may have also contributed. After factoring in direct precipitation and evaporation to the lake itself, the lower Bubbling Springs Pond is estimated to receive approximately 113,474.3 m^3 or 30 million gallons of water a year. It should be noted that the inlet stream entering Bubbling Springs Pond at times likely displays different flows than modeled, as this stream is used to fill the swimming lake during summer months.

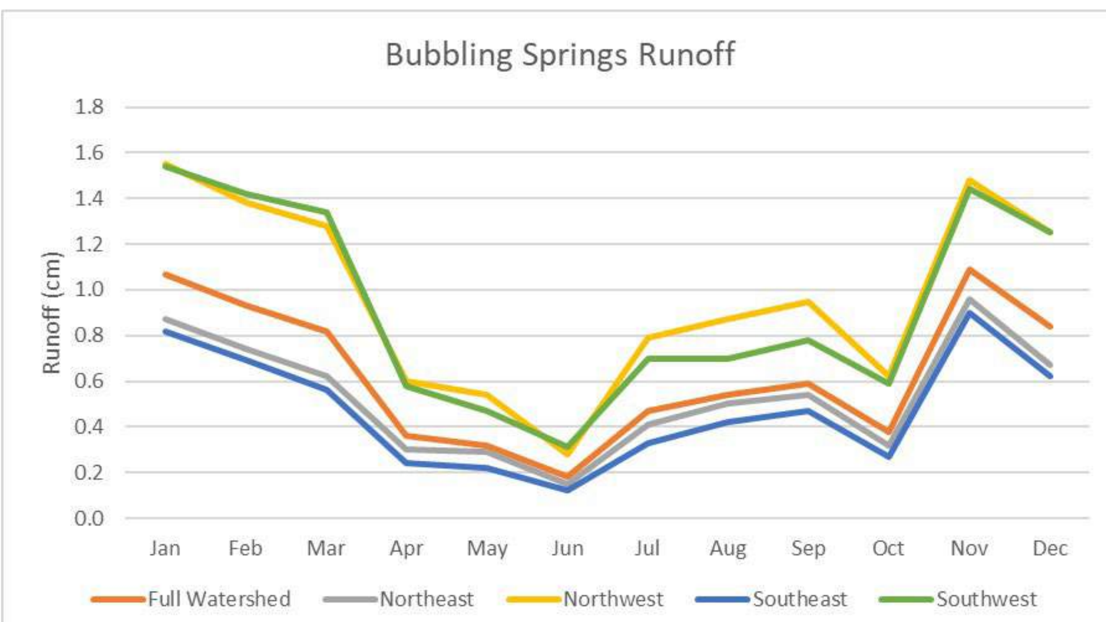


Figure 9. Average monthly runoff within subwatersheds of the Bubbling Springs watershed

No bathymetry data was found to exist for Bubbling Springs; as such, the pond's volume is an estimate based on depths of water quality sampling sites. The lower pond is estimated to contain approximately 10,325.4 m³ or 2.7 million gallons of water. As the pond's volume is much smaller than its estimated hydraulic load, the pond flushes relatively quickly, approximately 11 times a year. The pond's retention period is estimated to be approximately 33 days. The annualized monthly flushing rate for Bubbling Springs Pond follows a similar pattern to that of Algonquin Waters, reaching its lowest flushing rate in August.

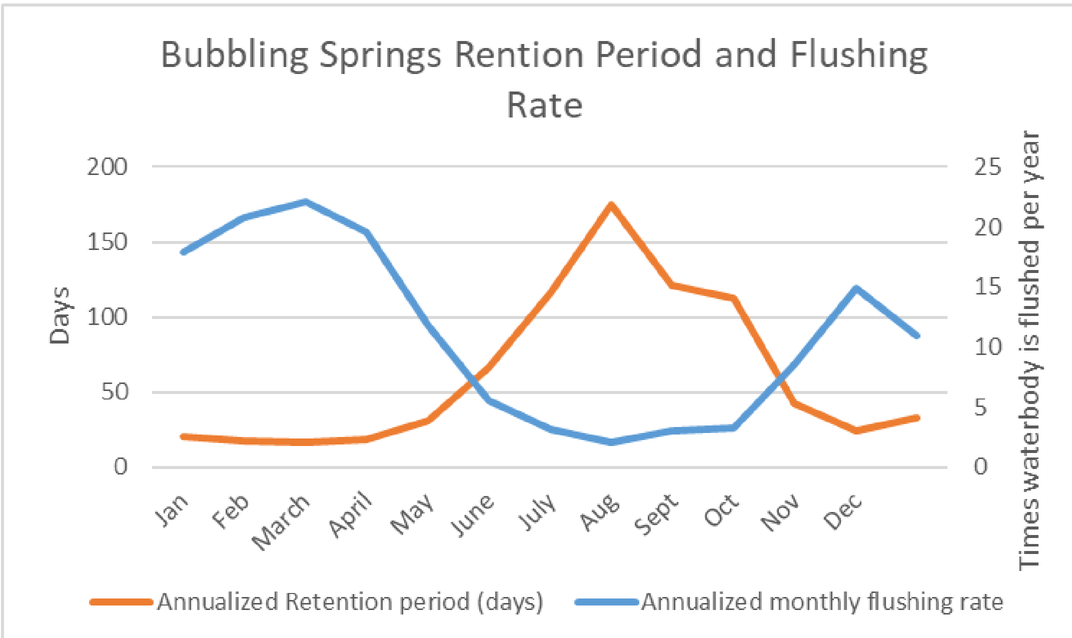


Figure 10. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Bubbling Springs, based on variations in hydraulic loads.

Table 15. Estimated annual loads of nitrogen in the total Bubbling Springs watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	1.9	2.70
	Cropland	0.0	0.00
	Forest	1.2	1.74
	Wetland	0.2	0.33
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	0.6	0.79
	Medium-Density Mixed	0.8	1.13
	High-Density Mixed	0.8	1.13
	Low-Density Open Space	0.7	1.02
Other Sources	Farm Animals and Waterfowl	0.3	0.38
	Stream Bank	0.0	0.00
	Groundwater	29.7	42.13
	Dryfall	9.6	13.58
	Septic Systems	24.7	35.06
	Total	70.5	100

Table 16. Estimated annual loads of nitrogen by subwatershed in the Bubbling Springs watershed

Category	Description	Full Watershed	Northeast	Northwest	Southeast	Southwest	
		kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	1.9	0.00	1.61	0.00	1.06	
	Cropland	0.0	0.00	0.00	0.00	0.00	
	Forest	1.2	0.50	0.24	0.39	0.22	
	Wetland	0.2	0.24	0.05	0.00	0.00	
	Open Land	0.0	0.00	0.00	0.00	0.00	
	Barren Land	0.0	0.00	0.00	0.00	0.00	
	Low-Density Mixed	0.6	0.11	0.00	0.05	0.43	
	Medium-Density Mixed	0.8	0.14	0.28	0.00	0.44	
	High-Density Mixed	0.8	0.00	0.00	0.37	0.53	
	Low-Density Open Space	0.7	0.05	0.12	0.05	0.31	
Other Sources	Farm Animals and Waterfowl	0.3	0.00	0.00	0.00	0.00	
	Stream Bank	0.0	0.00	0.00	0.00	0.00	
	Groundwater	29.7	9.32	3.99	7.36	8.81	
	Dryfall	9.6	.	.	.	.	
	Septic Systems	24.7	17.52	6.37	3.01	12.05	
	Total (kg)	70.5	27.88	12.66	11.23	23.85	0.00
	kg/acre	1.2	1.7	1.4	0.8	2.8	

A majority of Bubbling Spring's nitrogen load originates from septic systems and groundwater (Tables 15, 16). Hay/Pasture and forested land-use types were estimated to yield the largest runoff-based nitrogen loads. The Northeast subwatershed is estimated to yield the overall largest estimated annual load of nitrogen, largely due to the higher number of septic systems in the subwatershed. On a per-acre basis, the Southwest subwatershed isestimated to yield the most nitrogen per acre, with septic systems and groundwater yielding most of this and runoff from urbanized land-use areas yielding overall higher loads of nitrogen than the urbanized areas of the other subwatersheds.

Table 17: Estimated annual loads of phosphorus in the total Bubbling Springs watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.69	13.31
	Cropland	0.00	0.00
	Forest	0.14	2.70
	Wetland	0.01	0.19
	Open Land	0.00	0.00
	Barren Land	0.00	0.00
	Low-Density Mixed	0.05	0.96
	Medium-Density Mixed	0.07	1.35
	High-Density Mixed	0.07	1.35
	Low-Density Open Space	0.06	1.16
Other Sources	Farm Animals and Waterfowl	0.09	1.74
	Stream Bank	0.00	0.00
	Groundwater	0.70	13.51
	Dryfall	0.05	0.92
	Septic Systems	3.25	62.80
	Total	5.18	100.0

Table 18: Estimated annual loads of phosphorus by subwatershed for the Bubbling Springs watershed

Category	Description	Full Watershed kg	Northeast kg	Northwest kg	Southeast kg	Southwest kg
Runoff	Hay/Pasture	0.69	0.00	0.72	0.00	0.30
	Cropland	0.00	0.00	0.00	0.00	0.00
	Forest	0.14	0.08	0.02	0.04	0.01
	Wetland	0.01	0.02	0.00	0.00	0.00
	Open Land	0.00	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.05	0.01	0.00	0.00	0.03
	Medium-Density Mixed	0.07	0.01	0.03	0.00	0.03
	High-Density Mixed	0.07	0.00	0.00	0.02	0.03
	Low-Density Open Space	0.06	0.01	0.01	0.00	0.02
Other Sources	Farm Animals and Waterfowl	0.09	0.00	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00	0.00
	Groundwater	0.70	0.27	0.12	0.14	0.16
	Dryfall	0.05	.	.	.	.
	Septic Systems	3.25	0.84	0.84	0.00	0.00
	Total (kg)	5.18	1.24	1.74	0.20	0.58
	kg/acre	0.09	0.08	0.20	0.02	0.07

Septic systems, groundwater, and runoff from hay/pasture land types were estimated to be the largest source of phosphorus to bubbling springs, with septic systems yielding over half the total estimated load. The northwest subwatershed was estimated to yield both the overall highest annual load and the highest load per acre of the four subwatersheds.

During field sampling events in 2022, lower Bubbling Springs Pond was not measured to exhibit anoxia at any point during the season. While there were small differences between surface and deep phosphorus samples, these largely do not appear to be due to advanced internal loading and may instead be due to decomposition of organic matter. Internal loading was calculated using the assumption that anoxic loading does not typically occur in Bubbling Springs Pond and only the reduced oxic loading rate (approximately 0.6 mg TP/m²/day) was used. Bubbling Springs Pond is estimated to receive approximately 0.73 kg each year due to internal loading.

Table 19 below displays the external and internal loads of phosphorus for Bubbling Springs, as well as the grand total, which is estimated to be approximately 5.91 kg/year. External loading is estimated to be the primary source of phosphorus loading in Bubbling Springs representing over 80% of the entire annual load.

Table 19: Total estimated annual phosphorus loads for Bubbling Springs from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	5.18
Internal	0.73
Total	**5.91**

Table 20: Estimated annual loads of sediment in the Bubbling Springs watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.150	46.0
	Cropland	0.000	0.0
	Forest	0.060	18.4
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.010	3.1
	Medium-Density Mixed	0.020	6.1
	High-Density Mixed	0.020	6.1
	Low-Density Open Space	0.020	6.1
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.046	14.1
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.326	100.0

A majority of sediment entering Bubbling Springs Pond is estimated to originate in runoff from hay/pasture land types, with runoff from forested land and eroding stream banks also yielding notable yearly loads. The Northwest subwatershed is estimated to yield both the overall highest estimated yearly sediment load and the highest load per acre.

Table 21: Estimated annual loads of sediment by subwatershed in the Bubbling Springs watershed

Category	Description	Full Watershed kg x 1000	Northeast kg x 1000	Northwest kg x 1000	Southeast kg x 1000	Southwest kg x 1000
Runoff	Hay/Pasture	0.150	0.000	0.180	0.000	0.020
	Cropland	0.000	0.000	0.000	0.000	0.000
	Forest	0.060	0.050	0.010	0.010	0.000
	Wetland	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.010	0.000	0.000	0.000	0.000
	Medium-Density Mixed	0.020	0.010	0.020	0.000	0.000
	High-Density Mixed	0.020	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.020	0.000	0.010	0.000	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000
	Stream Bank	0.046	0.018	0.000	0.000	0.001
	Groundwater	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.326	0.078	0.220	0.010	0.021
	kg/acre	5.704	4.875	25.000	0.750	2.491

Table 22: Estimated annual loads of bacteria from various sources in the total Bubbling Springs watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.26E+08	0.6
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	8.75E+09	40.4
	Other Wildlife	1.28E+10	59.1
	Total	2.17E+10	100

Table 23: Estimated annual loads of bacteria by subwatershed in the Bubbling Springs watershed

Category	Description	Full Watershed %	Northeast %	Northwest %	Southeast %	Southwest %
Fecal Coliform	Farm Animals and Waterfowl	0.6	0	0	0	0
	WWTP	0	0	0	0	0
	Septic Systems	0	0	0	0	0
	Urban Areas	40.4	5.8	59.0	11.5	82.8
	Other Wildlife	59.1	94.2	40.7	88.5	17.2
	Total (organisms)	2.17E+10	4.85E+09	2.81E+09	4.58E+09	1.49E+10

Over half of the total bacterial load estimated to enter Bubbling Springs each year is estimated to originate from wildlife in the watershed, with approximately 40% of the load estimated to occur from urbanized areas. The Southwest subwatershed is estimated to yield the highest annual bacteria load, with over 80% of this load originating in urbanized areas.

CARPI LAKE

Carpi Lake features an approximately 177.6-acre watershed consisting largely of forested land and wetlands. Small areas of urbanized land are also present. The lake itself has a surface area of approximately 12.7 acres. A small inlet enters the lake at the southern end of the lake, while the lake's outlet (Morsetown Brook) flows north to a confluence with Belcher Creek and Greenwood Lake. Descriptions of the lake's subwatersheds are as follows:

- **East:** This approximately 46-acre subwatershed contains the length of Morsetown Road, as well as some lightly urbanized areas. An expanse of forested area is present in the southeastern portion of the subwatershed.
- **West:** This approximately 27.3-acre subwatershed is almost entirely forested, with the exception of a few houses located on the lake's shoreline.
- **Inlet:** This approximately 105-acre subwatershed is located in the southern portion of Carpi Lake's watershed and features a small stream that drains into the lake. While some houses and the length of Morsetown Road are present in this subwatershed, it is classified as containing only forested land and wetlands.

Table 24. Land-use by subwatershed in the Carpi Lake watershed.

Source	Full Watershed	East	Inlet	West
	Area (acres)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	149.5	34.8	88.2	26.4
Wetland	13.8	4.2	9.1	0.5
Open Land	0.7	0.2	0.7	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	1.0	0.5	0.5	0.2
Medium-Density Mixed	0.5	0.2	0.2	0.0
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	12.1	5.9	5.9	0.2
Total	177.6	45.8	104.6	27.3

Table 24 continued. Land-use by subwatershed in the Carpi Lake watershed.

Source	Full Watershed	East	Inlet	West
	Area (%)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	84.2	76.0	84.3	96.7
Wetland	7.8	9.2	8.7	1.8
Open Land	0.4	0.4	0.7	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	0.6	1.1	0.5	0.7
Medium-Density Mixed	0.3	0.4	0.2	0.0
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	6.8	12.9	5.6	0.7
Total	100.0	100	100	100

Soils within the Carpi Lake watershed are largely slow- to very slow-infiltration; however, approximately 20% of the soils are listed as Type B – "Moderate Infiltration". These occurred most frequently in the Inlet subwatershed. The eastern subwatershed featured the largest proportion of the soil type D – "very slow infiltration".

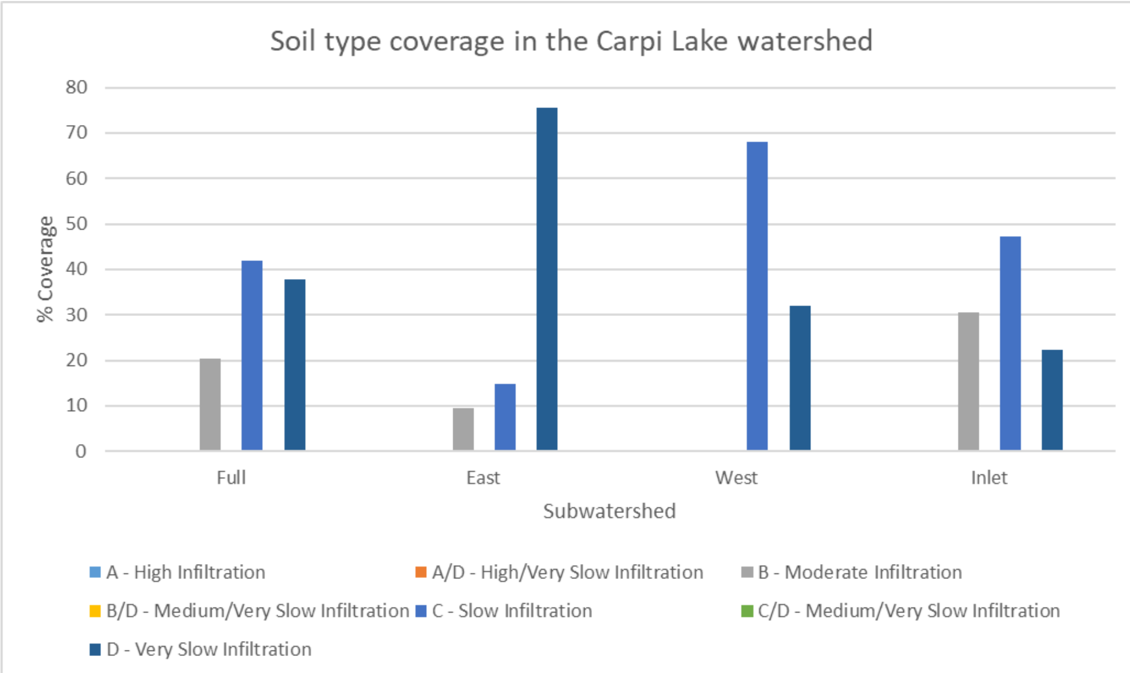


Figure 11. Percent coverage of Carpi Lake's Watershed and subwatersheds by different hydrologic soil groups.

Slopes in the Carpi Lake watershed are relatively low, with an overall average of only approximately 11%. Small areas of steeper slope exist, however, with the maximum slope of approximately 38.4% occurring in the East subwatershed.

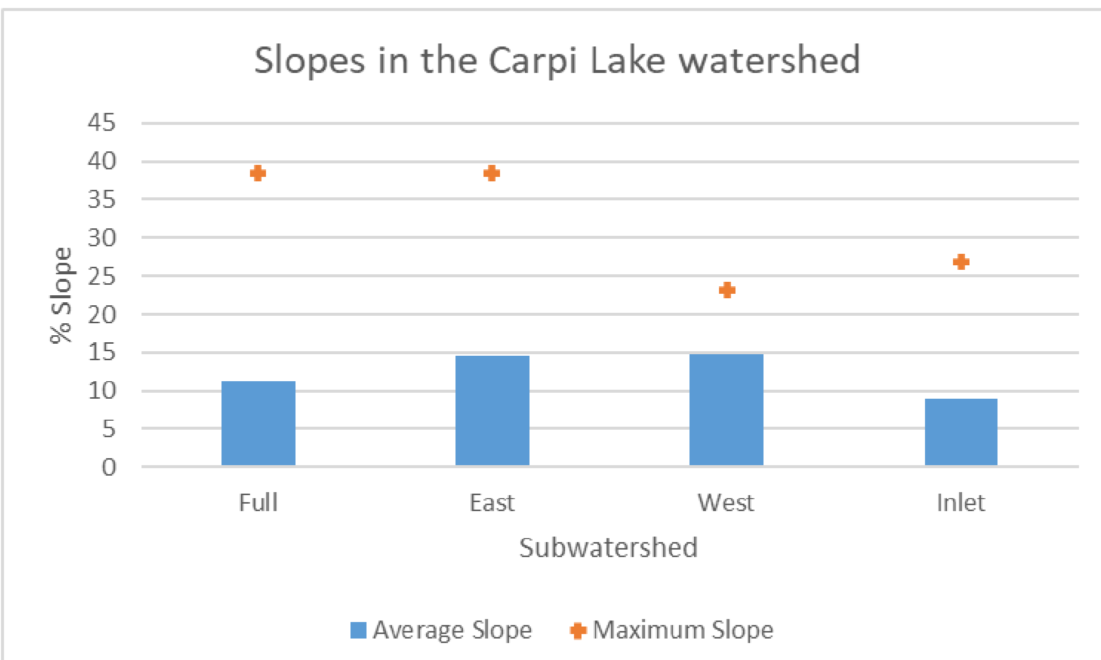


Figure 12. Variation in average and maximum percent slope between subwatersheds in the Carpi Lake watershed.

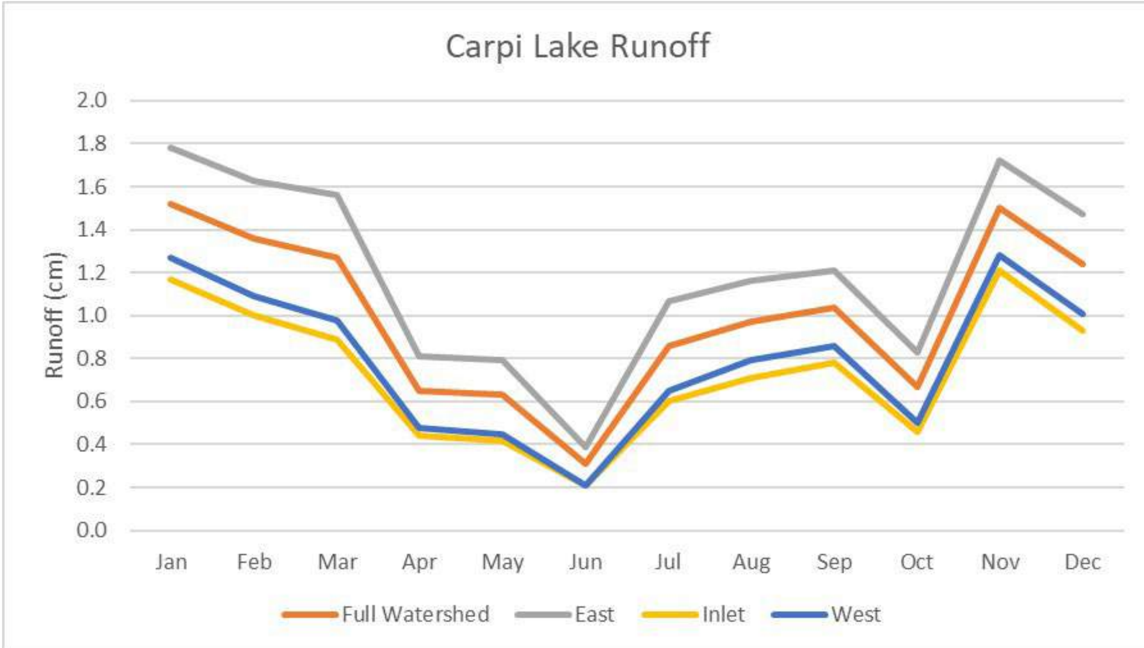


Figure 13. Estimated seasonal changes in hydrology in the Carpi Lake watershed

Table 25: Total hydrological parameters in the full Carpi Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.6	5.1	1.5	6.7	0.6
Feb	8.0	0.9	5.6	1.4	7.0	0.7
Mar	10.2	2.5	7.0	1.3	8.2	0.8
Apr	10.4	5.6	6.4	0.7	7.0	0.7
May	11.0	10.6	4.0	0.6	4.7	0.4
Jun	8.8	12.0	1.9	0.3	2.2	0.2
Jul	11.2	10.3	0.6	0.9	1.5	0.1
Aug	10.2	9.5	0.2	1.0	1.1	0.1
Sep	9.7	6.5	0.2	1.0	1.3	0.1
Oct	8.4	4.6	0.6	0.7	1.2	0.1
Nov	10.4	2.5	1.6	1.5	3.1	0.3
Dec	9.3	1.2	4.3	1.2	5.6	0.5
Total	116.4	66.7	37.4	12.0	49.5	0.4

While the Inlet and West subwatersheds don't feature a high variation between their runoff amounts, the eastern watershed was estimated to yield notably more runoff throughout the year. This is likely due to its increased proportion of very-slow infiltration soil compared to the other subwatersheds. When direct precipitation and evaporation to and from the lake itself are accounted for, Carpi Lake is estimated to receive 380,997 m³ or 100.7 million gallons of water in an average year.

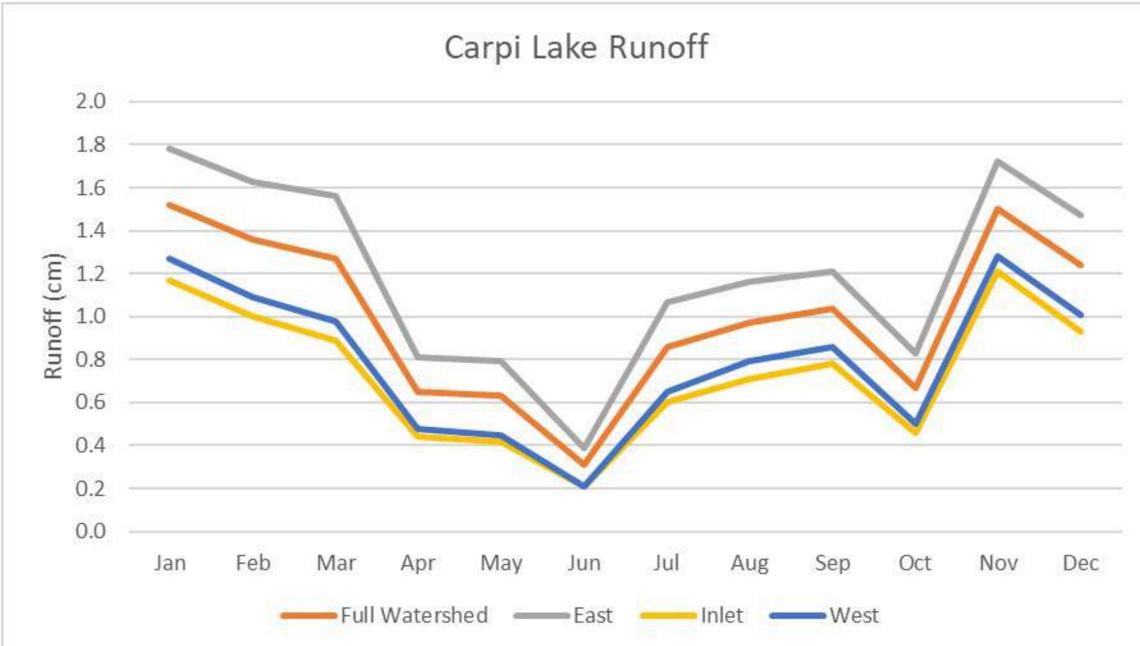


Figure 14. Average monthly runoff within each subwatershed in the Carpi Lake watershed

Table 26. Estimated annual loads of nitrogen in the total Carpi Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	12.9	5.29
	Wetland	3.4	1.40
	Open Land	0.4	0.16
	Barren Land	0.0	0.00
	Low-Density Mixed	0.1	0.05
	Medium-Density Mixed	0.3	0.11
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	1.4	0.57
Other Sources	Farm Animals and Waterfowl	0.1	0.03
	Stream Bank	0.0	0.00
	Groundwater	91.5	37.46
	Dryfall	30.7	12.56
	Septic Systems	103.5	42.37
	Total	244.3	100

Table 27. Estimated annual loads of nitrogen by subwatershed in the Carpi Lake watershed

Category	Description	Full Watershed kg	East kg	Inlet kg	West kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0
	Forest	12.9	3.7	5.1	2.0
	Wetland	3.4	1.0	1.7	0.1
	Open Land	0.4	0.0	0.4	0.0
	Barren Land	0.0	0.0	0.0	0.0
	Low-Density Mixed	0.1	0.1	0.1	0.1
	Medium-Density Mixed	0.3	0.1	0.1	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0
	Low-Density Open Space	1.4	0.8	0.8	0.02
Other Sources	Farm Animals and Waterfowl	0.1	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0
	Groundwater	91.5	21.5	57.9	15.8
	Dryfall	30.7	.	.	.
	Septic Systems	103.5	43.0	44.6	15.9
	Total (kg)	244.3	70.3	110.8	33.9
	kg/acre	1.4	1.5	1.1	1.2

Nitrogen loads in the Carpi Lake Watershed were modeled to largely originate from septic systems and groundwater, with dryfall also contributing a notable annual load. Runoff from forested land also was estimated to yield over 13 kg/yr. The Inlet subwatershed yielded the highest overall nitrogen load of the three subwatersheds, while the East subwatershed yielded the largest load per acre.

Table 28. Estimated annual loads of phosphorus in the total Carpi Lake watershed

Category	Description	Total Phosphorus kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	1.32	11.9
	Wetland	0.23	2.1
	Open Land	0.02	0.2
	Barren Land	0.00	0.0
	Low-Density Mixed	0.01	0.1
	Medium-Density Mixed	0.03	0.3
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.15	1.4
Other Sources	Farm Animals and Waterfowl	0.03	0.2
	Stream Bank	0.00	0.0
	Groundwater	2.40	21.6
	Dryfall	0.20	1.8
	Septic Systems	6.72	60.5
	Total	11.11	100.0

Table 29. Estimated annual load of phosphorus by subwatershed in the Carpi Lake watershed

Category	Description	Full Watershed kg	East kg	Inlet kg	West kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00
	Forest	1.32	0.34	0.50	0.19
	Wetland	0.23	0.07	0.11	0.01
	Open Land	0.02	0.00	0.02	0.00
	Barren Land	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.01	0.01	0.01	0.01
	Medium-Density Mixed	0.03	0.01	0.01	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.15	0.09	0.09	0.00
Other Sources	Farm Animals and Waterfowl	0.03	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00
	Groundwater	2.40	0.56	1.52	0.41
	Dryfall	0.20	.	.	.
	Septic Systems	6.72	0.84	3.36	2.52
	Total (kg)	11.11	1.92	5.62	3.14
	kg/acre	0.06	0.04	0.05	0.12

As with nitrogen loads, phosphorus loads in the Carpi Lake watershed are estimated to originate largely from groundwater and septic systems, particularly in the Inlet subwatershed. Runoff from forested areas also contributes notably to phosphorus loading. The Inlet subwatershed was estimated to yield the highest annual load of phosphorus, likely due to its larger number of septic systems, while the West subwatershed was estimated to yield the highest phosphorus load per acre.

Table 30. Estimated annual loads of sediment in the total Carpi Lake watershed

Category	Description	Sediment kgx1000	%
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.620	75.6
	Wetland	0.050	6.1
	Open Land	0.020	2.4
	Barren Land	0.000	0.0
	Low-Density Mixed	0.010	1.2
	Medium-Density Mixed	0.020	2.4
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.070	8.5
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.030	3.7
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.820	100.0

Table 31: Estimated annual loads of sediment by subwatershed in the Carpi Lake watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	Inlet kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000
	Forest	0.620	0.140	0.230	0.080
	Wetland	0.050	0.010	0.020	0.000
	Open Land	0.020	0.000	0.010	0.000
	Barren Land	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.010	0.000	0.000	0.000
	Medium-Density Mixed	0.020	0.010	0.010	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.070	0.040	0.040	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000
	Stream Bank	0.030	0.005	0.018	0.000
	Groundwater	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.820	0.205	0.328	0.080
	kg/acre	4.617	4.476	3.136	2.930

The Carpi Lake watershed was estimated to produce an overall annual sediment load of approximately 820 kg, or 4.617 kg/acre. A large majority of sediment is estimated to originate as runoff from forested land. The inlet subwatershed is estimated to yield the highest annual sediment load overall, while the East subwatershed yielded the highest load per acre. This may be due to this subwatershed's relatively high coverage with soils with very slow infiltration.

Table 32. Estimated annual loads of bacteria from various sources in the total Carpi Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	3.60E+07	0.1
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	1.12E+07	<0.1
	Other Wildlife	5.52E+10	99.9
	Total	5.52E+10	100.0

Table 33. Estimated annual loads of bacteria by subwatershed in the Carpi Lake watershed

Category	Description	Full Watershed %	East %	Inlet %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.1	0	0	0
	WWTP	0	0	0	0
	Septic Systems	0	0	0	0
	Urban Areas	<0.1	0.3	0	0.0
	Other Wildlife	99.9	99.7	100	1.0
	Total (organisms)	5.52E+10	1.38E+10	3.19E+10	9.61E+09

Due to the largely forested nature of Carpi Lake's watershed, almost the entirety of the pond's bacterial load is estimated to originate from wildlife. The Inlet subwatershed was estimated to yield the largest amount of bacteria of the three subwatersheds.

FARM CREST ACRES POND

Farm Crest Acres contains a main, upper pond, as well as a small lower pond that sits downgrade of the main pond's dam. For the purposes of this study, the upper pond's watershed was assessed. This pond featured a surface area of approximately 3.1 acres, with a watershed of approximately 17.8 acres, totaling 20.9 acres. Approximately 71% of the pond's watershed is classified as urbanized land, largely containing the low-density open space land-use type. Approximately 29% of the watershed is classified as forested land. The ponds' outlet flows south towards the Pequannock River. Descriptions of Farm Crest Acres Pond's subwatersheds are as follows:

- **East:** This 9.3-acre subwatershed is located along the eastern edge of the upper pond and is split almost evenly between urbanized and forested land. The subwatershed also contains the length of Crest Lake Drive.
- **West:** This 8.6-acre subwatershed is almost 100% urbanized, containing the developed areas around Greendale Drive, Crest Hill Drive, and a segment of Crest Lake Drive.

Table 34. Land-use by subwatershed in the Farm Crest Acres Pond watershed.

Source	Full Watershed	East	West
		Area (acres)	
Open Water	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0
Cropland	0.0	0.0	0.0
Forest	5.2	4.9	0.2
Wetland	0.0	0.0	0.0
Open Land	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0
Low-Density Mixed	2.7	0.2	2.7
Medium-Density Mixed	0.5	0.0	0.5
High-Density Mixed	0.0	0.0	0.0
Low-Density Open Space	9.4	4.2	5.2
Total	17.8	9.3	8.6

Table 34 continued. Land-use by subwatershed in the Farm Crest Acres Pond watershed

Source	Full Watershed	East	West
		Area (%)	
Open Water	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0
Cropland	0.0	0.0	0.0
Forest	29.2	52.7	2.3
Wetland	0.0	0.0	0.0
Open Land	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0
Low-Density Mixed	15.2	2.2	31.4
Medium-Density Mixed	2.8	0.0	5.8
High-Density Mixed	0.0	0.0	0.0
Low-Density Open Space	52.8	45.2	60.5
Total	100	100	100

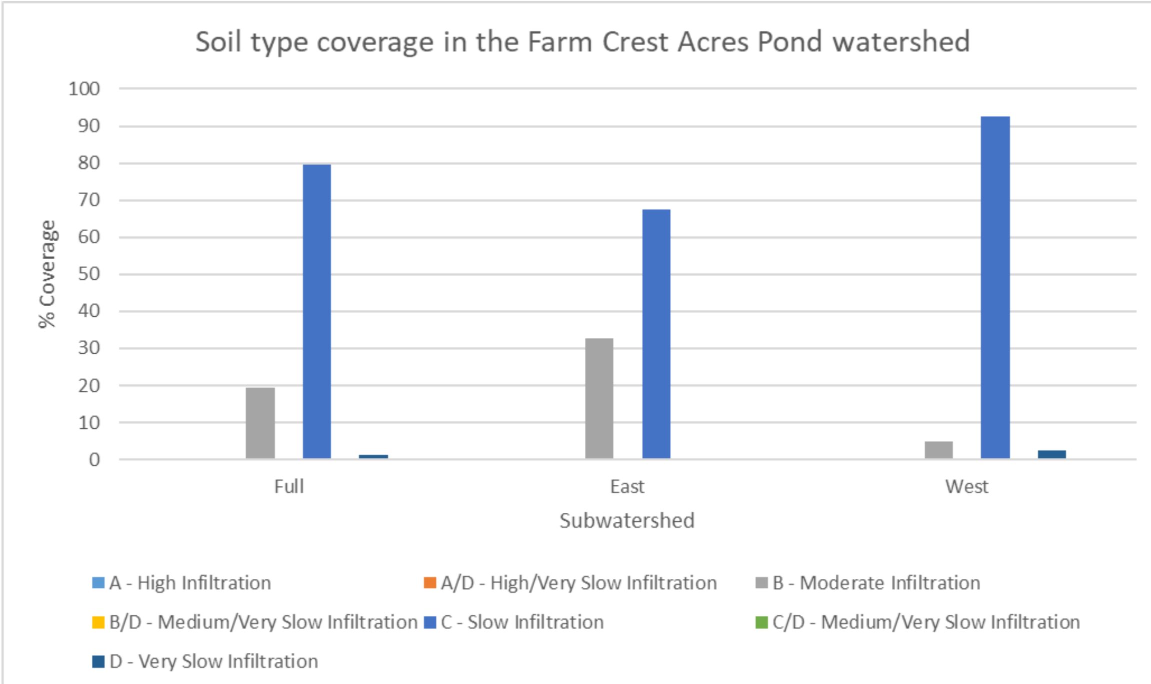


Figure 15. Percent coverage of Farm Crest Acres Watershed and subwatersheds by different hydrologic soil groups

The full Farm Crest Acres Pond watershed largely is modeled to consist of soil group "C – Slow Infiltration", with approximately 20% coverage with group "B – Moderate Infiltration" and a small percentage containing group "D – Very Slow Infiltration". The West subwatershed features the greatest percentage of lower-infiltrating soil groups.

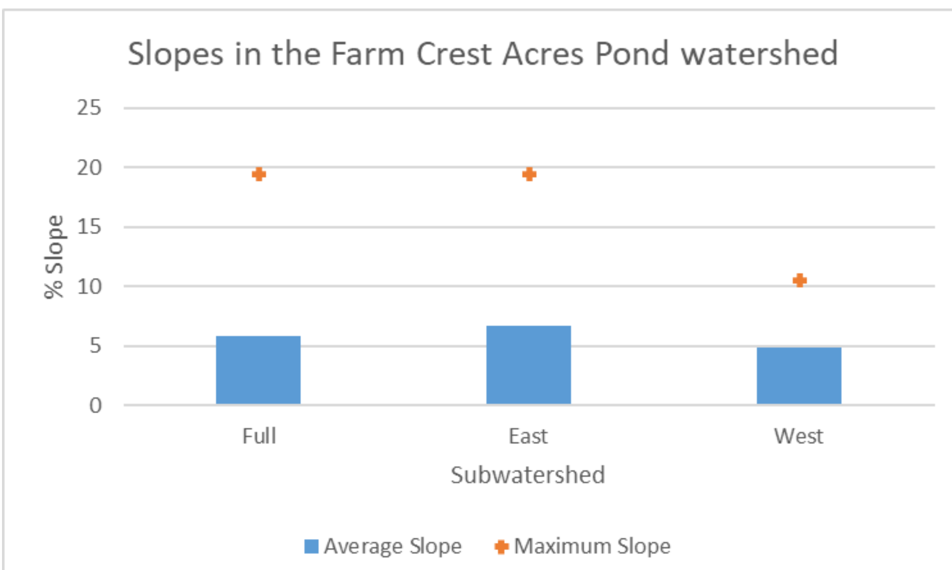


Figure 16. Variation in average and maximum percent slope between subwatersheds in the Farm Crest Acres Pond watershed.

Farm Crest Acres Pond's watershed features overall gradual slopes, with an average slope of only approximately 5.5%. Areas of steeper slopes are present however, with the East subwatershed featuring a maximum slope of approximately 19%.

Table 35. Land-use by subwatershed in the Farm Crest Acres Pond watershed

Source	Full Watershed	East	West
		Area (acres)	
Open Water	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0
Cropland	0.0	0.0	0.0
Forest	5.2	4.9	0.2
Wetland	0.0	0.0	0.0
Open Land	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0
Low-Density Mixed	2.7	0.2	2.7
Medium-Density Mixed	0.5	0.0	0.5
High-Density Mixed	0.0	0.0	0.0
Low-Density Open Space	9.4	4.2	5.2
Total	17.8	9.3	8.6

Table 35 continued. Land-use by subwatershed in the Farm Crest Acres watershed

Source	Full Watershed	East	West
		Area (%)	
Open Water	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0
Cropland	0.0	0.0	0.0
Forest	29.2	52.7	2.3
Wetland	0.0	0.0	0.0
Open Land	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0
Low-Density Mixed	15.2	2.2	31.4
Medium-Density Mixed	2.8	0.0	5.8
High-Density Mixed	0.0	0.0	0.0
Low-Density Open Space	52.8	45.2	60.5
Total	100	100	100

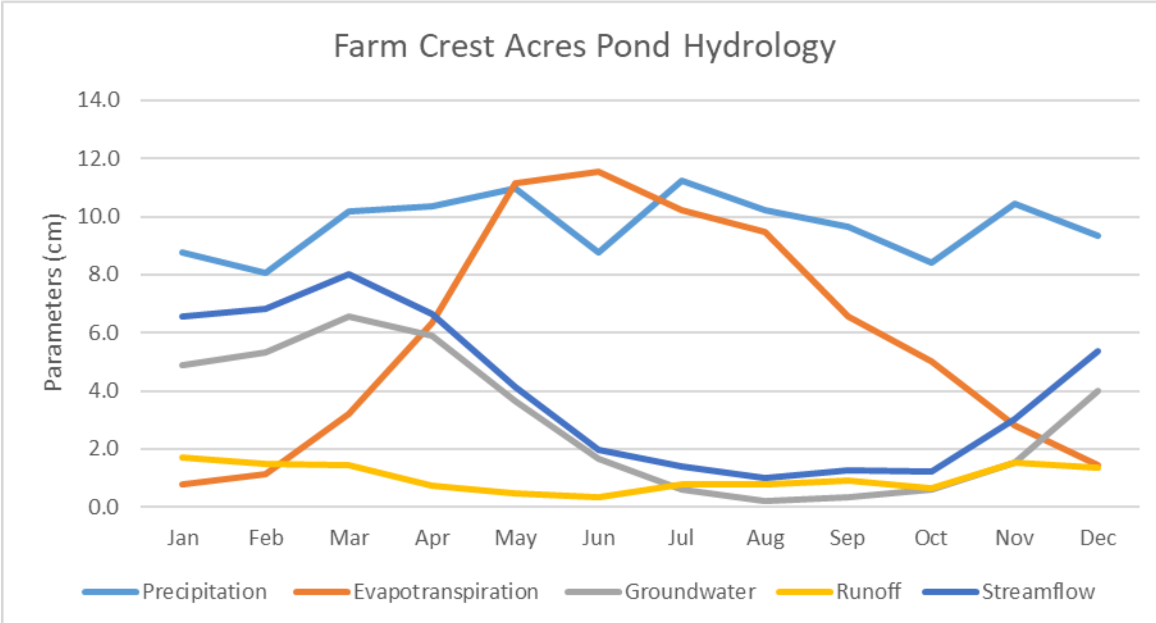


Figure 17. Estimated seasonal changes in hydrology in the Farm Crest Acres Pond watershed

Table 36. Total hydrological parameters in the full Farm Crest Acres Pond watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.8	4.9	1.7	6.6	0.06
Feb	8.0	1.1	5.3	1.5	6.8	0.07
Mar	10.2	3.2	6.5	1.5	8.0	0.08
Apr	10.4	6.3	5.9	0.8	6.6	0.07
May	11.0	11.2	3.7	0.5	4.1	0.04
Jun	8.8	11.6	1.7	0.3	2.0	0.02
Jul	11.2	10.2	0.6	0.8	1.4	0.01
Aug	10.2	9.5	0.2	0.8	1.0	0.01
Sep	9.7	6.6	0.4	0.9	1.3	0.01
Oct	8.4	5.0	0.6	0.6	1.2	0.01
Nov	10.4	2.8	1.5	1.5	3.0	0.03
Dec	9.3	1.4	4.0	1.4	5.4	0.05
Total	116.4	69.7	35.2	12.2	47.4	0.04

Some variability exists between the two subwatersheds in regard to runoff. Specifically, the Western subwatershed was estimated to yield a higher runoff than the Eastern subwatershed, likely due to the Western subwatershed's larger percentage of urbanized landcover and low-infiltrating soils. When direct precipitation and evaporation to and from the pond itself are factored in, Farm Crest Acres Pond is estimated to receive approximately 40,071.2 m³ or 10.6 million gallons of water a year.

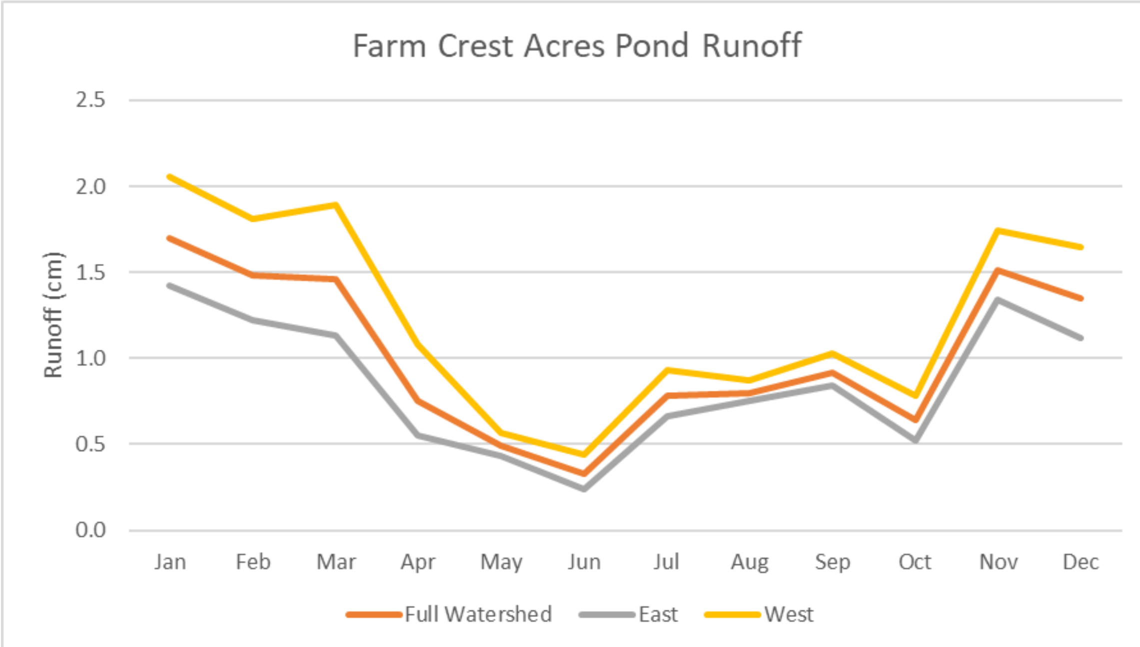


Figure 18. Average monthly runoff occurring within the Farm Crest Acres Watershed

Bathymetric data is not available for Farm Crest Acres Pond; as such, only an estimation of the pond's volume could be obtained. The estimated volume of the lake is approximately 21,063.5 m³ or 5.6 million gallons of water. Using the volume and hydraulic input estimates, the pond is estimated to flush approximately 1.9 times a year, with a retention rate of approximately 192 days. When examined on a monthly basis, the pond experiences a summer period of a lower annualized flushing rate and an increased retention period.

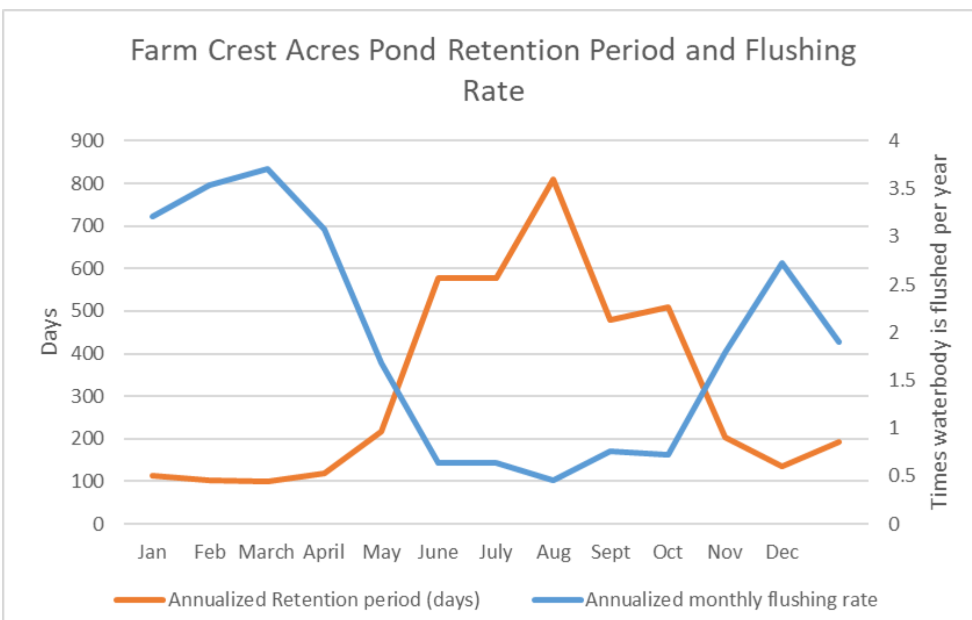


Figure 19. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Farm Crest Acres Pond, based on variations in hydraulic loads.

Most of the Farm Crest Acres external nitrogen load originates from septic systems and groundwater flows (Tables 37, 38). Runoff-based nitrogen was dominated by loads originating from urbanized areas, particularly in the Western watershed. Of the two subwatersheds, the Western subwatershed is estimated to yield the highest estimated annual nitrogen load and the highest nitrogen loads per acre.

Table 37. Estimated annual loads of nitrogen in the total Farm Crest Acres Watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	0.4	0.53
	Wetland	0.0	0.00
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	0.3	0.48
	Medium-Density Mixed	0.3	0.40
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	1.2	1.68
Other Sources	Farm Animals and Waterfowl	0.2	0.33
	Stream Bank	0.0	0.00
	Groundwater	8.6	12.29
	Dryfall	3.4	4.82
	Septic Systems	55.7	79.47
	Total	70.1	100

Table 38. Estimated annual loads of nitrogen by subwatershed in the Farm Crest Acres watershed

Category	Description	Full Watershed kg	East kg	West kg
Runoff	Hay/Pasture	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0
	Forest	0.4	0.4	0.0
	Wetland	0.0	0.0	0.0
	Open Land	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0
	Low-Density Mixed	0.3	0.0	0.4
	Medium-Density Mixed	0.3	0.0	0.3
	High-Density Mixed	0.0	0.0	0.0
	Low-Density Open Space	1.2	0.4	0.8
Other Sources	Farm Animals and Waterfowl	0.2	0.0	0.0
	Stream Bank	0.0	0.0	0.0
	Groundwater	8.6	4.9	3.9
	Dry Fall	3.4	.	.
	Septic Systems	55.7	23.9	31.9
	Total (kg)	70.1	29.5	37.3
	kg/acre	3.9	3.2	4.3

Table 39. Estimated annual loads of phosphorus in the total Farm Crest Acres Pond watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.03	0.8
	Wetland	0.00	0.0
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.04	1.0
	Medium-Density Mixed	0.03	0.8
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.13	3.3
Other Sources	Farm Animals and Waterfowl	0.08	2.0
	Stream Bank	0.00	0.0
	Groundwater	0.25	6.4
	Dryfall	0.02	0.4
	Septic Systems	3.36	85.3
	Total	3.94	100.0

Table 40. Estimated annual loads of phosphorus/subwatershed in the Farm Crest Acres Pond watershed

Category	Description	Full Watershed	East	West
		kg	kg	kg
Runoff	Hay/Pasture	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00
	Forest	0.03	0.03	0.00
	Wetland	0.00	0.00	0.00
	Open Land	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00
	Low-Density Mixed	0.04	0.00	0.05
	Medium-Density Mixed	0.03	0.00	0.03
	High-Density Mixed	0.00	0.00	0.00
	Low-Density Open Space	0.13	0.04	0.09
Other Sources	Farm Animals and Waterfowl	0.08	0.00	0.00
	Stream Bank	0.00	0.00	0.00
	Groundwater	0.25	0.14	0.11
	Dryfall	0.02	.	.
	Septic Systems	3.36	2.52	0.84
	Total (kg)	3.94	2.73	1.12
	kg/acre	0.22	0.29	0.13

As with nitrogen concentrations, phosphorus in the Farm Crest Acres Pond watershed largely originates from groundwater and septic systems (Tables 39, 40). Phosphorus inputs due to runoff are relatively small; these mostly originate from urbanized land. The Eastern subwatershed was estimated to yield a higher annual phosphorus load than the western subwatershed, as well as a higher load per acre.

Despite its relatively small surface area, Farm Crest Acres Pond was measured to feature anoxia and a large increase in phosphorus concentrations near the bottom of the water column during the July event. As such, internal loading was modeled to occur for 2.5 months (77 days) during an average growing season at approximately 15% of the lake's total surface area at the increased loading rate of 6 mg TP/m²/day. Farm Crest Acres Pond is estimated to receive approximately 1.91 kg of phosphorus per year via internal loading. Were a year to occur with no anoxia and associated increased internal loading, the internal phosphorus load would instead be approximately 1.14 kg/year.

Table 41 below displays the external and internal loads of phosphorus for Farm Crest Acres Pond, as well as the grand total, which is estimated to be approximately 5.85 kg/year. This is overall not as large as what many of the other lakes in the study are anticipated to receive, due to the small area at which internal loading is estimated to occur and the relatively small watershed. External loading is estimated to produce the largest annual phosphorus load, contributing approximately 67% of the total annual load.

Table 41. Total estimated annual phosphorus loads for Farm Crest Acres Pond from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	3.94
Internal	1.91
Total	**5.85**

Table 42. Estimated annual loads of sediment in the total Farm Crest Acres Pond watershed

Category	Description	Sediment	
		kgx1000	%
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.010	10.8
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.010	10.8
	Medium-Density Mixed	0.020	21.5
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.050	53.8
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.003	3.2
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.093	100.0

Table 43. Estimated annual loads of sediment by subwatershed in the Farm Crest Acres Pond watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000
	Forest	0.010	0.010	0.000
	Wetland	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000
	Low-Density Mixed	0.010	0.000	0.020
	Medium-Density Mixed	0.020	0.000	0.020
	High-Density Mixed	0.000	0.000	0.000
	Low-Density Open Space	0.050	0.020	0.030
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000
	Stream Bank	0.003	0.005	0.003
	Groundwater	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000
	Total (kgx1000)	0.093	0.035	0.073
	kg/acre	5.225	3.763	8.488

The overall sediment load for Farm Crest Acres Pond is relatively low, at only an estimated 93 kg/yr, likely due to its relatively small watershed. A majority of sediment is estimated to originate from urbanized areas. The Western subwatershed is estimated to yield the highest annual sediment load, both in total and on a per-acre basis, due to its high amount of urbanized landcover.

A majority of the bacterial load in the Farm Crest Acres Pond watershed is estimated to originate from urban areas, while a relatively small amount is estimated to originate from wildlife in the forested areas of the watershed.

Table 44. Estimated annual loads of bacteria for the full Farm Crest Acres Pond watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.08E+08	0.4
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.34E+10	92.3
	Other Wildlife	1.85E+09	7.3
	Total	2.54E+10	100

Table 45. Estimated annual loads of bacteria by subwatershed in the Farm Crest Acres Pond watershed

Category	Description	Full Watershed	East	West
		%	%	%
Fecal Coliform	Farm Animals and Waterfowl	0.4	0.0	0.0
	WWTP	0.0	0.0	0.0
	Septic Systems	0.0	0.0	0.0
	Urban Areas	92.3	72.7	99.6
	Other Wildlife	7.3	27.3	0.4
	Total (organisms)	2.35E+10	6.45E+09	2.39E+10

FOREST HILL LAKE

Forest Hill Lake features a watershed spanning approximately 164 acres, while the lake itself has a surface area of approximately 9.2 acres. The watershed is over 80% forested, with 27.1 acres of urbanized land immediately surrounding the lake and in the northeast portion of the watershed. The watershed contains the length of Germantown Road. The lake's outlet travels south for a short distance before entering Johns Lake. Descriptions of Forest Hill Lake's subwatersheds are as follows:

- **Northeast:** This is the largest subwatershed to Forest Hill Lake at 106.7 acres. This subwatershed contains the lake's main inlet tributary, and consists largely of forested land, as well as approximately 14 acres of urbanized area. Horse stables and a small pond are also present along the inlet.
- **Northwest:** This 29.9-acre subwatershed is entirely classified as forested land.
- **Southeast:** This 12.2-acre subwatershed consists largely of urbanized land, as well as a small amount of forested area. It also contains the eastern length of Forest Hill Dr., and Cross Oak Ln.
- **Southwest:** This 11.8-acre subwatershed is classified as mostly forested, however it also contains the western length of Forest Hill Dr. and a few residential houses, classified as 2.2 acres of urbanized area.

Table 46. Land-use by subwatershed in the Forest Hill Lake watershed.

Source	Full Watershed	Northeast	Northwest	Southeast	Southwest
			Area (acres)		
Open Water	1.2	1.2	0.0	0.0	0.0
Hay/Pasture	3.0	3.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0
Forest	132.4	88.5	29.9	1.2	9.6
Wetland	0.0	0.0	0.0	0.0	0.0
Open Land	0.0	0.0	0.0	0.0	0.0
Barren Land	0.2	0.0	0.0	0.2	0.0
Low-Density Mixed	9.6	4.9	0.0	3.7	1.0
Medium-Density Mixed	2.7	1.2	0.0	1.2	0.2
High-Density Mixed	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	14.8	7.9	0.0	5.9	1.0
Total	163.9	106.7	29.9	12.2	11.8

Table 46 continued. Land-use by subwatershed in the Forest Hill Lake watershed.

Source	Full Watershed	Northeast	Northwest	Southeast	Southwest
			Area (%)		
Open Water	0.7	1.1	0.0	0.0	0.0
Hay/Pasture	1.8	2.8	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0
Forest	80.8	82.9	100.0	9.8	81.4
Wetland	0.0	0.0	0.0	0.0	0.0
Open Land	0.0	0.0	0.0	0.0	0.0
Barren Land	0.1	0.0	0.0	1.6	0.0
Low-Density Mixed	5.9	4.6	0.0	30.3	8.5
Medium-Density Mixed	1.6	1.1	0.0	9.8	1.7
High-Density Mixed	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	9.0	7.4	0.0	48.4	8.5
Total	100	100	100	100	100

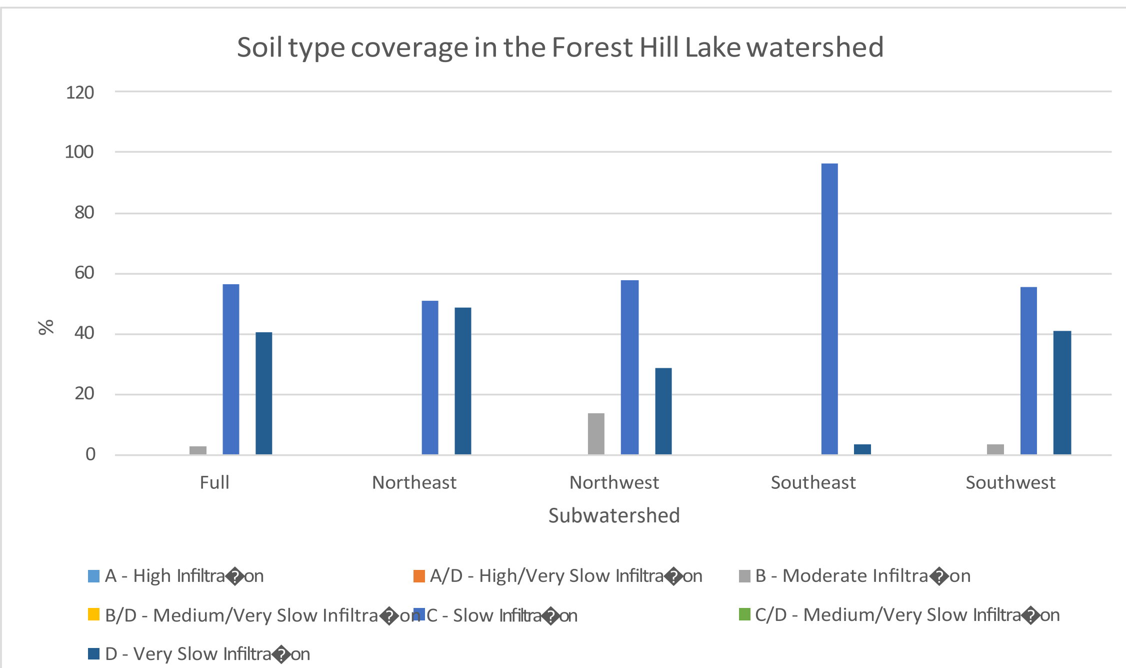


Figure 20. Percent coverage of Forest Hill Lake's watershed and subwatersheds by different hydrologic soil groups.

Soils in Forest Hill Lake's watershed consist largely of type C and type D, both of which are slow-infiltrating and prone to runoff. The Northeastern subwatershed in particular yields the highest amount of type D soils – "very slow infiltration". The two western subwatersheds, however, feature a small amount of type B ("moderate infiltration") soils, as these subwatersheds have a higher percentage of forested land. The average percent slopes of each subwatershed do not feature a wide variation, although the Northeast subwatershed does feature a notably higher maximum percent slope than the other three subwatersheds, making this subwatershed likely more slightly prone to erosion.

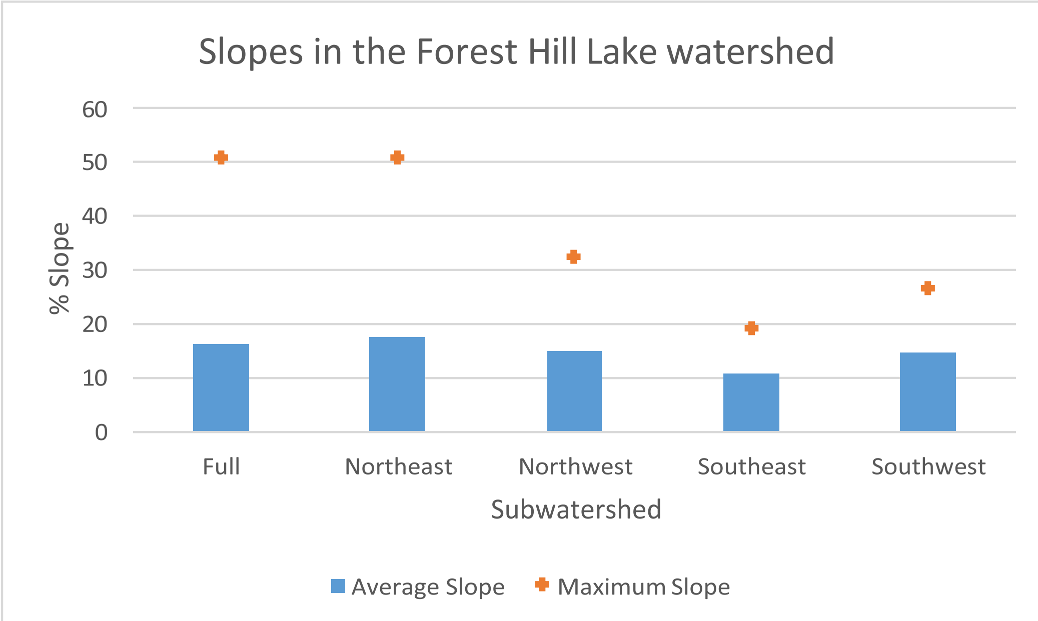


Figure 21. Variation in average and maximum percent slope between subwatersheds in the Forest Hill Lake watershed.

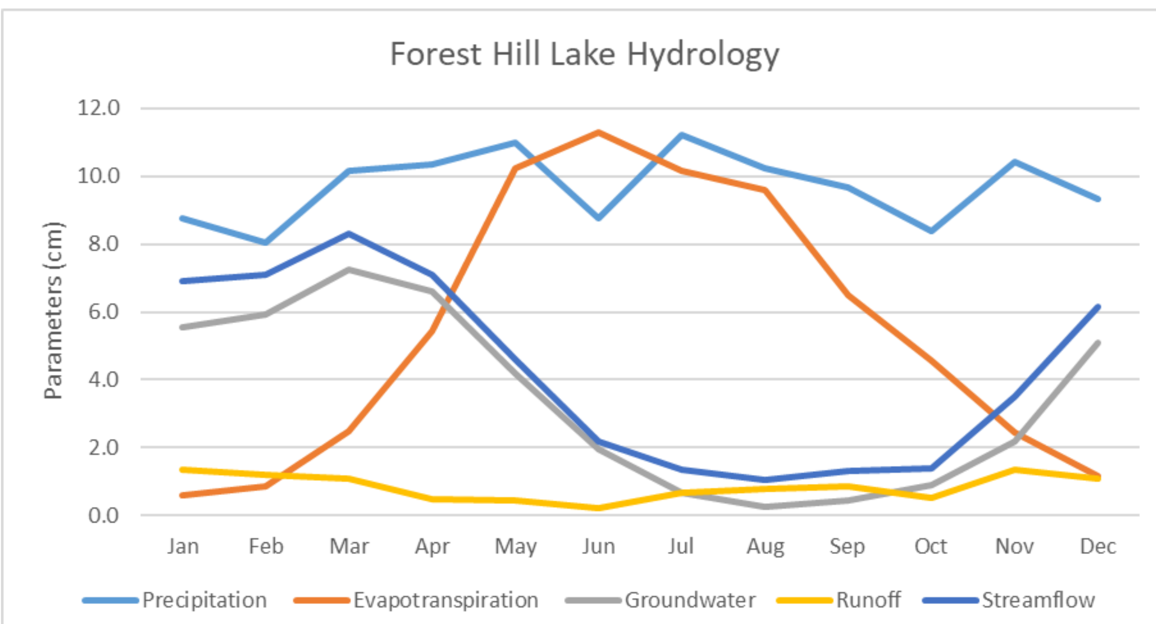


Figure 22. Estimated seasonal changes in hydrology in the Forest Hill Lake watershed

Table 47. Total hydrological parameters in the full Forest Hill Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.6	5.6	1.4	6.9	0.6
Feb	8.0	0.9	5.9	1.2	7.1	0.7
Mar	10.2	2.5	7.2	1.1	8.3	0.7
Apr	10.4	5.5	6.6	0.5	7.1	0.6
May	11.0	10.2	4.2	0.5	4.6	0.4
Jun	8.8	11.3	2.0	0.2	2.2	0.2
Jul	11.2	10.2	0.7	0.7	1.4	0.1
Aug	10.2	9.6	0.3	0.8	1.0	0.1
Sep	9.7	6.5	0.4	0.9	1.3	0.1
Oct	8.4	4.6	0.9	0.5	1.4	0.1
Nov	10.4	2.4	2.2	1.3	3.5	0.3
Dec	9.3	1.2	5.1	1.1	6.2	0.5
Total	116.4	65.3	41.0	10.0	51.0	0.4

Runoff is highest in the southeastern subwatershed, likely a product of the higher degree of urbanization in this area of the watershed. When direct precipitation and evaporation to and from the lake are factored for, the lake is estimated to receive approximately 357,120 m³ or 94.3 million gallons of water each year.

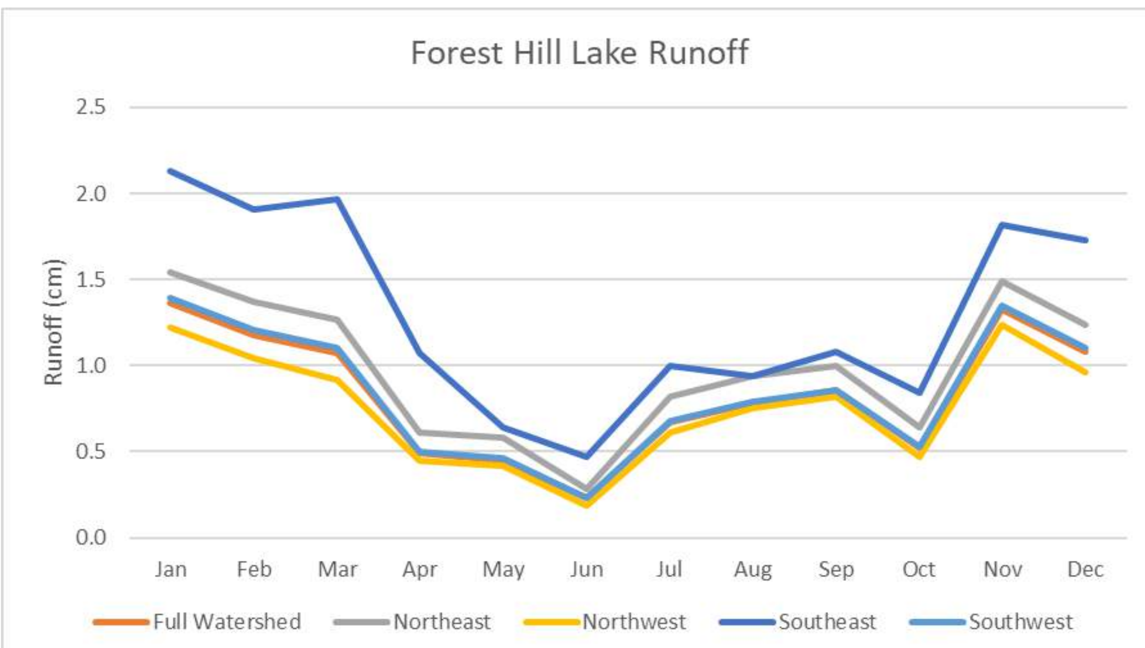


Figure 23. Average monthly runoff within each subwatershed in the Forest Hill Lake watershed

As no bathymetric map was available for Forest Hill Lake, the lake's volume was estimated from water depths collected during field sampling events to be approximately 92,906 m³ or 24.5 million gallons of water. Given these estimates and the results of the hydrologic model, the lake is estimated to flush approximately 3.8 times/year, with the hydraulic retention time being approximately 95 days. When changes over the course of the year in flushing rate are examined, the lake was calculated to flush slowest in August and highest in March in average years.

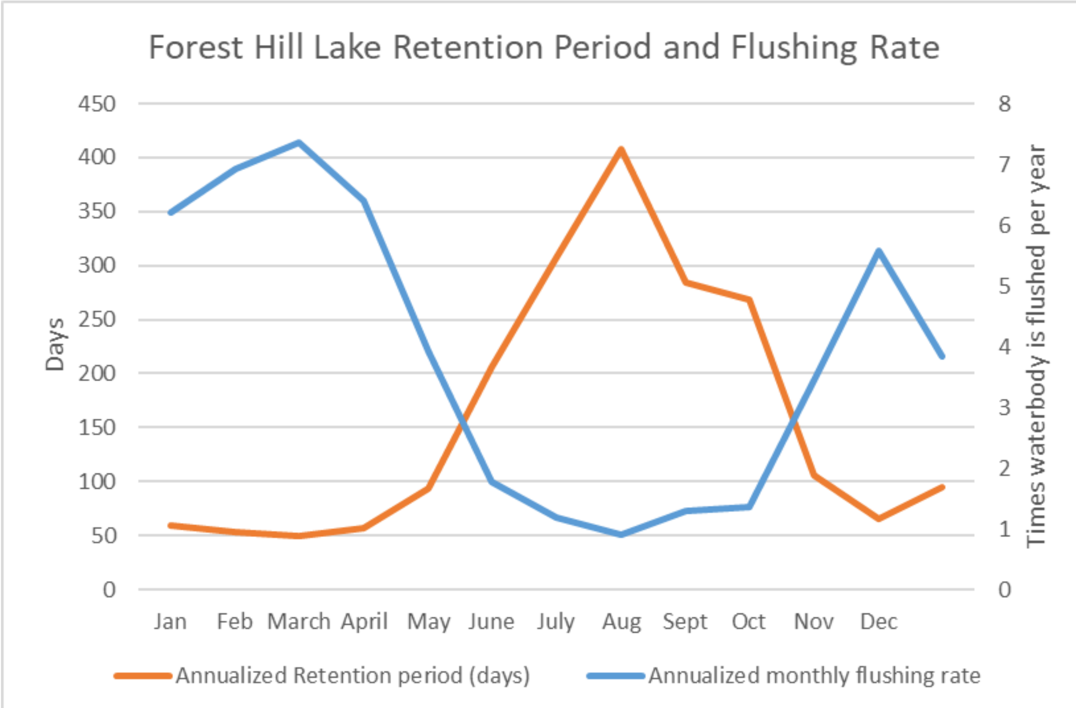


Figure 24. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Forest Hill Lake, based on variations in hydraulic loads.

Table 48. Estimated annual loads of nitrogen in the total Forest Hill Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	1.3	0.32
	Cropland	0.0	0.00
	Forest	9.5	2.35
	Wetland	0.4	0.09
	Open Land	0.0	0.00
	Barren Land	0.1	0.02
	Low-Density Mixed	1.4	0.34
	Medium-Density Mixed	1.6	0.40
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	2.1	0.53
Other Sources	Farm Animals and Waterfowl	22.3	5.53
	Stream Bank	0.0	0.00
	Groundwater	88.5	21.91
	Dryfall	28.0	6.93
	Septic Systems	248.7	61.58
	Total	403.9	100

Table 49. Estimated annual loads of nitrogen by subwatershed in the Forest Hill Lake watershed

Category	Description	Full Watershed	Northeast	Northwest	Southeast	Southwest
		kg	kg	kg	kg	kg
Runoff	Hay/Pasture	1.3	1.3	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0
	Forest	9.5	7.7	2.4	0.1	0.7
	Wetland	0.4	0.0	0.0	0.0	0.0
	Open Land	0.0	0.0	0.0	0.0	0.0
	Barren Land	0.1	0.0	0.0	0.1	0.0
	Low-Density Mixed	1.4	0.7	0.0	0.5	0.2
	Medium-Density Mixed	1.6	0.3	0.0	0.4	0.1
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	2.1	1.2	0.0	0.9	0.1
Other Sources	Farm Animals and Waterfowl	22.3	22.3	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0	0.0
	Groundwater	88.5	54.1	17.0	6.7	6.7
	Dryfall	28.0	.	.	.	.
	Septic Systems	248.7	143.1	0.0	81.2	20.7
	Total (kg)	403.9	230.8	19.4	89.8	28.6
	kg/acre	2.5	2.2	0.6	7.4	2.4

As a lake with a developed area immediately near the lake, Forest Hill Lake receives a majority of its nitrogen from septic tank influence, especially in the Northeastern subwatershed. This subwatershed also features a notable annual nitrogen load resulting from farm animals. Groundwater flows and dryfall were also modeled to be relatively high sources of nitrogen for Forest Hill Lake. The Southeastern subwatershed is estimated to yield the highest annual nitrogen load on a per-acre basis, likely due to the relatively high number of septic systems in this subwatershed compared to its size.

Table 50. Estimated annual loads of phosphorus in the total Forest Hill Lake watershed

Description	Total Phosphorus	
	kg	%
Hay/Pasture	0.42	2.5
Cropland	0.00	0.0
Forest	0.61	3.6

Table 51. Estimated annual loads of phosphorus by subwatershed in the Forest Hill Lake watershed

Category	Description	Full Watershed	Northeast	Northwest	Southeast	Southwest
		kg	kg	kg	kg	kg
Runoff	Hay/Pasture	0.42	0.35	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00
	Forest	0.61	0.38	0.28	0.01	0.06
	Wetland	0.02	0.00	0.00	0.00	0.00
	Open Land	0.00	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.11	0.05	0.00	0.06	0.02
	Medium-Density Mixed	0.12	0.02	0.00	0.04	0.01
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.17	0.08	0.00	0.09	0.01
Other Sources	Farm Animals and Waterfowl	5.66	5.64	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00	0.00
	Groundwater	1.75	0.89	0.45	0.17	0.18
	Dryfall	0.14	.	.	.	.
	Septic Systems	7.97	3.50	0.00	2.52	2.52
	Total (kg)	16.97	10.9	0.7	2.9	2.8
	kg/acre	0.10	0.10	0.02	0.24	0.24

Estimated annual loads of phosphorus in Forest Hill Lake's watershed follow a similar pattern to those of nitrogen, with septic systems yielding the highest amount of phosphorus, and farm animals also contributing a relatively high load. The Southeast and Southwest subwatersheds yield the highest amount of phosphorus per acre.

Over the course of the 2022 growing season, Forest Hill Lake was only measured to go anoxic towards the bottom of the water column once during the July event, although deep dissolved oxygen was also measured to be somewhat low during the Spring event. Discrete water quality sample results from this date show surface and deep concentrations of total phosphorus to be somewhat similar. Forest Hill Lake was observed to have an aeration system; this may possibly lead to some mixing of deep phosphorus towards the surface. Internal load modeling for Forest Hill Lake used the assumption that the lake featured anoxia for 2.5 months over a relatively small percentage (15%) of the lake bottom. Using these assumptions, Forest Hill Lake's internal phosphorus load was estimated to be 5.73 kg/yr. In a scenario where the lake does not feature anoxia, the lake's internal phosphorous load was estimated to be approximately 3.41 kg/yr. With the presence of the aeration system in the lake, however, further testing should be conducted in order to gain a more accurate period of time in which benthic anoxia occurs and whether or not any updates to the system may be beneficial.

Table 52 below compares Forest Hill Lake's estimated annual external phosphorus loads and the annual internal load estimate. Given these results, external loading appears to be a larger source of phosphorus in this lake than internal loading is, contributing approximately 75% of the total annual load. Overall, the lake is estimated to receive 22.7 kg of phosphorus a year.

Table 52. Total estimated annual phosphorus loads for Forest Hill Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	17.0
Internal	5.7
Total	**22.7**

Table 53. Estimated annual loads of sediment in the total Forest Hill Lake watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.030	6.6
	Cropland	0.000	0.0
	Forest	0.130	28.4
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.020	4.4
	Medium-Density Mixed	0.040	8.7
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.040	8.7
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.198	43.2
	Groundwater	0.000	0.0
	Dryfall	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.458	100.0

Table 54. Estimated annual loads of sediment by subwatershed in the Forest Hill Lake watershed

Category	Description	Full Watershed kg x 1000	Northeast kg x 1000	Northwest kg x 1000	Southeast kg x 1000	Southwest kg x 1000
Runoff	Hay/Pasture	0.030	0.010	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000
	Forest	0.130	0.030	0.150	0.000	0.020
	Wetland	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.020	0.000	0.000	0.020	0.010
	Medium-Density Mixed	0.040	0.000	0.000	0.020	0.010
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.040	0.010	0.000	0.030	0.010
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000
	Stream Bank	0.198	0.042	0.001	0.014	0.002
	Groundwater	0.000	0.000	0.000	0.000	0.000
	Dryfall	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.458	0.092	0.151	0.084	0.052
	kg/acre	2.79	0.86	5.05	6.89	4.41

Given Forest Hill Lake's largely forested watershed, the estimated annual sediment load for the lake is relatively low, at 458 kg/yr. A majority of this sediment is estimated to enter the lake in runoff from forested areas and stream bank erosion. While the Northwestern subwatershed is estimated to yield the highest overall annual load of sediment, the Southeast subwatershed is estimated to yield the highest load per acre.

Table 55. Estimated annual loads of bacteria for the full Forest Hill Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	4.97E+10	45.4
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	1.26E+10	11.5
	Other Wildlife	4.72E+10	43.1
	Total	1.10E+11	100

The bacterial load for Forest Hill Lake is largely split between that originating from farm animals in the Northeastern subwatershed and from wildlife in the large expanses of forested land throughout the total watershed. Approximately 11.5% of the bacterial load is also estimated to originate in urbanized areas.

Table 56. Estimated annual loads of bacteria by subwatershed in the Forest Hill Lake watershed

Category	Description	Full Watershed %	Northeast %	Northwest %	Southeast %	Southwest %
Fecal Coliform	Farm Animals and Waterfowl	45	58	0	0	0
	WWTP	0	0	0	0	0
	Septic Systems	0	0	0	0	0
	Urban Areas	12	6	0	99	26
	Other Wildlife	43	37	100	1	74
	Total (organisms)	1.10E+11	8.63E+10	1.07E+10	3.05E+10	4.65E+09

GORDON LAKES

The full Gordon Lakes watershed spans an area of approximately 667 acres. The lower lake features a surface area of approximately 13.8 acres, while the smaller upper lake features a surface area of approximately 4.77 acres (most of which Model My Watershed classifies as wetland rather than open water). The following modeling will be focused on the larger lower lake; however, the upper subwatershed largely drains into the upper lake, and the results of modeling for this subwatershed can mostly be seen as an estimate for the watershed-based nutrients the upper lake receives.

The total Gordon Lakes watershed contains the watersheds of Algonquin Waters and Post Brook Farms Lake. Most of the area contains forests and wetlands, with approximately 15% of the area containing urbanized land. The watershed also contains a length of Otterhole Rd. Descriptions of the subwatersheds are as follows:

- **Algonquin:** This is the largest of the Gordon Lakes subwatersheds at approximately 429 acres. In addition to the full watersheds for Algonquin Waters and Post Brook Farms Lake, this subwatershed also contains Newton Dr. and the northern portion of Setting Sun Trail.
- **East:** This approximately 22-acre subwatershed compasses the entire eastern shoreline of the lower lake, as well as the urbanized areas around it and the forested area to the east of Otterhole Rd. The area is mostly classified as forested land.
- **North:** This 5.2-acre subwatershed contains a relatively small area between the Algonquin and Upper subwatersheds. This area is almost evenly split between forested and urbanized land.
- **Northwest:** This approximately 47-acre subwatershed consists largely of a forested area to the west of the lower lake, as well as a small, developed area along Setting Sun Trail.
- **Upper:** As described above, this 161.1-acre subwatershed contains and mostly drains into Upper Gordon Lake. While the area consists mostly of forested areas, it also contains approximately 33.9 acres of

urbanized land, particularly along Otterhole Road.

- **West:** This approximately 3-acre subwatershed contains the urbanized areas along the northwestern edge of the lake, with an approximately half-acre of forested land.

Table 57. Land-use by subwatershed in the Gordon Lakes watershed.

Source	Full Watershed	Algonquin	East	North	Northwest	Upper	West
	Area (acres)						
Open Water	23.1	22.2	0.0	0.0	0.0	0.9	0.0
Hay/Pasture	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
Forest	490.3	303.4	16.3	2.5	41.3	126.3	0.7
Wetland	53.6	53.6	0.0	0.0	0.0	0.0	0.0
Open Land	1.5	1.2	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
Low-Density Mixed	24.0	11.1	1.7	1.0	1.0	8.4	0.5
Medium-Density Mixed	5.4	1.5	0.5	0.5	0.5	2.5	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	69.4	35.6	3.7	1.2	4.0	23.0	1.5
Total	667.3	428.6	22.2	5.2	46.8	161.1	2.7

Table 57 continued. Land-use by subwatershed in the Gordon Lakes watershed.

Source	Full Watershed	Algonquin	East	North	Northwest	Upper	West
	Area (%)						
Open Water	3.5	5.2	0.0	0.0	0.0	0.6	0.0
Hay/Pasture	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
Forest	73.5	70.8	73.4	48.1	88.2	78.4	25.9
Wetland	8.0	12.5	0.0	0.0	0.0	0.0	0.0
Open Land	0.2	0.3	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
Low-Density Mixed	3.6	2.6	7.7	19.2	2.1	5.2	18.5
Medium-Density Mixed	0.8	0.3	2.3	9.6	1.1	1.6	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	10.4	8.3	16.7	23.1	8.5	14.3	55.6
Total	100	100	100	100	100	100	100

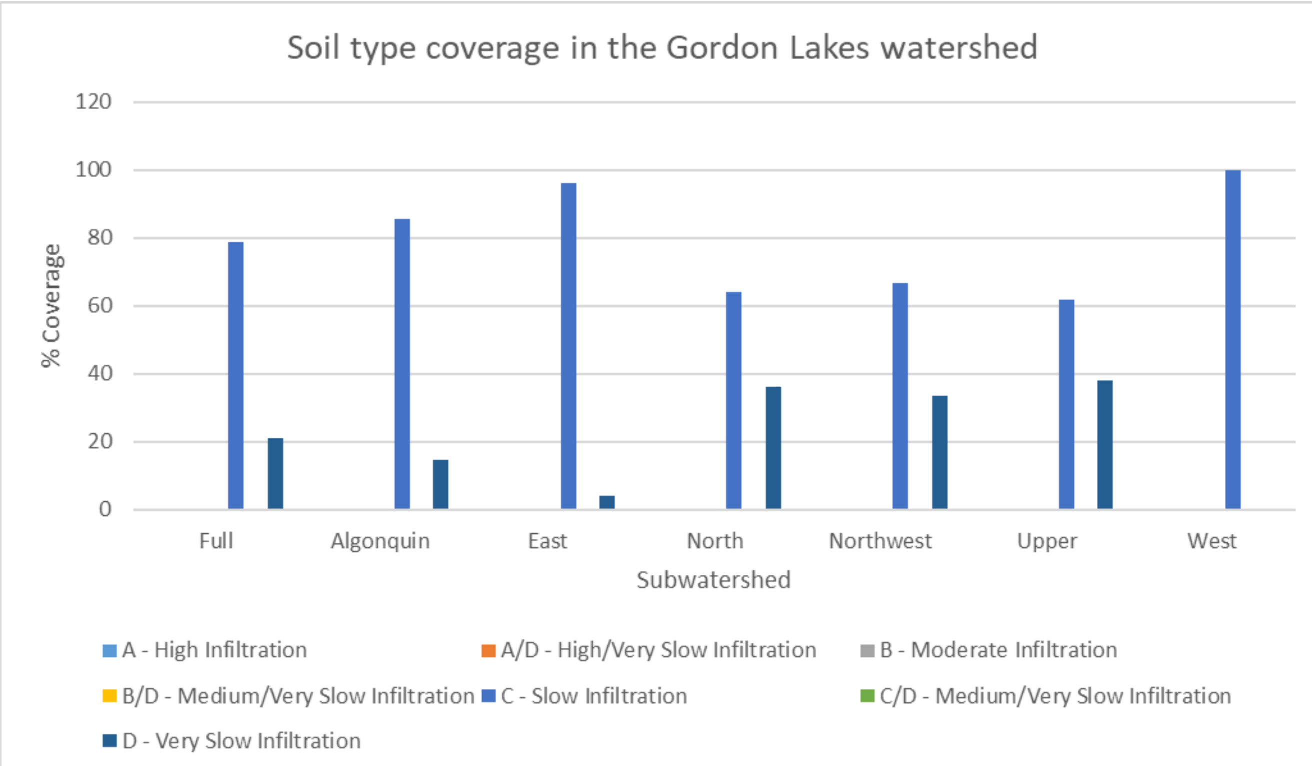


Figure 25. Percent coverage of Gordon Lakes watershed and subwatersheds by different hydrologic soil groups.

The Gordon Lakes Watershed largely consists of the soil-type C – "slow infiltration", although a significant portion also contains soil-type D – "very slow infiltration". This slower infiltration group is most prevalent in the North, Northwest, and Upper subwatersheds. The percent slope in the full Gordon Lakes watershed averages approximately 11%, while the maximum slope measures approximately 36%, occurring in the Algonquin subwatershed.

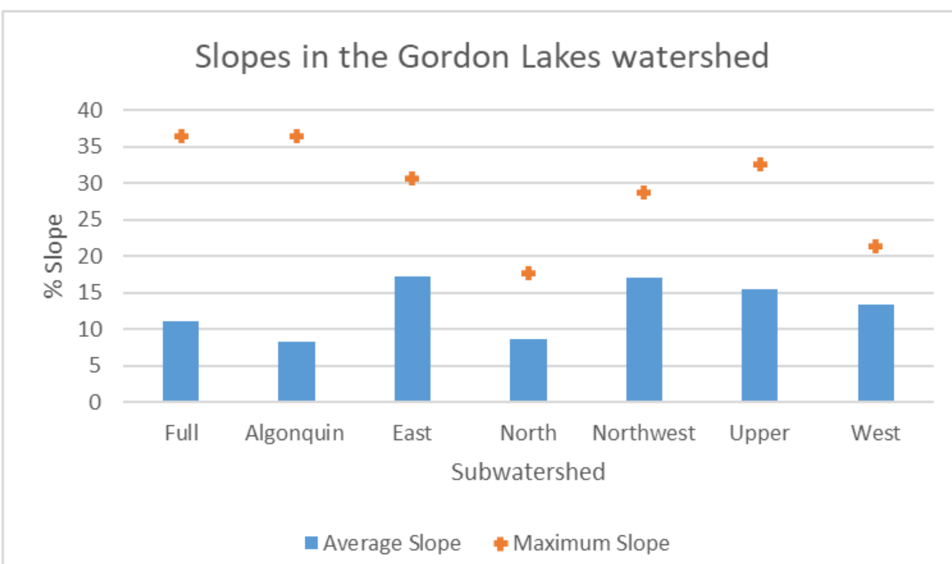


Figure 26. Variation in average and maximum percent slope between subwatersheds in the Gordon Lakes watershed.

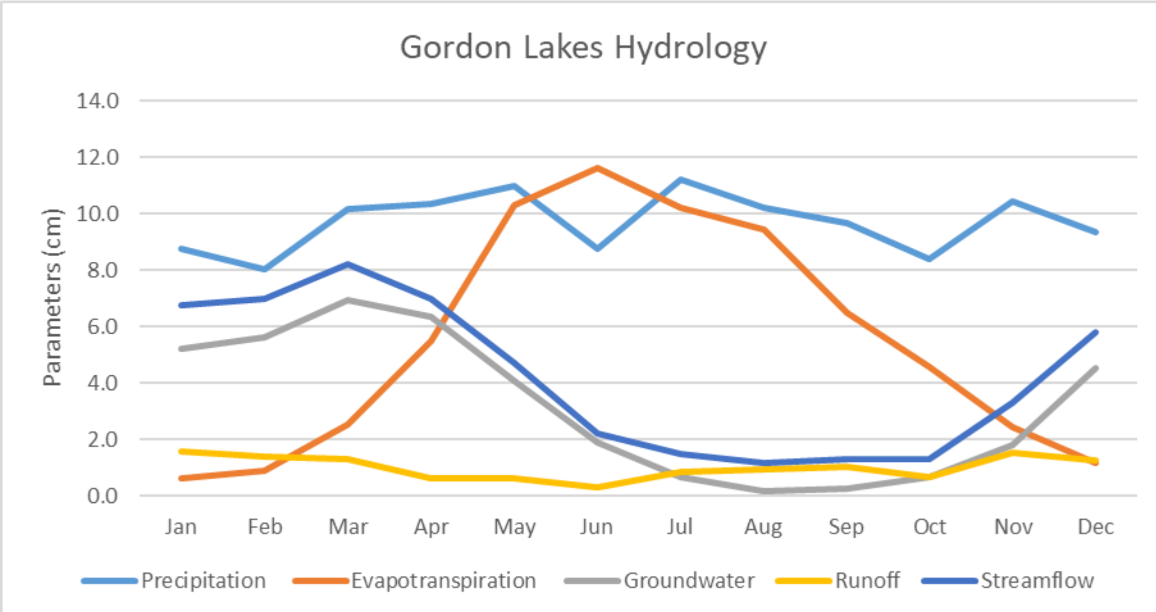


Figure 27. Estimated seasonal changes in hydrology in the Gordon Lakes watershed

Table 58. Total hydrological parameters in the full Gordon Lakes watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.6	5.2	1.6	6.8	2.4
Feb	8.0	0.9	5.6	1.4	7.0	2.7
Mar	10.2	2.5	6.9	1.3	8.2	2.9
Apr	10.4	5.5	6.4	0.6	7.0	2.6
May	11.0	10.3	4.1	0.6	4.7	1.7
Jun	8.8	11.6	1.9	0.3	2.2	0.8
Jul	11.2	10.2	0.7	0.9	1.5	0.5
Aug	10.2	9.5	0.2	1.0	1.2	0.4
Sep	9.7	6.5	0.3	1.0	1.3	0.5
Oct	8.4	4.6	0.7	0.7	1.3	0.5
Nov	10.4	2.5	1.8	1.5	3.3	1.2
Dec	9.3	1.2	4.5	1.3	5.8	2.1
Total	116.4	65.9	38.2	12.1	50.3	1.5

There is an approximately 47% range of difference between modeled runoff trends of each subwatershed. The North subwatershed is estimated to yield the highest runoff throughout the season, likely as a product of poor-draining soils and a relatively high amount of urbanized area. Taking into account direct precipitation and evapotranspiration to and from the lake itself, Lower Gordon Lake is estimated to receive approximately 1,386,808 m³ or 366.4 million gallons of water a year.

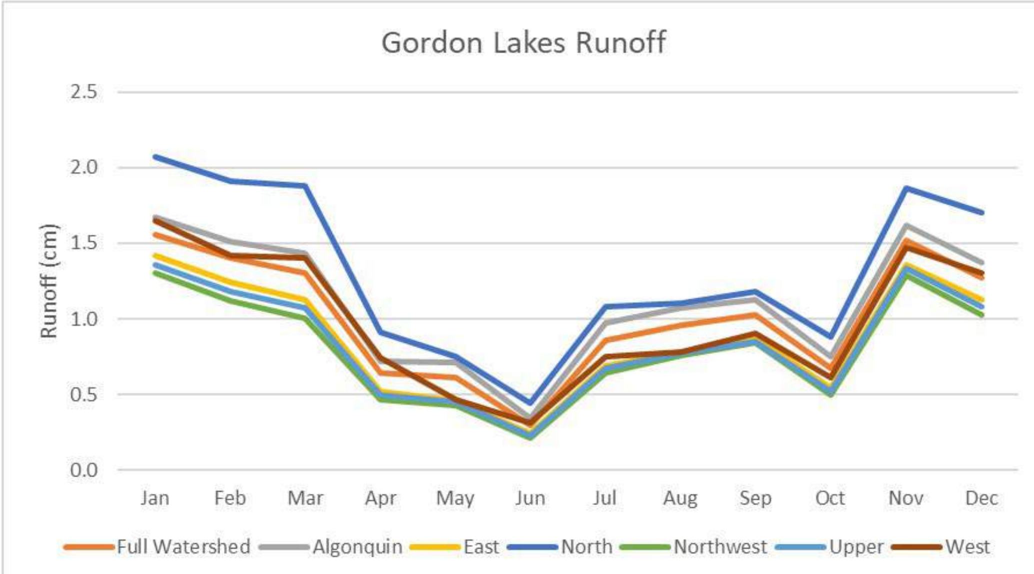


Figure 28. Average monthly runoff occurring in each subwatershed in the Gordon Lakes watershed

As no bathymetry is available for Gordon Lakes, the volume of the lower lake was estimated using depths collected in the field to be approximately 11,272,728 m³ or 29.8 million gallons of water. Using this estimate and the above annual hydraulic input, Lower Gordon Lake has a flushing rate of approximately 0.5, meaning that the lake flushes entirely approximately once every two years. The lake's hydraulic retention period is approximately 713 days. When the changes in hydraulic input each month are taken into account, the annualized retention period and flushing rates follow a pattern similar to the other lakes in this study, with the flushing rate at its lowest and the retention period at its highest typically in August.

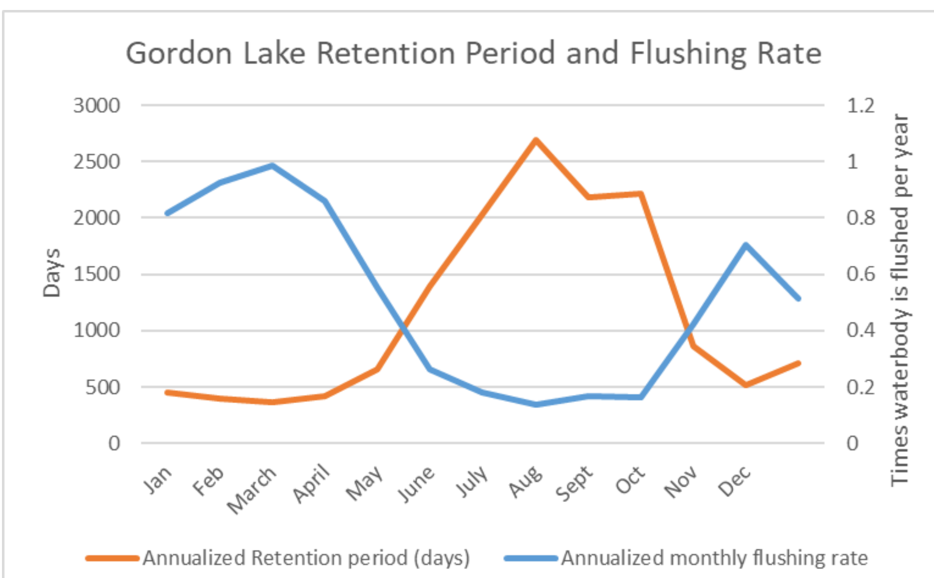


Figure 29. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Lower Gordon Lake, based on variations in hydraulic loads.

Table 59. Estimated annual loads of nitrogen in the total Gordon Lake watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	38.6	2.68
	Wetland	9.6	0.67
	Open Land	0.8	0.06
	Barren Land	0.0	0.00
	Low-Density Mixed	3.0	0.21
	Medium-Density Mixed	3.2	0.22
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	8.7	0.61
Other Sources	Farm Animals and Waterfowl	0.3	0.02
	Stream Bank	0.0	0.00
	Groundwater	323.4	22.44
	Dryfall	110.5	7.67
	Septic Systems	943.0	65.43
	Total	1441.2	100

Table 60. Estimated annual loads of nitrogen by subwatershed in the Gordon Lakes watershed

Category	Description	Full Watershed	Algonquin	East	North	Northwest	Upper	West
		kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	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
	Forest	38.6	25.5	1.3	0.3	3.3	9.4	0.1
	Wetland	9.6	9.5	0.0	0.0	0.0	0.0	0.0
	Open Land	0.8	0.7	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
	Low-Density Mixed	3.0	1.4	0.2	0.1	0.1	1.1	0.1
	Medium-Density Mixed	3.2	0.5	0.3	0.3	0.3	1.3	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	8.7	4.4	0.4	0.2	0.5	3.1	0.2
Other Sources	Farm Animals and Waterfowl	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	323.4	196.8	12.1	2.5	26.3	82.9	1.4
	Dryfall	110.5	.	.	.	.	.	.
	Septic Systems	943.0	452.0	92.4	60.5	87.6	200.7	55.7
	Total (kg)	1441.2	690.7	106.5	63.9	118.0	298.5	57.4
	kg/acre	2.2	1.6	4.8	12.3	2.5	1.9	21.3

A large majority of the nitrogen entering Lower Gordon Lake is due to septic systems, groundwater, and dryfall. Forested land contributed the largest runoff-based nitrogen load in the watershed. On a per-acre basis, the West subwatershed was estimated to contribute the highest amount of nitrogen per acre. This is likely as a product of the relatively high number of septic systems within a small area and the number of systems in this area within 15 m of the lake. As the largest subwatershed, Algonquin yielded the highest overall annual load of nitrogen.

Table 61. Estimated annual loads of phosphorus in the total Gordon Lakes watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	1.71	1.5
	Wetland	0.38	0.3
	Open Land	0.03	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.23	0.2
	Medium-Density Mixed	0.23	0.2
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.66	0.6
Other Sources	Farm Animals and Waterfowl	0.11	0.1
	Stream Bank	1.00	0.9
	Groundwater	9.11	8.2
	Dryfall	0.55	0.5
	Septic Systems	97.37	87.4
	Total	111.38	100.0

Table 62. Estimated annual loads of phosphorus by subwatershed in the Gordon Lakes watershed

Category	Description	Full Watershed kg	Algonquin kg	East kg	North kg	Northwest kg	Upper kg	West kg
Runoff	Hay/Pasture	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
	Forest	1.71	0.97	0.14	0.02	0.40	0.80	0.00
	Wetland	0.38	0.34	0.00	0.00	0.00	0.00	0.00
	Open Land	0.03	0.02	0.00	0.00	0.00	0.01	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.23	0.09	0.02	0.02	0.01	0.07	0.01
	Medium-Density Mixed	0.23	0.03	0.03	0.03	0.03	0.08	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.66	0.30	0.04	0.02	0.05	0.20	0.02
Other Sources	Farm Animals	0.11	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	9.11	5.03	0.32	0.06	0.69	1.28	0.04
	Dryfall	0.55	.	.	.	.	.	.
	Septic Systems	97.37	32.48	31.92	16.80	16.80	5.59	15.96
	Total (kg)	111.38	39.26	32.47	16.95	17.98	8.03	16.03
	kg/acre	0.17	0.09	1.46	3.26	0.38	0.05	5.94

Similar to its nitrogen load, a large majority of the phosphorus entering Lower Gordon Lake is estimated to originate from septic systems throughout the watershed. Groundwater was also estimated to be a large influence, with forested land contributing the most runoff-based phosphorus. The Algonquin subwatershed yielded the overall highest annual phosphorus load of the lake's subwatersheds, however the North subwatershed yielded the highest annual load per acre.

Anoxia was observed in Lower Gordon Lake during the July event; however this was only within the bottom-most 0.4 m of the water column and did not coincide with a deep phosphorus concentration that was higher than that obtained at the surface. An internal loading model was run with the assumption that increased deep phosphorus loading doesn't typically occur in Lower Gordon Lake; water quality monitoring in future years on at least a monthly basis would be needed to confirm this, however. The internal phosphorus load during a year when no increased loading occurs is estimated to be approximately 5.1 kg/yr. During a growing season when a greater portion of the water column is anoxic, however, this loading may be an order of magnitude higher.

Table 63 below displays the external and internal loads of phosphorus for Lower Gordon Lake, as well as the grand total, which is estimated to be approximately 116.51 kg/year. External loading is estimated to dominate the total load, representing approximately 96% of all phosphorus entering the lake. Even if the lake experiences anoxia and a larger internal load occurs, external loading from the watershed would still likely dominate loading processes.

Table 63. Total estimated annual phosphorus loads for Lower Gordon Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	111.38
Internal	5.13
Total	**116.51**

Table 64. Estimated annual loads of sediment in the total Gordon Lake watershed

Category	Description	Sediment	
		kgx1000	%
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.120	6.4
	Wetland	0.010	0.5
	Open Land	0.010	0.5
	Barren Land	0.000	0.0
	Low-Density Mixed	0.040	2.1
	Medium-Density Mixed	0.060	3.2
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.110	5.9
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	1.517	81.3
	Groundwater	0.000	0.0
	Dryfall	0.000	0.0
	Septic Systems	0.000	0.0
	Total	1.867	100.0

Table 65. Estimated annual loads of sediment by subwatershed in the Gordon Lake watershed

Category	Description	Full Watershed kg x 1000	Algonquin kg x 1000	East kg x 1000	North kg x 1000	Northwest kg x 1000	Upper kg x 1000	West kg x 1000
Runoff	Hay/Pasture	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
	Forest	0.120	0.030	0.070	0.000	0.220	0.050	0.000
	Wetland	0.010	0.000	0.000	0.000	0.000	0.000	0.000
	Open Land	0.010	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
	Low-Density Mixed	0.040	0.010	0.010	0.010	0.010	0.000	0.000
	Medium-Density Mixed	0.060	0.000	0.020	0.020	0.020	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.110	0.030	0.020	0.010	0.020	0.010	0.010
Other Sources	Farm Animls and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	1.517	0.408	0.007	0.004	0.001	0.020	0.004
	Groundwater	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Dryfall	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
	Total (kgx1000)	1.867	0.478	0.127	0.044	0.271	0.080	0.014
	kg/acre	2.798	1.115	5.721	8.462	5.791	0.497	5.185

The annual sediment load estimated to enter Gordon Lakes largely occurs as runoff from forested areas and low-density open space and as erosion from stream banks. The Northern subwatershed was estimated to yield the highest annual sediment load per acre, modeled to largely originate as runoff from urbanized land.

Table 66. Estimated annual loads of bacteria in the total Gordon Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals	1.44E+08	0.1
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	3.79E+10	17.8
	Wildlife	1.75E+11	82.1
	Total	2.13E+11	100

Table 67. Estimated annual loads of bacteria by subwatershed in the Gordon Lake watershed

Category	Description	Full Watershed %	Algonquin %	East %	North %	Northwest %	Upper %	West %
Fecal Coliform	Farm Animals	0.1	0	0	0	0	0	0
	WWTP	0	0	0	0	0	0	0
	Septic Systems	0	0	0	0	0	0	0
	Urban Areas	17.8	11.2	42.3	84.1	10	29.2	93.1
	Wildlife	82.1	88.8	57.7	15.9	90	70.8	6.9
	Total (organisms)	2.13E+11	1.22E+11	1.01E+10	5.55E+09	1.63E+10	6.36E+10	3.84E+09

Due to its largely forested watershed, a majority of the bacteria in the Gordon Lakes watershed originates from wildlife. Urban areas were also estimated to contribute to approximately 18% of the total bacteria load.

HIGH CREST LAKE

High Crest Lake is located in the southern portion of the township and features a surface area of approximately 39.3 acres. Its approximately 313-acre watershed is over 55% forested, with urbanized land-use comprising approximately 36% of the entire area. As with many of the other lakes in this study, most of the urbanized land is located in the area immediately surrounding the lake. High Crest Lake receives flow via small inlets that drain the

Apshawa Preserve to the north. Its outlet stream continues south under Rt. 23 before its confluence with the Pequannock River. Descriptions of the lake's subwatersheds are as follows:

- **Apshawa Preserve:** This approximately 137-acre subwatershed is located at the northern end of High Crest Lake and contains a portion of the Apshawa Nature Preserve and the lake's primary inlet. The area is over 75% forested, with 15 acres of urbanized land along the lake's shoreline.
- **East:** This approximately 71-acre subwatershed contains the lake's swimming beach, as well as the Apshawa Elementary School. The subwatershed stretches to the northern side of Macopin Road, and is largely urbanized, with approximately 23% of the area also consisting of forested land.
- **North:** This 14.6-acre subwatershed is approximately half comprised of urbanized land and half comprised of forested areas to the north and contains a portion of the Apshawa Nature Preserve.
- **Northwest:** This 35.8-acre subwatershed consists mainly of forested land, stretching north into the Apshawa Nature Preserve. A minor inlet also enters the lake in this subwatershed.
- **West:** The subwatershed covers an area of approximately 54 acres, consisting mainly of urbanized land-use. It also contains the lake's dam.

Table 68. Land-use by subwatershed in the High Crest Lake watershed.

Source	Full Watershed	Apshawa Preserve	East	North	Northwest	West
	Area (acres)					
Open Water	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	1.2	0.0	1.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0
Forest	177.7	107.5	16.3	7.2	32.6	14.3
Wetland	20.8	14.3	5.2	0.0	1.0	0.5
Open Land	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
Low-Density Mixed	31.4	2.7	13.3	2.5	1.0	11.9
Medium-Density Mixed	9.6	0.2	4.4	1.2	0.0	3.5
High-Density Mixed	1.0	0.0	0.5	0.0	0.0	0.5
Low-Density Open Space	70.7	12.1	30.1	3.7	1.2	23.5
Total	312.4	136.8	70.8	14.6	35.8	54.2

Table 68 continued. Land-use by subwatershed in the High Crest Lake watershed.

Source	Full Watershed	Apshawa Preserve	East	North	Northwest	West
			Area (%)			
Open Water	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.4	0.0	1.4	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0
Forest	56.9	78.6	23.0	49.3	91.1	26.4
Wetland	6.7	10.5	7.3	0.0	2.8	0.9
Open Land	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
Low-Density Mixed	10.1	2.0	18.8	17.1	2.8	22.0
Medium-Density Mixed	3.1	0.1	6.2	8.2	0.0	6.5
High-Density Mixed	0.3	0.0	0.7	0.0	0.0	0.9
Low-Density Open Space	22.6	8.8	42.5	25.3	3.4	43.4
Total	100	100	100	100	100	100

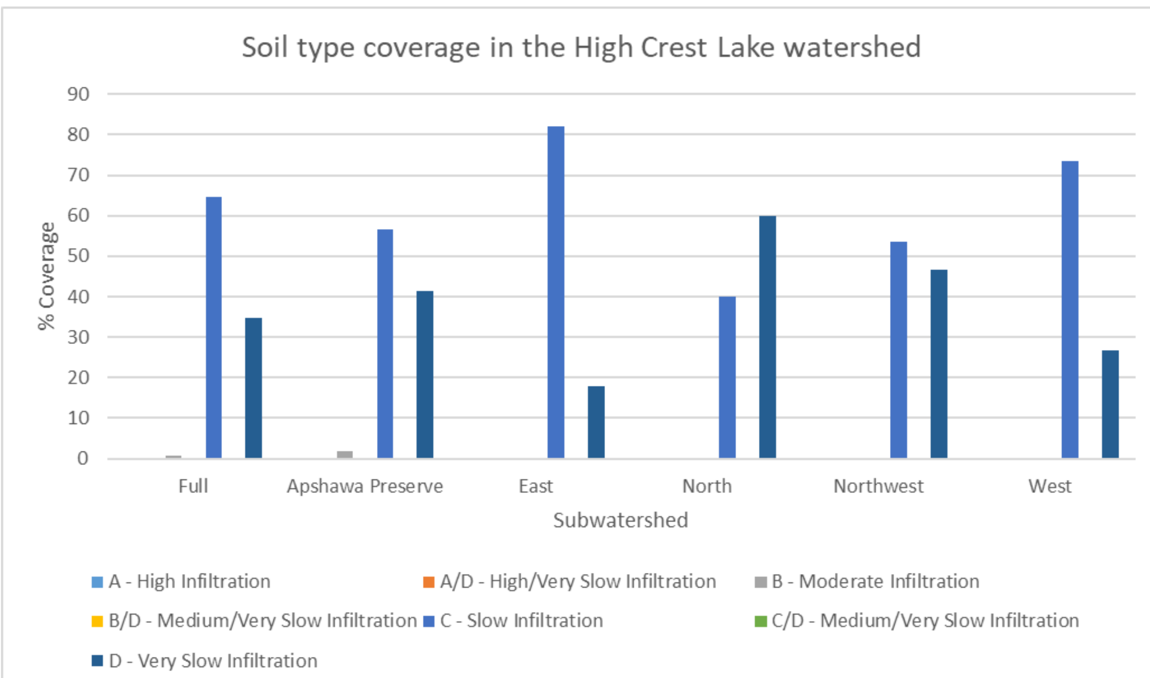


Figure 29. Percent coverage of High Crest watershed and subwatersheds by different hydrologic soil groups.

High Crest Lake Watershed is almost entirely covered by slower infiltration soil groups, with the North subwatershed in particular featuring approximately 60% coverage by soil group "D – Very Slow Infiltration". As such, High Crest Lake's watershed is likely prone to increased runoff. The average slope for the full watershed is approximately 12%, with a maximum slope of approximately 51% occurring in the Apshawa subwatershed. These areas of steeper slopes are likely to yield larger amounts of soil erosion.

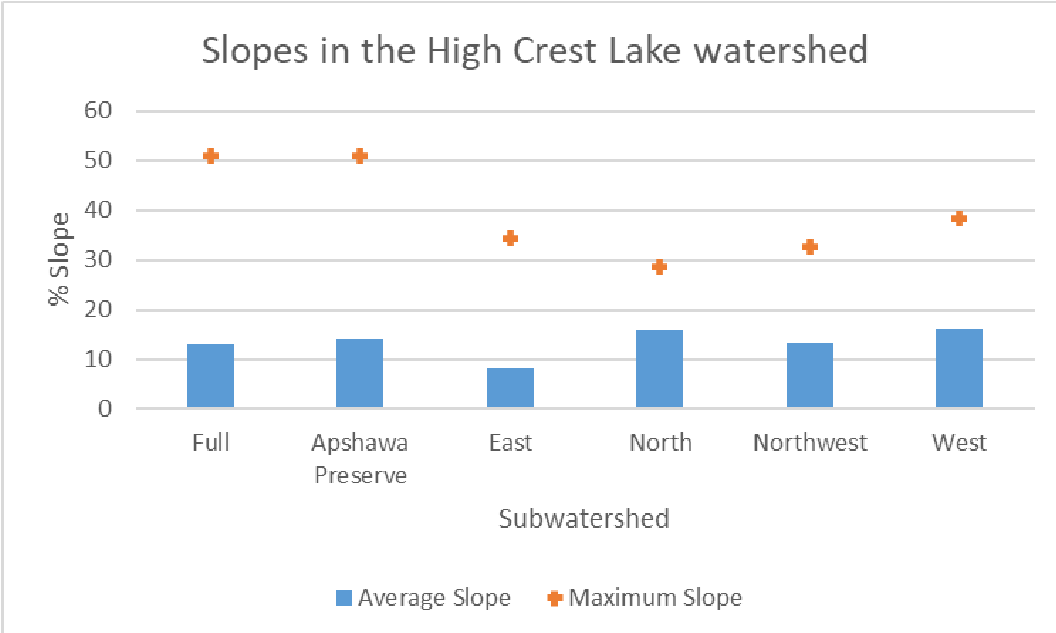


Figure 30. Variation in average and maximum percent slope between subwatersheds in the High Crest Lake watershed.

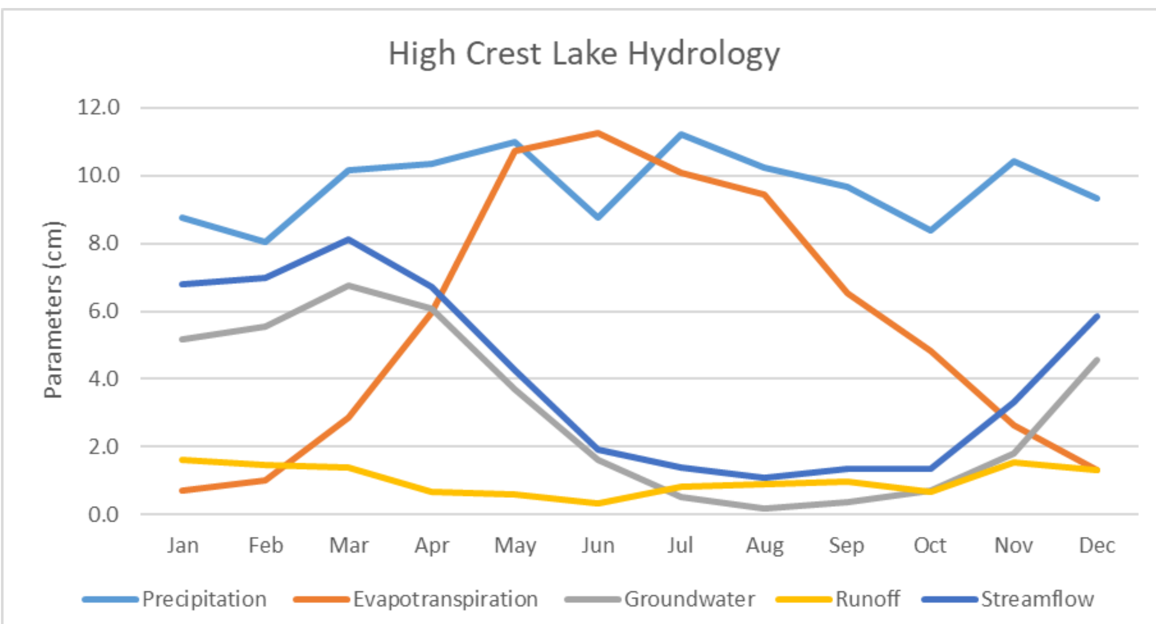


Figure 31. Estimated seasonal changes in hydrology in the High Crest Lake watershed

Table 69. Total hydrological parameters in the full High Crest Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.2	1.6	6.8	1.1
Feb	8.0	1.0	5.6	1.5	7.0	1.3
Mar	10.2	2.9	6.8	1.4	8.1	1.4
Apr	10.4	6.0	6.1	0.7	6.7	1.2
May	11.0	10.7	3.7	0.6	4.3	0.7
Jun	8.8	11.3	1.6	0.3	1.9	0.3
Jul	11.2	10.1	0.5	0.8	1.4	0.2
Aug	10.2	9.4	0.2	0.9	1.1	0.2
Sep	9.7	6.5	0.4	1.0	1.3	0.2
Oct	8.4	4.8	0.7	0.7	1.4	0.2
Nov	10.4	2.7	1.8	1.5	3.3	0.6
Dec	9.3	1.3	4.6	1.3	5.9	1.0
Total	116.4	67.3	36.9	12.2	49.1	0.7

The subwatersheds of High Crest Lake vary by as much as 42% over the course of an average year. The North subwatershed features the highest runoff rate for most of the year, likely due to the high rate of urbanized area in this area. The Northwest subwatershed is modeled to feature the highest runoff during the later summer months. When direct precipitation and evaporation to and from the lake itself is factored in, High Crest Lake is estimated to receive approximately 699,003 m³ or 184.7 million gallons of water a year.

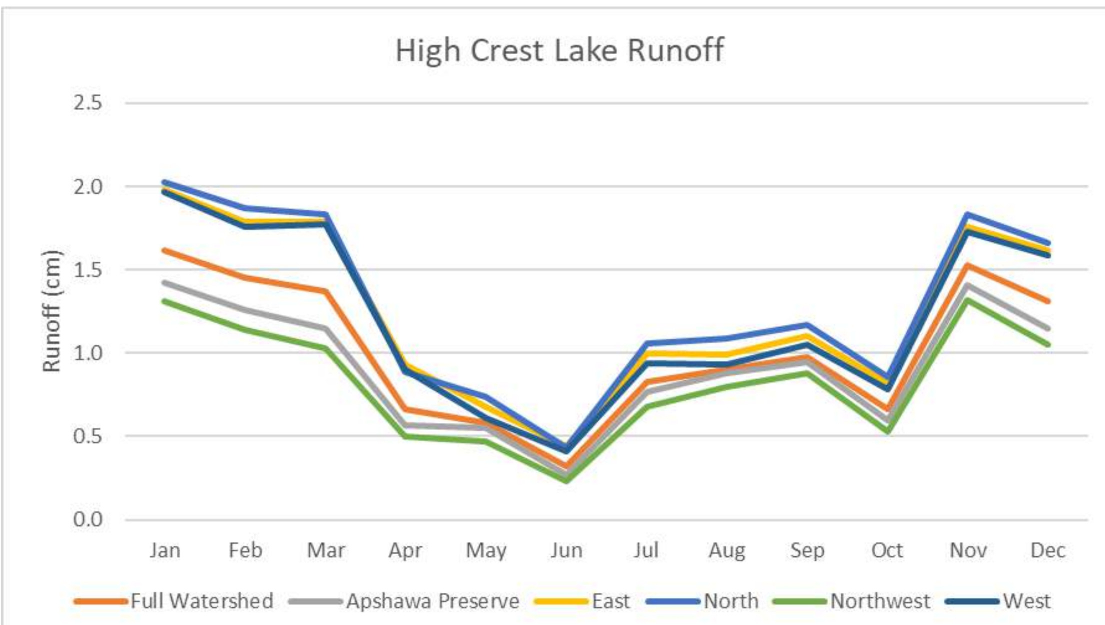


Figure 32. Average monthly runoff occurring in each subwatershed in the High Crest Lake watershed

No bathymetric data could be obtained for High Crest Lake; based on depths collected during field events, the estimated volume is approximately 405,132 m³ or 107 million gallons. Using this number and the hydraulic input estimate above, the lake is estimated to flush completely approximately 1.7 times each year, with a hydraulic retention period of approximately 211.7 days. When examined on a monthly basis, the annualized monthly flushing rate is estimated to typically be at its lowest during August. During this time, the annualized retention period is estimated to increase to approximately 847.8 days.

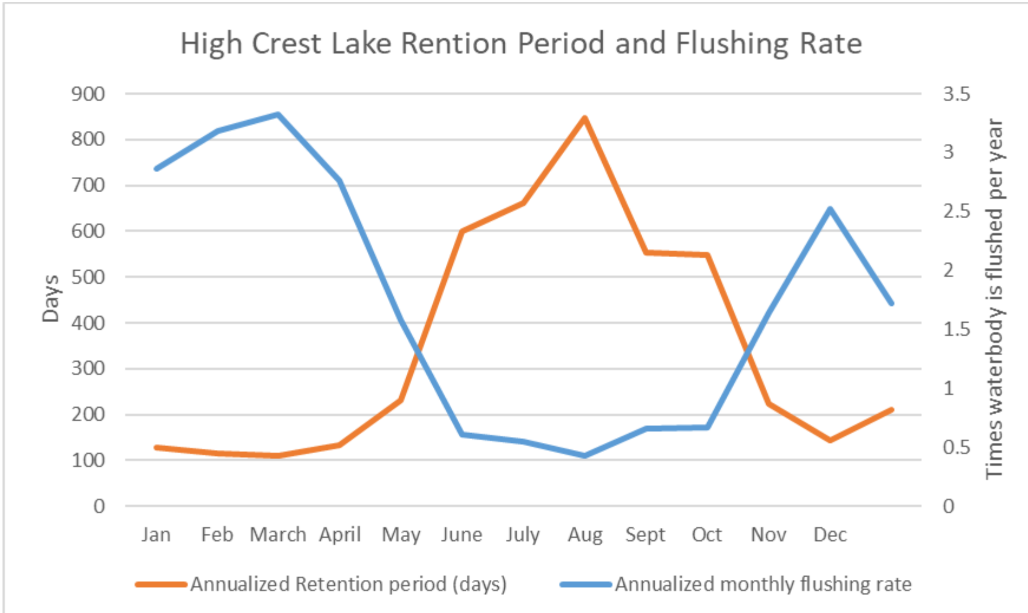


Figure 33. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for High Crest Lake, based on variations in hydraulic loads.

Table 70. Estimated annual loads of nitrogen in the total High Crest Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.5	0.04
	Cropland	0.0	0.00
	Forest	14.3	1.14
	Wetland	4.4	0.35
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	4.3	0.34
	Medium-Density Mixed	6.0	0.48
	High-Density Mixed	0.6	0.05
	Low-Density Open Space	9.6	0.77
Other Sources	Farm Animals and Waterfowl	0.3	0.02
	Stream Bank	1.0	0.08
	Groundwater	157.8	12.59
	Dryfall	57.3	4.57
	Septic Systems	997.3	79.57
	Total	1253.4	100

Table 71. Estimated annual loads of nitrogen by subwatershed in the High Crest Lake watershed

Category	Description	Full Watershed kg	Apshawa Preserve kg	East kg	North kg	Northwest kg	West kg
Runoff	Hay/Pasture	0.54	0.00	0.44	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	14.28	8.21	1.19	0.82	2.49	1.31
	Wetland	4.35	2.55	1.26	0.00	0.24	0.09
	Open Land	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
	Low-Density Mixed	4.27	0.32	1.92	0.31	0.14	1.62
	Medium-Density Mixed	6.03	0.13	2.61	0.35	0.00	3.28
	High-Density Mixed	0.62	0.00	0.29	0.00	0.00	0.47
	Low-Density Open Space	9.61	1.41	4.34	0.47	0.17	3.20
Other Sources	Farm Animals and Waterfowl	0.27	0.00	0.00	0.00	0.00	0.00
	Stream Bank	1.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	157.80	66.06	34.29	7.47	19.81	27.55
	Dryfall	57.3	.	.	.	.	.
	Septic Systems	997.3	92.5	420.5	68.5	23.9	393.4
	Total (kg)	1253.44	171.17	466.80	77.90	46.74	430.90
	kg/acre	4.0	1.3	6.6	5.3	1.3	8.0

Given the development in the High Crest Lake watershed, particularly in areas closest to the lake, septic system influence is estimated to be the largest contributor of nitrogen, with groundwater also yielding a relatively high load. Runoff-based nitrogen loading was largely comprised of runoff from forested and urbanized land. The Eastern subwatershed is estimated to yield the highest overall estimated yearly amount of nitrogen, while the Western Subwatershed is estimated to yield the largest load/acre.

Table 72 Estimated annual loads of phosphorus in the total High Crest Lake watershed

Category	Description	Total Phosphorus kg	Total Phosphorus %
Runoff	Hay/Pasture	0.22	0.31
	Cropland	0.00	0.00
	Forest	1.77	2.46
	Wetland	0.22	0.31
	Open Land	0.00	0.00
	Barren Land	0.00	0.00
	Low-Density Mixed	0.44	0.61
	Medium-Density Mixed	0.59	0.82
	High-Density Mixed	0.06	0.08
	Low-Density Open Space	1.00	1.39
Other Sources	Farm Animals and Waterfowl	0.09	0.13
	Stream Bank	0.00	0.00
	Groundwater	3.97	5.51
	Dryfall	0.28	0.40
	Septic Systems	63.36	87.99
	Total	72.01	100.00

Table 73. Estimated annual loads of phosphorus by subwatershed in the High Crest Lake watershed

Category	Description	Full Watershed kg	Apshawa Preserve kg	East kg	North kg	Northwest kg	West kg
Runoff	Hay/Pasture	0.22	0.00	0.18	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	1.77	0.68	0.09	0.05	0.25	0.10
	Wetland	0.22	0.09	0.07	0.00	0.01	0.01
	Open Land	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
	Low-Density Mixed	0.44	0.02	0.21	0.03	0.01	0.17
	Medium-Density Mixed	0.59	0.01	0.27	0.04	0.00	0.33
	High-Density Mixed	0.06	0.00	0.03	0.00	0.00	0.05
	Low-Density Open Space	1.00	0.10	0.47	0.05	0.02	0.34
Other Sources	Farm Animals and Waterfowl	0.09	0.00	0.00	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	3.97	1.16	0.90	0.20	0.52	0.72
	Dryfall	0.28	.	.	.	.	.
	Septic Systems	63.36	1.61	27.72	12.60	2.52	21.00
	Total (kg)	72.01	3.67	29.94	12.97	3.33	22.72
	kg/acre	0.23	0.03	0.42	0.89	0.09	0.42

As with nitrogen, a majority of High Crest Lake's estimated annual phosphorus load originates from septic tanks in the watershed. The Eastern subwatershed yielded the largest overall phosphorus load, while the Northern subwatershed yielded the highest load/acre.

Measurements collected during the field events of 2022 indicated that the bottom of High Crest Lake was anoxic both during the May event and the late-July event. Both instances of anoxia coincided with deep water concentrations of total phosphorus that were higher than those collected at the surface, particularly during the July event. Internal loading was modeled assuming an area of 5% of the lake bottom being anoxic mid-May through mid-June and 10% of the lake bottom being anoxic from mid-June through August.

When oxic loading in other areas of the lake and other points in the growing season was taken into account, High Crest Lake is estimated to have an annual internal load of approximately 22.48 kg/yr. If the lake bottom were to stay sufficiently oxygenated for the entirety of the growing season, the internal load would instead be approximately 14.89 kg/yr.

Table 74 below displays the external and internal loads of phosphorus for High Crest Lake, as well as the grand total, which is estimated to be approximately 94.49 kg/year. The total estimated annual phosphorus load is dominated by inputs from external sources, which make up over 75% of the total annual load.

Table 74: Total estimated annual phosphorus loads for High Crest Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	72.01
Internal	22.48
Total	**94.49**

Table 75. Estimated annual loads of sediment in the High Crest Lake watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.020	0.6
	Cropland	0.000	0.0
	Forest	0.960	28.1
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.160	4.7
	Medium-Density Mixed	0.300	8.8
	High-Density Mixed	0.030	0.9
	Low-Density Open Space	0.370	10.8
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	1.578	46.2
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	3.418	100.0

Table 76. Estimated annual loads of sediment by subwatershed in the High Crest Lake watershed

Category	Description	Full Watershed kg x 1000	Apshawa Preserve kg x 1000	East kg x 1000	North kg x 1000	Northwest kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.020	0.000	0.020	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.960	0.140	0.030	0.010	0.110	0.030
	Wetland	0.000	0.000	0.010	0.000	0.000	0.000
	Open Land	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
	Low-Density Mixed	0.160	0.000	0.080	0.010	0.010	0.070
	Medium-Density Mixed	0.300	0.000	0.140	0.020	0.000	0.170
	High-Density Mixed	0.030	0.000	0.020	0.000	0.000	0.020
	Low-Density Open Space	0.370	0.020	0.180	0.020	0.010	0.130
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	1.578	0.086	0.026	0.008	0.002	0.005
	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)	3.418	0.246	0.506	0.068	0.132	0.425
	kg/acre	10.9	1.8	7.1	4.7	3.7	7.8

A majority of sediment entering High Crest Lake originates as streambank erosion. Runoff from forested and urbanized areas are also notable contributors to the annual sediment load. The East subwatershed was estimated to generate the largest amount of sediment in an average year, while the West subwatershed yields the largest amount of sediment per acre. Most of this sediment in these subwatersheds is modeled to originate from urbanized land.

Most of the bacterial loading to High Crest Lake is estimated to originate from urban areas or from wildlife within the watershed. The Eastern subwatershed is estimated to produce the highest bacterial load.

Table 77. Estimated annual loads of bacteria in the total High Crest Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.26E+08	0.1
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	1.13E+11	64.0
	Other Wildlife	6.34E+10	35.9
	Total	1.77E+11	100

Table 78. Estimated annual loads of bacteria by subwatershed in the High Crest Lake watershed

Category	Description	Full Watershed %	Apshawa Preserve %	East %	North %	Northwest %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.1	0.0	0.0	0.0	0.0	0.0
	WWTP	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	64.0	9.0	94.4	82.4	2.8	94.3
	Other Wildlife	35.9	91.0	5.6	17.6	97.2	5.7
	Total (organisms)	1.77E+11	4.21E+10	1.03E+11	1.45E+10	1.20E+10	9.05E+10

JOHNS LAKE

The watershed for Johns Lake covers an area of approximately 206.4 acres, while the lake itself has a surface area of approximately 2.3 acres. While the watershed is mostly (approximately 78%) forested, approximately 20% of the watershed is urbanized. Forest Hill lake and its watershed are present in Johns Lake's watershed, as are a length of Germantown Road and Forest Hill Dr. The lake's outlet travels south towards its confluence with the Pequannock River. Descriptions of Johns Lake's subwatersheds are as follows:

- **North:** This is the largest of Johns Lake's subwatersheds at approximately 192 acres. It contains the lake's main inlet, as well as Forest Hill Lake and its watershed. The subwatershed is approximately 77% forested, with approximately 21% of the area being urbanized.
- **Southeast:** This 3.4-acre subwatershed contains the lake's beach and is modeled as being almost entirely forested with a small amount of hay/pasture land also present. Some camp buildings are present as well.
- **Southwest:** This 12-acre subwatershed is also modeled as being largely forested with only half an acre of urbanized landcover present. Some camp structures are present, as are some residential homes to the far west, near Peach Ln.

Table 79. Land-use by subwatershed in the Johns Lake watershed.

Source	Full Watershed	North	Southeast	Southwest
	Area (acres)			
Open Water	0.9	0.9	0.0	0.0
Hay/Pasture	3.7	3.0	0.7	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	161.1	148.5	2.7	11.4
Wetland	0.0	0.0	0.0	0.0
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.2	0.2	0.0	0.0
Low-Density Mixed	17.1	16.6	0.0	0.2
Medium-Density Mixed	4.4	4.4	0.0	0.2
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	19.0	18.8	0.0	0.2
Total	206.4	192.4	3.4	12.0

Table 79 continued. Land-use by subwatershed in the Johns Lake watershed.

Source	Full Watershed	North	Southeast	Southwest
	Area (%)			
Open Water	0.4	0.5	0.0	0.0
Hay/Pasture	1.8	1.6	20.6	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	78.1	77.2	79.4	95.0
Wetland	0.0	0.0	0.0	0.0
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.1	0.1	0.0	0.0
Low-Density Mixed	8.3	8.6	0.0	1.7
Medium-Density Mixed	2.1	2.3	0.0	1.7
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	9.2	9.8	0.0	1.7
Total	100.0	100.0	100.0	100.0

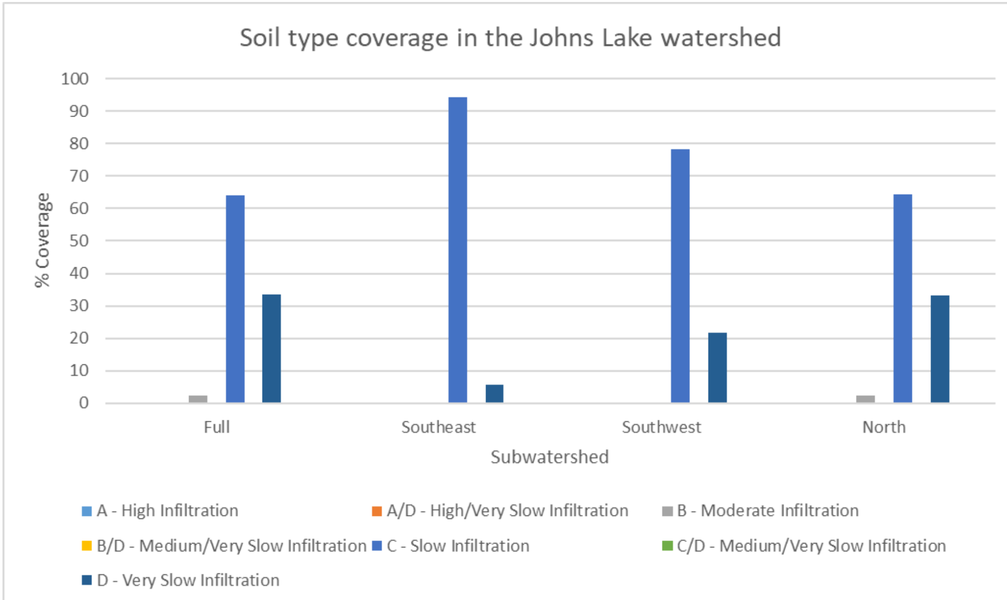


Figure 34. Percent coverage of Johns Lake watershed and subwatersheds by different hydrologic soil groups.

As with many of the other watersheds in West Milford, Johns Lake watershed largely consists of the C and D soil types, indicating that water typically does not quickly infiltrate into the soil and instead has a high potential for runoff. The Northern subwatershed features the highest amount of very slow infiltrating soil, but however also contains a small amount of type B soil ("moderate infiltration"). The average percent slopes are overall somewhat low, with an average of approximately 15% for the full watershed. The maximum percent slope, however, is approximately 51 percent, occurring in the north subwatershed

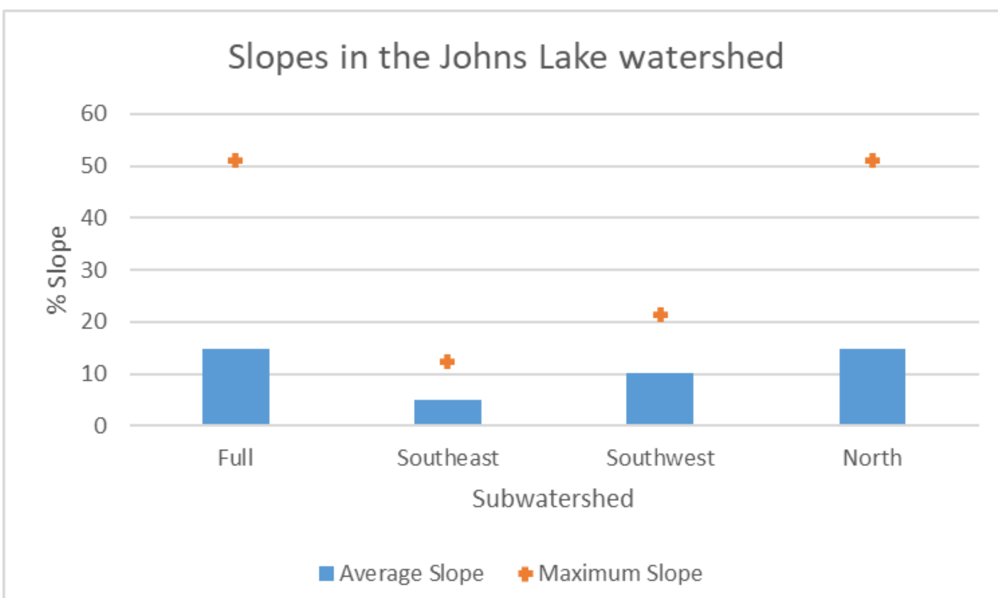


Figure 35. Variation in average and maximum percent slope between subwatersheds in the Johns Lake watershed.

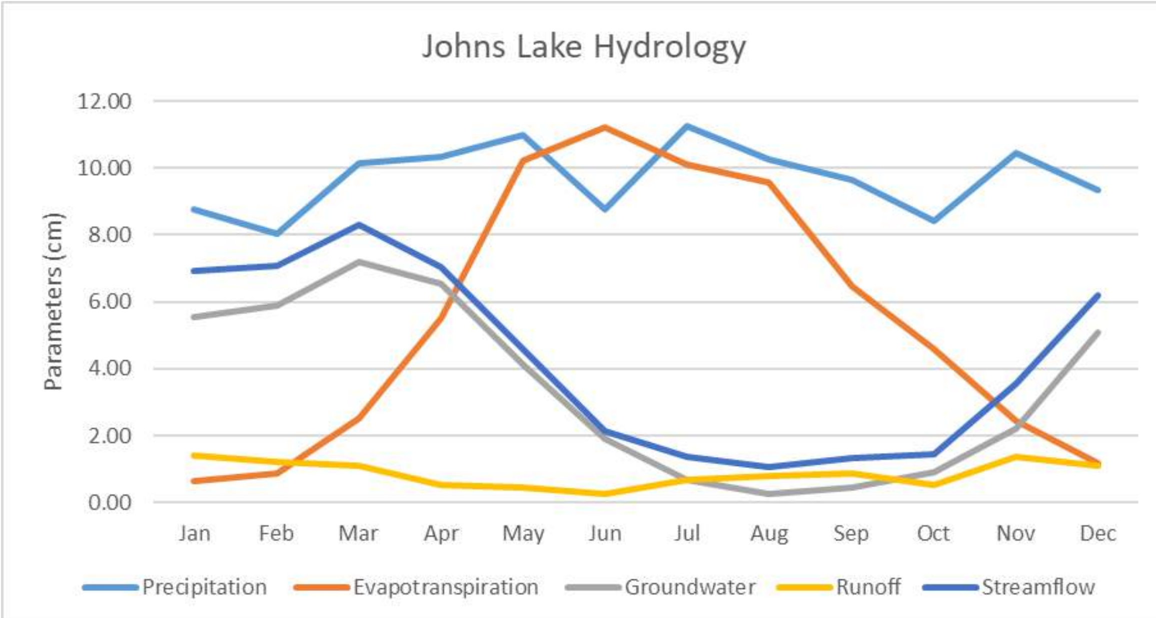


Figure 36. Estimated seasonal changes in hydrology in the Johns Lake watershed

Table 80. Total hydrological parameters in the full Johns Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.75	0.62	5.54	1.39	6.93	0.76
Feb	8.04	0.87	5.87	1.22	7.09	0.86
Mar	10.16	2.50	7.19	1.11	8.29	0.91
Apr	10.35	5.49	6.54	0.51	7.05	0.80
May	10.98	10.23	4.13	0.46	4.59	0.51
Jun	8.76	11.20	1.92	0.24	2.15	0.24
Jul	11.24	10.12	0.67	0.69	1.36	0.15
Aug	10.24	9.57	0.25	0.79	1.04	0.11
Sep	9.66	6.48	0.46	0.87	1.32	0.15
Oct	8.40	4.57	0.89	0.54	1.43	0.16
Nov	10.44	2.45	2.20	1.36	3.55	0.40
Dec	9.34	1.16	5.08	1.11	6.19	0.68
Total	116.4	65.3	40.7	10.3	51.0	0.5

The three subwatersheds are very similar in regard to runoff throughout the year, likely due to their largely forested land-cover and relatively similar soil compositions. The Southeast subwatershed features the highest runoff throughout the season. When direct precipitation and evapotranspiration to the pond itself are considered, Johns Lake is estimated to receive approximately 430,906 m³ or approximately 113.8 million gallons of water a year.

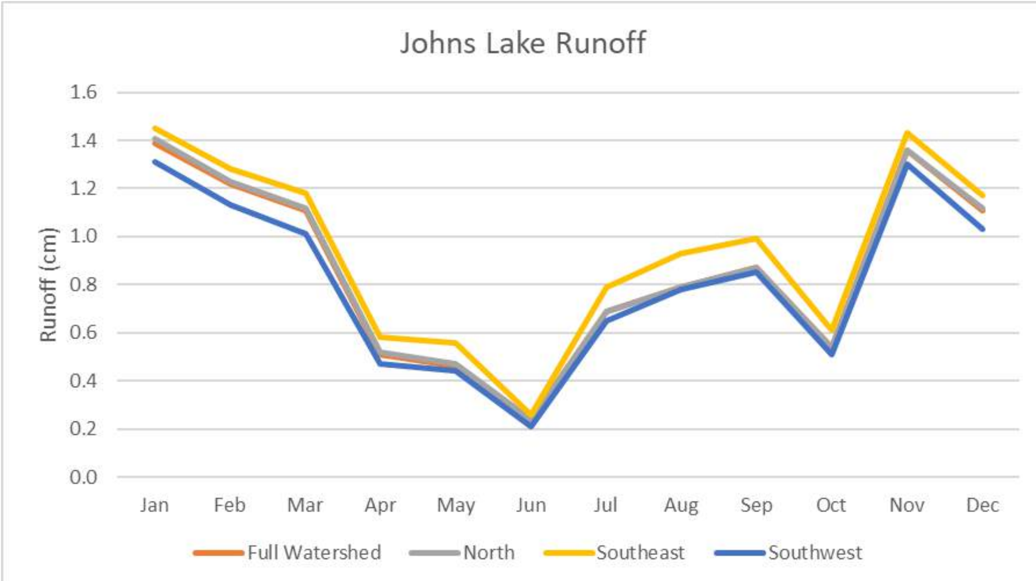


Figure 37. Average monthly runoff occurring in each subwatershed in the Johns Lake watershed

As with several of the other waterbodies in this study, bathymetric data was not available for Johns Lake. An estimate of the pond's volume yielded approximately 13,417 m³ or 33.5 million gallons of water. The lake is accordingly estimated to have a relatively high flushing rate at approximately 32.1 times a year, with a water retention period of approximately 11.4 days. On a monthly basis, Johns Lake features a similar pattern of variation as the other waterbodies assessed, with the lowest annualized flushing rate occurring in August. This is a very swift flushing rate and may serve to flush nutrients and algae from the system regularly.

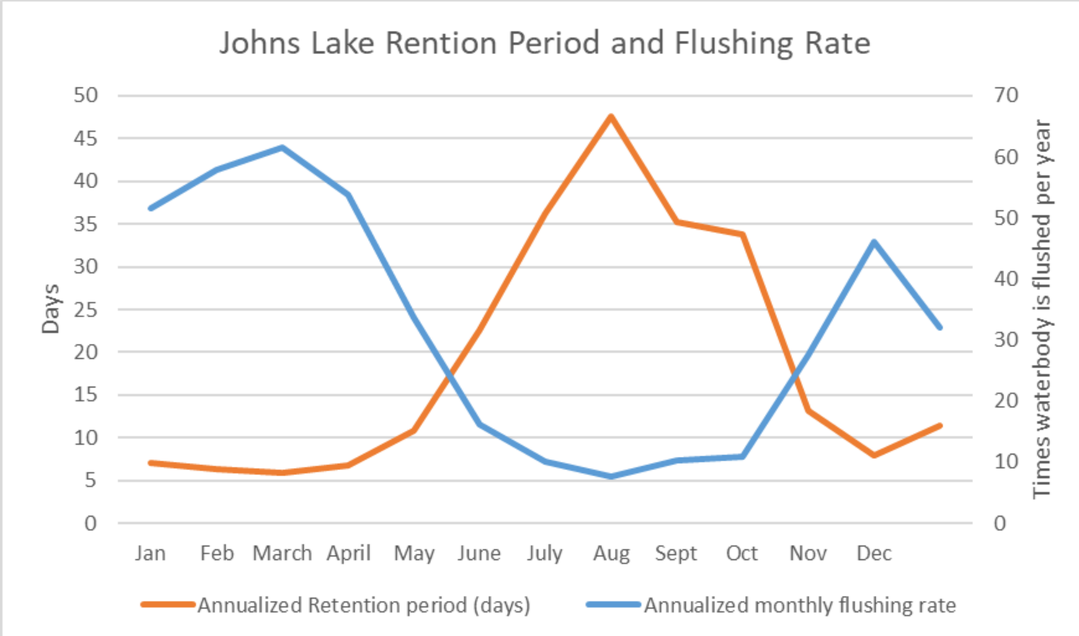


Figure 38. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Johns Lake, based on variations in hydraulic loads.

Table 81. Estimated annual loads of nitrogen in the total Johns Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	1.7	0.24
	Cropland	0.0	0.00
	Forest	11.4	1.65
	Wetland	0.0	0.00
	Open Land	0.0	0.00
	Barren Land	0.1	0.01
	Low-Density Mixed	2.6	0.37
	Medium-Density Mixed	2.2	0.31
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	2.9	0.41
Other Sources	Farm Animals and Waterfowl	22.4	3.24
	Stream Bank	0.0	0.00
	Groundwater	110.4	15.94
	Dryfall	33.8	4.88
	Septic Systems	505.0	72.95
	Total	692.3	100

Table 82. Estimated annual loads of nitrogen by subwatershed in the Johns Lake watershed

Category	Description	Full Watershed	North	Southeast	Southwest
		kg	kg	kg	kg
Runoff	Hay/Pasture	1.7	1.3	0.4	0.0
	Cropland	0.0	0.0	0.0	0.0
	Forest	11.4	10.4	0.2	0.8
	Wetland	0.0	0.0	0.0	0.0
	Open Land	0.0	0.0	0.0	0.0
	Barren Land	0.1	0.1	0.0	0.0
	Low-Density Mixed	2.6	2.4	0.0	0.1
	Medium-Density Mixed	2.2	2.1	0.0	0.1
	High-Density Mixed	0.0	0.0	0.0	0.0
	Low-Density Open Space	2.9	2.7	0.0	0.0
Other Sources	Farm Animals and Waterfowl	22.4	22.3	0.0	0.0
	Stream Bank	0.0	1.0	0.0	0.0
	Groundwater	110.4	105.4	1.8	6.9
	Dryfall	33.8	.	.	.
	Septic Systems	505.0	489.7	3.2	3.2
	Total (kg)	692.3	637.2	5.6	11.2
	kg/acre	3.4	3.3	1.7	0.9

Johns Lake's nitrogen load is estimated to largely originate from septic systems in the watershed, particularly coming from the North subwatershed. Most of these systems are located within Forest Hill lake's watershed, and this lake may be sequestering nitrogen and other nutrients before they enter Johns Lake. This Northern subwatershed yielded the highest estimated annual nitrogen load, both overall and by acre. Nitrogen loads from farm animals and waterfowl in the watershed were also a notable source of nitrogen. Most runoff-based nitrogen loads were estimated to originate in forested land.

Table 83. Estimated annual loads of phosphorus in the total Johns Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.51	2.3
	Cropland	0.00	0.0
	Forest	0.65	2.9
	Wetland	0.00	0.0
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.20	0.9
	Medium-Density Mixed	0.16	0.7
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.22	1.0
Other Sources	Farm Animals and Waterfowl	5.70	25.5
	Stream Bank	0.00	0.0
	Groundwater	2.07	9.3
	Dryfall	0.17	0.8
	Septic Systems	12.66	56.7
	Total	22.34	100.0

Table 84. Estimated annual loads of phosphorus by subwatershed in the Johns Lake watershed

Category	Description	Full Watershed kg	North kg	Southeast kg	Southwest kg
Runoff	Hay/Pasture	0.51	0.35	0.16	0.00
	Cropland	0.00	0.00	0.00	0.00
	Forest	0.65	0.52	0.02	0.06
	Wetland	0.00	0.00	0.00	0.00
	Open Land	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.20	0.16	0.00	0.01
	Medium-Density Mixed	0.16	0.14	0.00	0.01
	High-Density Mixed	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.22	0.18	0.00	0.00
Other Sources	Farm Animals and Waterfowl	5.70	5.64	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00
	Groundwater	2.07	1.73	0.05	0.18
	Dryfall	0.17	.	.	.
	Septic Systems	12.66	10.49	0.00	0.00
	Total (kg)	22.34	19.21	0.23	0.26
	kg/acre	0.11	0.10	0.07	0.02

Similar to annual nitrogen loads, a majority of the phosphorus in Johns Lake was estimated to originate from septic system influence in the North subwatershed, with farm animals also contributing a notable annual load.

The North subwatershed yielded both the highest overall estimated annual phosphorus load and the highest amount of phosphorus per acre.

As a relatively shallow waterbody with a high flushing rate, Johns Lake was not observed to feature bottom anoxia at any point during the 2022 growing season. Accordingly, internal loading was estimated using the lower oxic loading rate of 0.6 mg TP/m^2/day. The lake's estimated yearly internal load was calculated to be approximately 0.84 kg/yr.

Table 85 below displays the external and internal loads of phosphorus for Johns Lake, as well as the grand total, which is estimated to be approximately 23.18 kg/year. According to modeled loads, the lake is estimated to receive a majority of phosphorus (approximately 97%) from watershed-based loads.

Table 85. Total estimated annual phosphorus loads for Johns Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	22.34
Internal	0.84
Total	**23.18**

Table 86. Estimated annual loads of sediment in the total Johns Lake watershed

Category	Description	Sediment	
		kgx1000	%
Runoff	Hay/Pasture	0.040	7.0
	Cropland	0.000	0.0
	Forest	0.110	19.3
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.030	5.3
	Medium-Density Mixed	0.040	7.0
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.040	7.0
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.309	54.3
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.569	100.0

Table 87. Estimated annual loads of sediment by subwatershed in the Johns Lake watershed

Category	Description	Full Watershed kg x 1000	North kg x 1000	Southeast kg x 1000	Southwest kg x 1000
Runoff	Hay/Pasture	0.040	0.010	0.040	0.000
	Cropland	0.000	0.000	0.000	0.000
	Forest	0.110	0.040	0.000	0.020
	Wetland	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.030	0.010	0.000	0.000
	Medium-Density Mixed	0.040	0.020	0.000	0.010
	High-Density Mixed	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.040	0.020	0.000	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000
	Stream Bank	0.309	0.203	0.000	0.001
	Groundwater	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.569	0.303	0.040	0.031
	kg/acre	2.757	1.575	11.765	2.583

Johns Lake's watershed is estimated to yield a relatively low annual sediment load, at less than 600 kg/yr. Most of the sediment that is produced is modeled to originate from eroding streambanks and as runoff from forested areas. The Northern subwatershed is estimated to yield the highest annual sediment load overall and per acre of the three subwatersheds, while the Southeast subwatershed is estimated to yield the highest load peracre.

Table 88. Estimated annual loads of bacteria for the full Johns Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	4.98E+10	38.2
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.30E+10	17.7
	Other Wildlife	5.75E+10	44.1
	Total	1.30E+11	100

Table 89. Estimated annual loads of bacteria by subwatershed for the Johns Lake watershed

Category	Description	Full Watershed %	North %	Southeast %	Southwest %
Fecal Coliform	Farm Animals and Waterfowl	38.2	39.3	0.0	0.0
	WWTP	0.0	0.0	0.0	0.0
	Septic Systems	0.0	0.0	0.0	0.0
	Urban Areas	17.7	18.8	0.0	3.9
	Other Wildlife	44.1	41.9	100.0	96.1
	Total (organisms)	1.30E+11	1.26E+11	9.69E+08	4.22E+09

Johns Lake's annual bacteria load is estimated to largely be contributed to by wildlife in the watershed, however the farm animals in the North subwatershed also were modeled to produce a relatively high bacterial load. This Northern subwatershed yielded the highest estimated bacteria load for an average year.

KITCHELL LAKE

Kitchell Lake is located northeast of the intersection of Morsetown Rd. and Westbrook Rd. and features a watershed with an area of approximately 512.2 acres. As with many other lakes in this study, the watershed is dominated by forested land, but also features notable areas of urbanization, particularly immediately around the lake and along some of the major roadways. The lake's major inlet, West Brook, is a category 1 trout production stream, and enters the lake in the southwestern corner near the swimming beach. After flowing out of the lake's dam, this stream is joined by another branch of West Brook before flowing east, eventually into Wanaque Reservoir. A description of the lake's subwatersheds are as follows:

- **East Shore:** This 35.6-acre subwatershed is situated along the southeastern shoreline of Kitchell Lake and contains lengths of Kitchell Lake Dr. East and Skyview Rd. The subwatershed is approximately 63% forested, with the remaining portion of the land being classified as urban.
- **Northeast:** This approximately 33.4-acre subwatershed contains a small length of Kitchell Lake Dr. and approximately 2.5 acres of urbanized land close to the lake, with the remaining area being classified as entirely forested.
- **North:** This approximately 51.4-acre subwatershed, similarly to the Northeast subwatershed, features a small amount of urbanized area adjacent to the lake, with much of the remaining land being forested. The North subwatershed also includes one of the lake's smaller inlets and a small wetland south of Kitchell Lake Dr.
- **Skyview:** This subwatershed covers an area of approximately 36.6 acres and is located at the northeastern corner of the lake. In addition to Kitchell Lake Dr. East and a segment of Skyview Rd., the subwatershed contains one of the lake's lesser inlets. The area is largely forested with some urbanized land and wetlands also present.
- **West Brook:** As its name suggests, this subwatershed contains West Brook and its drainage prior to entering

Kitchell Lake. It is the largest of Kitchell Lake's subwatersheds at approximately 331.0 acres. The area is approximately 74.4% forested.

- **West Shore:** This approximately 24.7-acre subwatershed contains most of Kitchell Lake Dr. West, as well as 14.6 acres of urbanized area surrounding this corridor. The subwatershed also contains approximately 10 acres of forested land and less than an acre of wetland.

Table 90. Land-use by subwatershed in the Kitchell Lake watershed.

Source	Full Watershed	East Shore	Northeast	North	Skyview	West Brook	West Shore
	Area (acres)						
Open Water	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	0.5	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	389.7	22.5	30.9	50.4	30.1	246.4	9.6
Wetland	16.8	0.0	0.0	0.0	1.7	14.8	0.5
Open Land	7.7	0.0	0.0	0.0	0.0	7.7	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	20.0	4.0	0.5	0.0	0.2	12.1	3.2
Medium-Density Mixed	4.4	0.2	0.0	0.0	0.2	3.5	0.5
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	73.1	8.9	2.0	1.0	4.4	46.0	10.9
Total	512.2	35.6	33.4	51.4	36.6	331.0	24.7

Table 90 continued. Land-use by subwatershed in the Kitchell Lake watershed

Source	Full Watershed	East Shore	Northeast	North	Skyview	West Brook	West Shore
	Area (%)						
Open Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.1	0.0	0.0	0.0	0.0	0.2	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	76.1	63.2	92.5	98.1	82.2	74.4	38.9
Wetland	3.3	0.0	0.0	0.0	4.6	4.5	2.0
Open Land	1.5	0.0	0.0	0.0	0.0	2.3	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	3.9	11.2	1.5	0.0	0.5	3.7	13.0
Medium-Density Mixed	0.9	0.6	0.0	0.0	0.5	1.1	2.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	14.3	25.0	6.0	1.9	12.0	13.9	44.1
Total	100	100	100	100	100	100	100

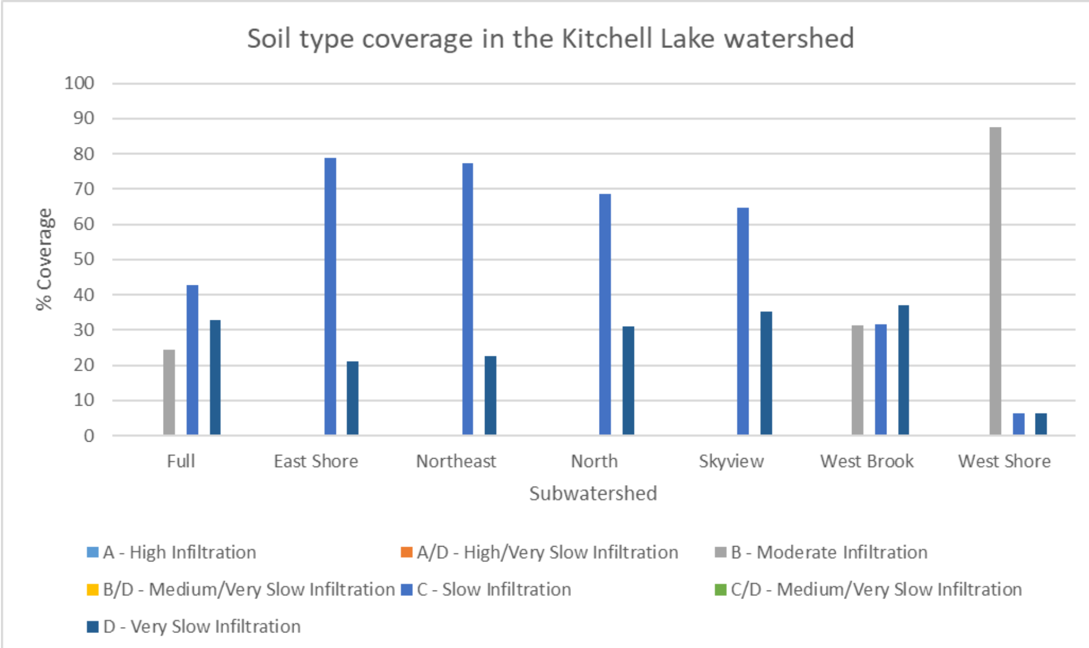


Figure 39. Percent coverage of Kitchell Lake watershed and subwatersheds by different hydrologic soil groups.

The full Kitchell Lake Watershed features a relatively high coverage with slower infiltration soil groups, with group C soils being the most prevalent. Subwatersheds along the northern and eastern edge of the lake were modeled to be entirely covered with groups C and D soils and are more likely to yield higher amounts of runoff. Conversely, subwatersheds along the western side of the lake featured notable amounts of soil group "B – Moderate Infiltration", particularly in the West Shore subwatershed, where this soil type covered approximately 88% of the area. These subwatersheds are less likely to produce high amounts of runoff, as soils are present that allow additional infiltration of water into the water table. Overall, the full watershed was modeled to feature an average slope of approximately 12%, while the steepest slope of approximately 48% exists in the West Brook subwatershed. Areas of increased slope may yield higher yearly amounts of erosion.

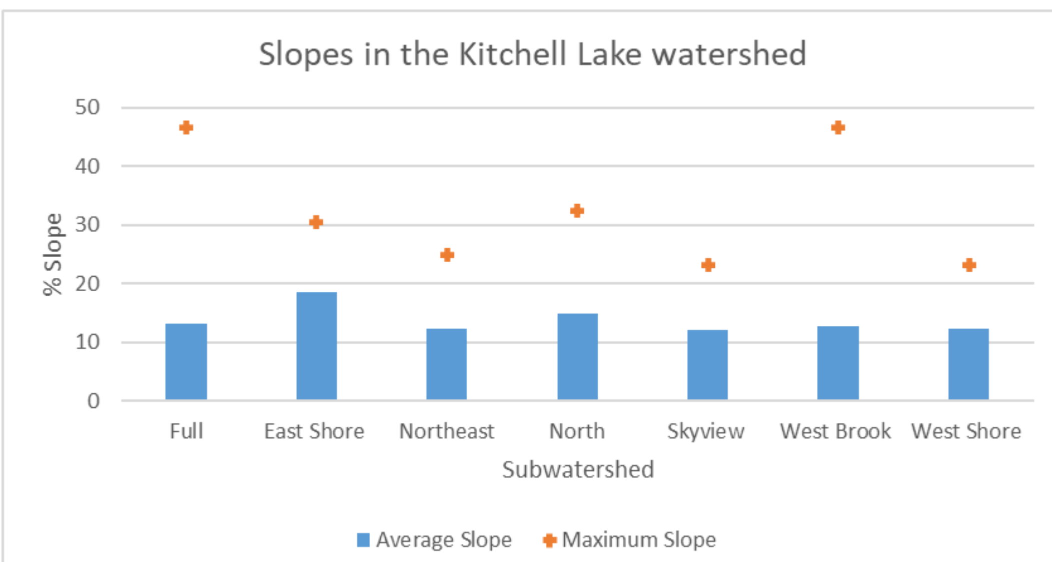


Figure 40. Variation in average and maximum percent slope between subwatersheds in the Kitchell Lake watershed.

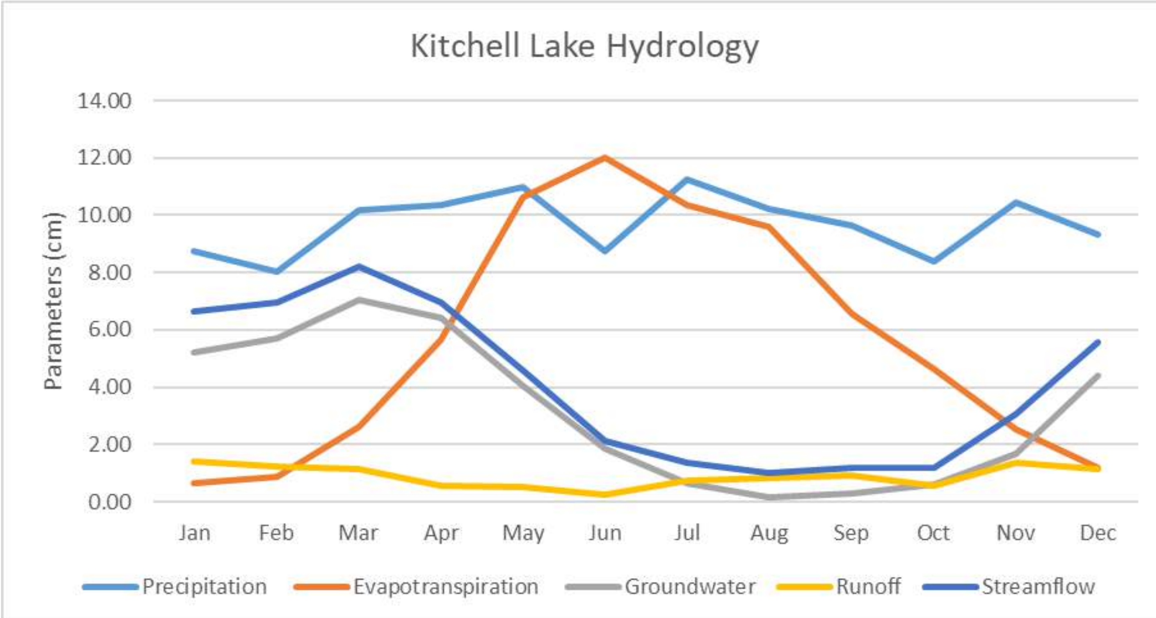


Figure 41. Estimated seasonal changes in hydrology in the Kitchell Lake watershed

Table 91. Total hydrological parameters in the full Kitchell Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.75	0.65	5.23	1.42	6.64	1.81
Feb	8.04	0.90	5.72	1.24	6.96	2.09
Mar	10.16	2.60	7.05	1.14	8.19	2.24
Apr	10.35	5.65	6.43	0.55	6.98	1.97
May	10.98	10.63	4.06	0.51	4.57	1.25
Jun	8.76	11.99	1.88	0.26	2.15	0.61
Jul	11.24	10.35	0.64	0.74	1.37	0.37
Aug	10.24	9.60	0.18	0.84	1.02	0.28
Sep	9.66	6.56	0.28	0.91	1.19	0.34
Oct	8.40	4.65	0.61	0.57	1.19	0.33
Nov	10.44	2.51	1.69	1.39	3.08	0.87
Dec	9.34	1.20	4.43	1.14	5.57	1.52
Total	116.36	67.29	38.20	10.71	48.91	1.14

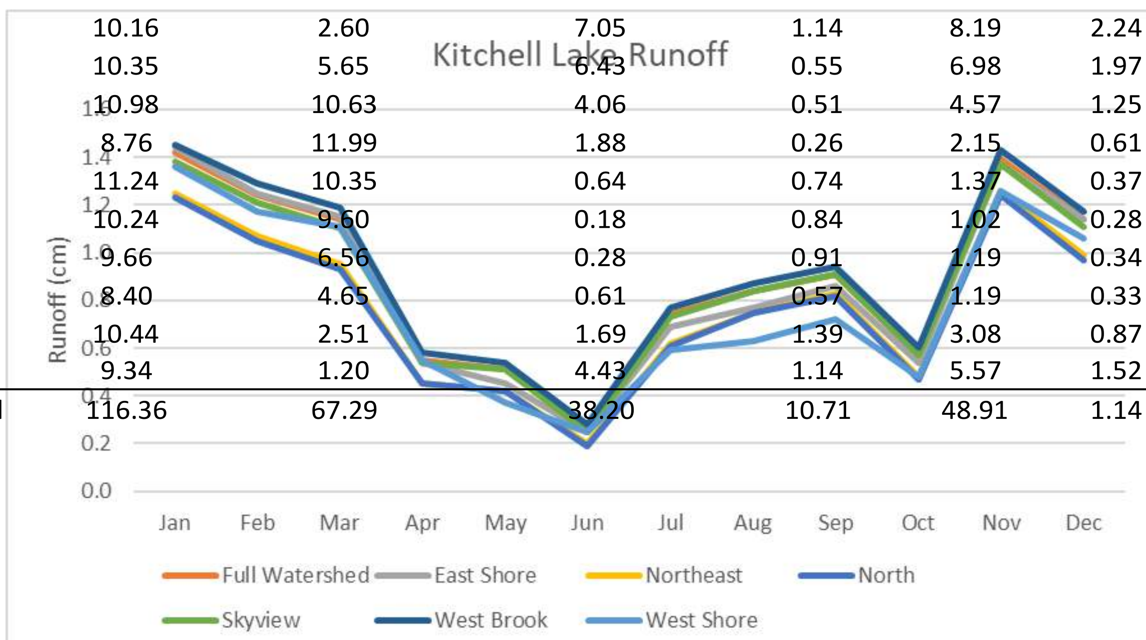


Figure 42. Average monthly runoff occurring in each subwatershed in the Kitchell Lake watershed

There is relatively little variation between the subwatersheds in regard to runoff, with the East Shore and Skyview subwatersheds both being modeled to produce the highest runoff over the course of an average year. When direct precipitation and evaporation to and from the lake itself are taken into account, Kitchell Lake is estimated to receive approximately 1,058,884 m³ or 279.7 million gallons of water during an average year.

As a full bathymetry of Kitchell Lake was not available, the total volume of the lake was estimated using depths taken during field sampling, yielding a volume of approximately 151,511 m³ or 40.1 million gallons of water. Usingthis estimate and the total hydrologic input above, Kitchell Lake was calculated to flush approximately 7 times a year, with a hydraulic retention period of approximately 52.3 days. When examined on a monthly basis, the lake's annualized flushing rate and retention periods feature a pattern similar to those of other lakes in this study, with the flushing rate typically at its lowest during August and highest during March.

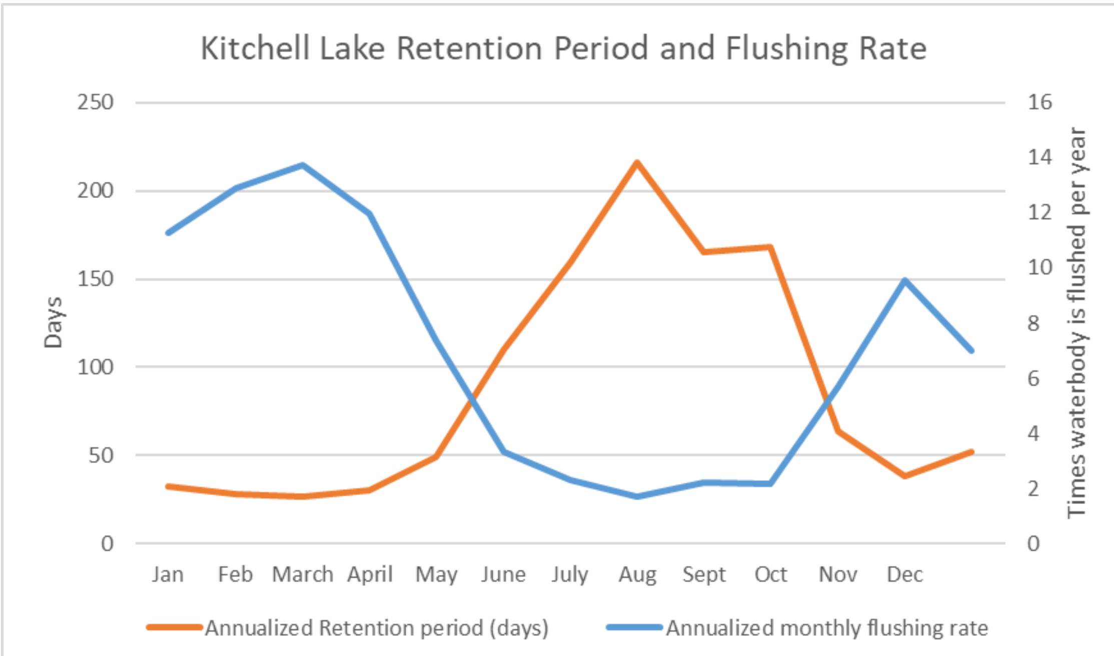


Figure 43. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Kitchell Lake, based on variations in hydraulic loads

Table 92. Estimated annual loads of nitrogen in the total Kitchell Lake watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	0.2	0.02
	Cropland	0.0	0.00
	Forest	27.8	2.75
	Wetland	4.0	0.39
	Open Land	4.6	0.45
	Barren Land	0.0	0.00
	Low-Density Mixed	2.5	0.24
	Medium-Density Mixed	2.2	0.22
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	9.0	0.89
Other Sources	Farm Animals and Waterfowl	0.3	0.03
	Stream Bank	3.0	0.30
	Groundwater	262.0	25.99
	Dryfall	86.6	8.59
	Septic Systems	605.9	60.11
	Total	1008.0	100

Table 93. Estimated annual loads of nitrogen by subwatershed in the Kitchell Lake watershed

Category	Description	Full Watershed	East Shore	Northeast	North	Skyview	West Brook	West Shore
		kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	0.2	0.0	0.0	0.0	0.0	0.2	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	27.8	1.8	2.4	3.5	2.3	17.5	0.3
	Wetland	4.0	0.0	0.0	0.0	0.4	3.5	0.1
	Open Land	4.6	0.0	0.0	0.0	0.0	4.5	0.0
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	2.5	0.5	0.1	0.0	0.0	1.5	0.5
	Medium-Density Mixed	2.2	0.1	0.0	0.0	0.1	2.6	0.3
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	9.0	1.1	0.3	0.1	0.5	5.5	1.6
Other Sources	Farm Animals and Waterfowl	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	3.0	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	262.0	18.6	18.8	28.4	19.9	165.4	12.9
	Dryfall	86.6	.	.	.	.	.	.
	Septic Systems	605.9	160.9	23.9	7.6	39.8	284.3	97.2
	Total (kg)	1008.0	182.9	45.3	39.6	63.0	484.9	112.8
	kg/acre	2.0	5.1	1.4	0.8	1.7	1.5	4.6

Modeled annual nitrogen loads entering Kitchell Lake from the watershed were dominated by loads originating from septic systems and groundwater, while most runoff-based nitrogen was modeled to originate from forested land. As the largest subwatershed, the West Brook subwatershed yielded the highest overall annual nitrogen load, although the East Shore subwatershed was estimated to produce the most nitrogen per acre.

Table 94. Estimated annual loads of phosphorus in the total Kitchell Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.09	0.2
	Cropland	0.00	0.0
	Forest	1.81	4.3
	Wetland	0.20	0.5
	Open Land	0.56	1.3
	Barren Land	0.00	0.0
	Low-Density Mixed	0.22	0.5
	Medium-Density Mixed	0.18	0.4
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.80	1.9
Other Sources	Farm Animals and Waterfowl	0.12	0.3
	Stream Bank	2.00	4.7
	Groundwater	5.62	13.3
	Dryfall	0.43	1.0
	Septic Systems	30.14	71.5
	Total	42.17	100.0

Table 95. Estimated annual loads of phosphorus by subwatershed in the Kitchell Lake watershed

Category	Description	Full Watershed kg	East Shore kg	Northeast kg	North kg	Skyview kg	West Brook kg	West Shore kg
Runoff	Hay/Pasture	0.09	0.00	0.00	0.00	0.00	0.08	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	1.81	0.22	0.23	0.18	0.21	1.11	0.04
	Wetland	0.20	0.00	0.00	0.00	0.02	0.17	0.00
	Open Land	0.56	0.00	0.00	0.00	0.00	0.53	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.22	0.05	0.01	0.00	0.00	0.13	0.05
	Medium-Density Mixed	0.18	0.01	0.00	0.00	0.01	0.21	0.03
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.80	0.12	0.03	0.01	0.05	0.48	0.17
Other Sources	Farm Animals and Waterfowl	0.12	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	2.00	0.00	0.00	0.00	0.00	1.00	0.00
	Groundwater	5.62	0.49	0.49	0.51	0.52	3.46	0.34
	Dryfall	0.43	.	.	.	.	.	.
	Septic Systems	30.14	8.40	2.52	1.67	3.36	14.32	2.52
	Total (kg)	42.17	9.29	3.28	2.37	4.17	21.49	3.15
	kg/acre	0.08	0.26	0.10	0.05	0.11	0.06	0.13

Similar to nitrogen, annual estimated phosphorus loads in the Kitchell Lake watershed were dominated by those contributed by septic systems, with groundwater and runoff from forested land also being notable contributors. Streambank erosion was also modeled to yield a notable annual phosphorus load. While the West Brook subwatershed was estimated to yield the overall highest annual phosphorus load, the East Shore subwatershed yielded the largest phosphorus load per acre.

Kitchell Lake features an aeration system, and measurements collected in the field in 2022 strongly suggest that the system kept the water column relatively well-mixed throughout the season. Anoxic conditions were not observed during any of the three sampling events, and there were no large differences between deep and surface total phosphorus. As such, internal loading of phosphorus for Kitchell Lake was modeled only using the oxic loading coefficient of 0.6 mg TP/m²/day. Internal phosphorus loading was calculated to occur at a rate of approximately 8.44 kg/year.

Table 96 compares modeled external phosphorus loading and internal phosphorus loading in Kitchell Lake and displays the total yearly phosphorus load, calculated to be approximately 50.61 kg/year. A majority of the yearly phosphorus load (approximately 83%) is estimated to originate from external sources.

Table 96. Total estimated annual phosphorus loads for Kitchell Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	42.17
Internal	8.44
Total	**50.61**

Table 97. Estimated annual loads of sediment in the total Kitchell Lake watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.010	0.2
	Cropland	0.000	0.0
	Forest	0.420	7.1
	Wetland	0.020	0.3
	Open Land	0.320	5.4
	Barren Land	0.000	0.0
	Low-Density Mixed	0.060	1.0
	Medium-Density Mixed	0.080	1.4
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.230	3.9
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	4.736	80.6
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	5.876	100.0

Table 98. Estimated annual loads of sediment by subwatershed in the Kitchell Lake watershed

Category	Description	Full Watershed kg x 1000	East Shore kg x 1000	Northeast kg x 1000	North kg x 1000	Skyview kg x 1000	West Brook kg x 1000	West Shore kg x 1000
Runoff	Hay/Pasture	0.010	0.000	0.000	0.000	0.000	0.010	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.420	0.120	0.100	0.020	0.090	0.240	0.020
	Wetland	0.020	0.000	0.000	0.000	0.000	0.020	0.000
	Open Land	0.320	0.000	0.000	0.000	0.000	0.280	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.060	0.020	0.000	0.000	0.000	0.030	0.020
	Medium-Density Mixed	0.080	0.010	0.000	0.000	0.010	0.080	0.020
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.230	0.040	0.010	0.000	0.020	0.130	0.070
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	4.736	0.010	0.002	0.017	0.142	2.325	0.061
	Groundwater	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
	Total (kgx1000)	5.876	0.200	0.112	0.037	0.262	3.115	0.191
	kg/acre	11.472	5.618	3.353	0.720	7.158	9.411	7.733

Annual sediment loads in the Kitchell Lake watershed are estimated to largely originate as streambank erosion. The West Brook subwatershed was estimated to yield the largest overall annual sediment load, as well as the highest load per acre.

Table 99. Estimated annual loads of bacteria for the full Kitchell Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.62E+08	0.1
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	4.54E+10	24.6
	Other Wildlife	1.39E+11	75.3
	Total	1.85E+11	100.0

Table 100. Estimated annual loads of bacteria by subwatershed in the Kitchell Lake watershed

Category	Description	Full Watershed %	East Shore %	Northeast %	North %	Skyview %	Westbrook %	Westshore %
Fecal Coliform	Farm Animals and Waterfowl	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	WWTP	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	24.6	59.8	3.6	0.2	12.5	24.4	86.5
	Other Wildlife	75.3	40.2	96.4	99.8	87.5	75.6	13.5
	Total (organisms)	1.85E+11	2.00E+10	1.14E+10	1.80E+10	1.23E+10	1.16E+11	2.54E+10

A large majority (approximately 75%) of the annual bacterial load estimated to enter Kitchell Lake was modeled to originate from wildlife in the forested areas of the watershed, with approximately 25% of the total originating from urban areas. The West Brook subwatershed was estimated to yield the highest bacterial load of the six subwatersheds, likely due to its large surface area.

LINDY'S LAKE

The Lindy's Lake Watershed covers an area of approximately 60.3 acres, while the lake itself has a surface area of approximately 19.3 acres. The watershed is over 93% urbanized, with the remaining land featuring forests, wetlands, and open land. The lake's southern outlet drains southeast into Upper Mount Glen Lake, while the northern outlet drains north to a confluence with West Brook. The lake features no major inlets and is likely largely spring-fed. Descriptions of the lake's subwatersheds are as follows:

- **Northeast:** This 7.7-acre subwatershed consists almost entirely of urbanized landcover, with forested and wetlands being represented by only half an acre each.
- **Northwest:** This approximately 20-acre subwatershed is also largely urbanized, with only 2.2 acres of forested land being present.
- **South:** This approximately 32-acre subwatershed is over 98% urbanized, with open land making up the remaining area.

Table 101. Land-use by subwatershed in the Lindy's Lake watershed.

Source	Full Watershed	Northeast	Northwest	South
	Area (acres)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	2.7	0.5	2.2	0.0
Wetland	0.5	0.5	0.0	0.0
Open Land	0.5	0.0	0.0	0.5
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	19.5	0.5	8.2	11.1
Medium-Density Mixed	2.5	0.0	1.2	1.2
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	34.6	6.2	8.6	19.5
Total	60.3	7.7	20.2	32.3

Table 101 continued. Land-use by subwatershed in the Lindy's Lake watershed.

Source	Full Watershed	Northeast	Northwest	South
	Acres			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	4.5	6.5	10.9	0.0
Wetland	0.8	6.5	0.0	0.0
Open Land	0.8	0.0	0.0	1.5
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	32.3	6.5	40.6	34.4
Medium-Density Mixed	4.1	0.0	5.9	3.7
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	57.4	80.5	42.6	60.4
Total	100	100	100	100

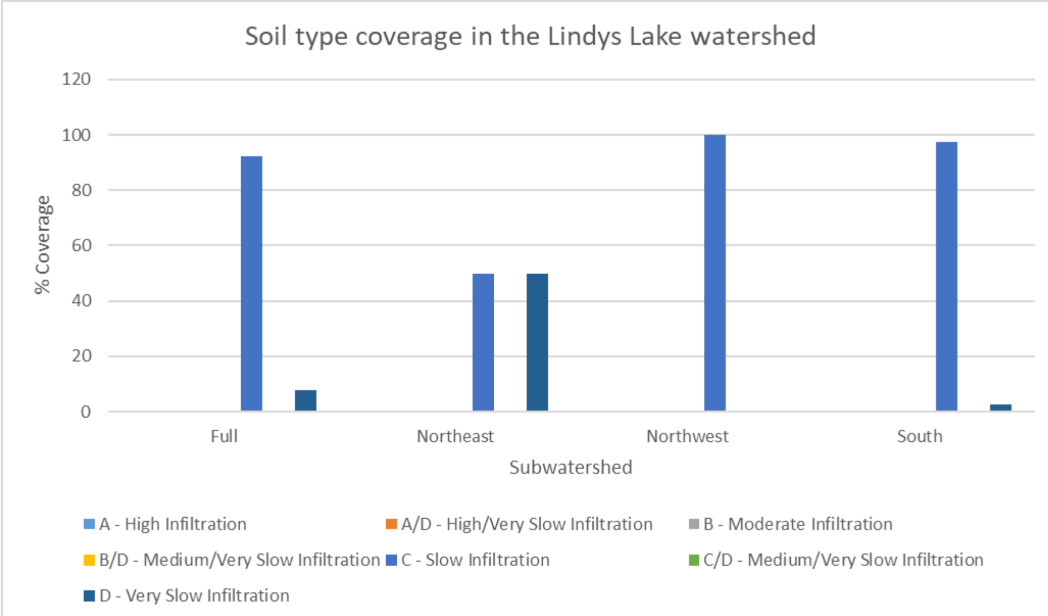


Figure 44. Percent coverage of Lindy's Lake's watershed and subwatersheds by different hydrologic soil groups.

Lindy's Lake's watershed is largely covered with the soil-type C ("slow infiltration"), with only a small amount of soil type D ("very slow infiltration") present in the Northeast and South subwatersheds. The average percent slope for the full watershed is approximately 9%, while a maximum percent slope of approximately 27% is present in the south subwatershed.

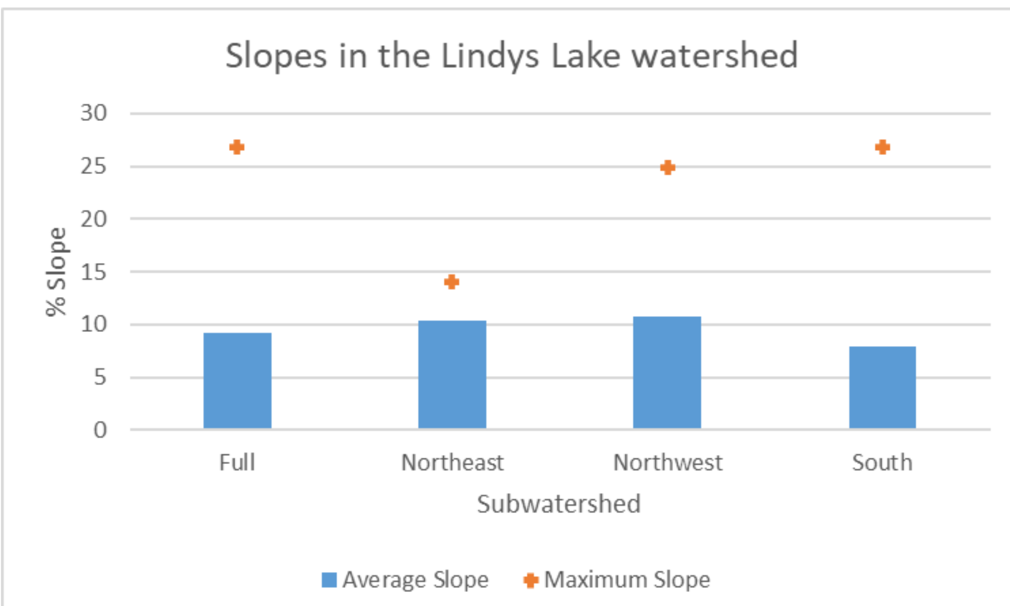


Figure 45. Variation in average and maximum percent slope between subwatersheds in the Lindy's Lake watershed.

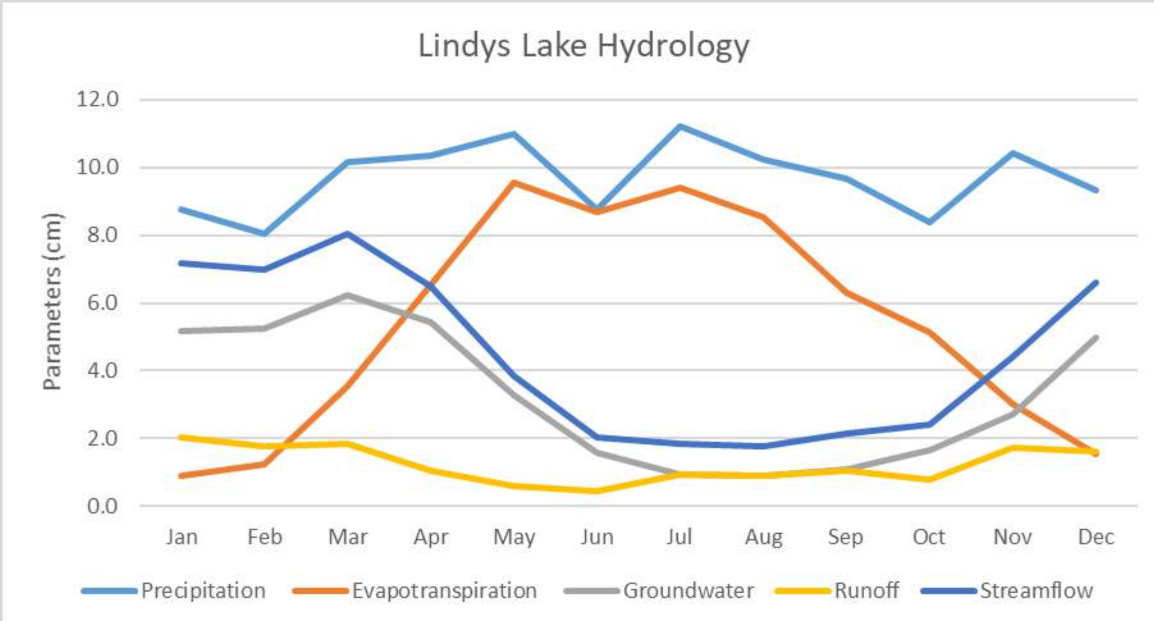


Figure 46. Estimated seasonal changes in hydrology in the Lindy's Lake watershed

Table 102. Total hydrological parameters in the full Lindy's Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.9	5.2	2.0	7.2	0.2
Feb	8.0	1.2	5.2	1.8	7.0	0.2
Mar	10.2	3.6	6.2	1.8	8.1	0.3
Apr	10.4	6.5	5.4	1.1	6.5	0.2
May	11.0	9.6	3.3	0.6	3.8	0.1
Jun	8.8	8.7	1.6	0.4	2.0	0.1
Jul	11.2	9.4	0.9	0.9	1.9	0.1
Aug	10.2	8.6	0.9	0.9	1.8	0.1
Sep	9.7	6.3	1.1	1.0	2.1	0.1
Oct	8.4	5.1	1.6	0.8	2.4	0.1
Nov	10.4	3.0	2.7	1.7	4.4	0.1
Dec	9.3	1.6	5.0	1.6	6.6	0.2
Total	116.4	64.4	39.1	14.7	53.8	0.1

Runoff is very similar between the three subwatersheds and is overall somewhat high due to the relatively high amount of urbanized landcover, as well as the prevalence of poorly draining soils throughout the watershed. When precipitation and evaporation directly influencing the lake itself are accounted for, Lindy's Lake is estimated to receive approximately 717,812 m^3 or 45.4 million gallons of water in an average year.

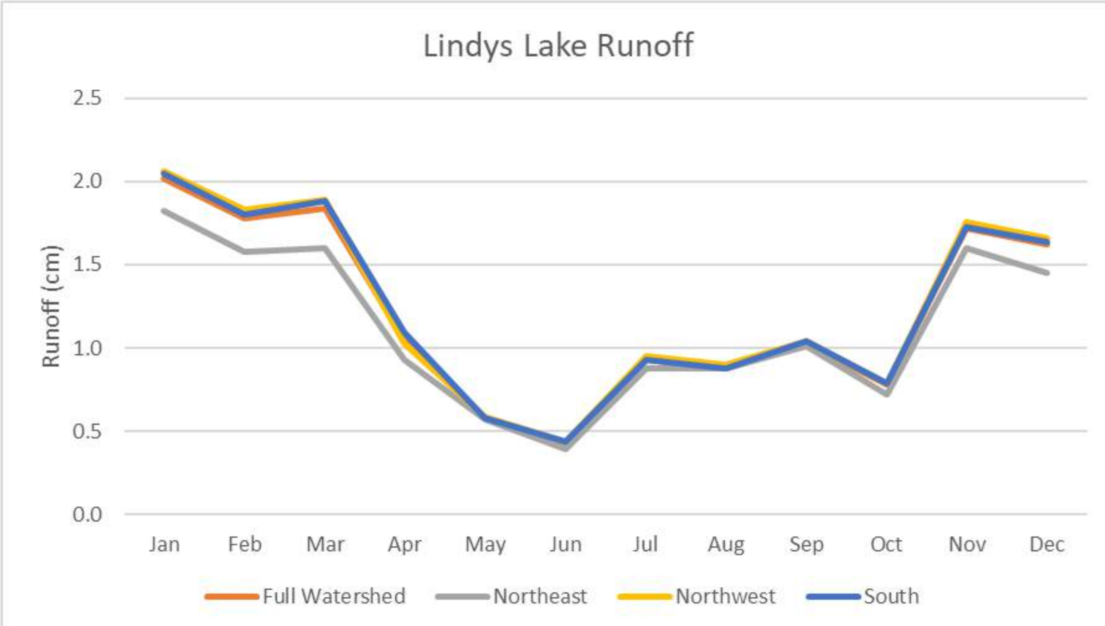


Figure 47. Average monthly runoff occurring in each subwatershed in the Lindy's Lake watershed

As no bathymetry was available for Lindy's Lake, lake volume was estimated using depths collected during field events to be approximately 237,131 m³ or 62.4 million gallons of water. Using this volume and the estimated hydraulic input above, the lake can be estimated to flush completely once every 1.4 years, with a hydraulic retention period of approximately 504 days. When examined on a monthly basis, the lowest annualized monthly flushing rate and highest retention time is estimated to normally occur in June.

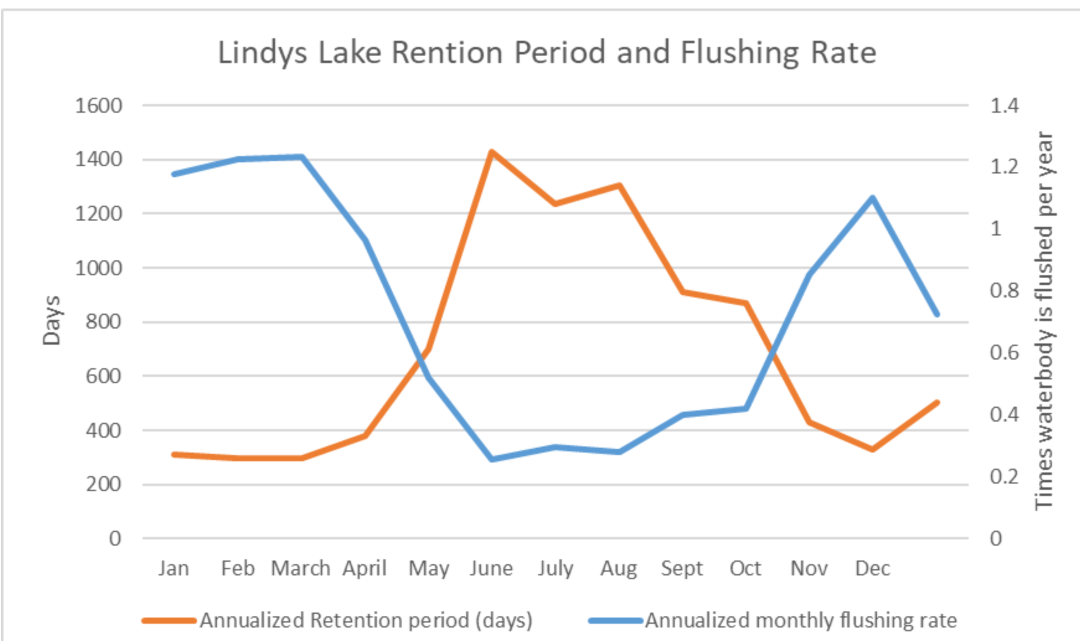


Figure 48. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Lindy's Lake, based on variations in hydraulic loads.

Table 103. Estimated annual loads of nitrogen in the total Lindy's Lake watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	0.0	0.0
	Cropland	0.0	0.0
	Forest	0.2	0.0
	Wetland	0.1	0.0
	Open Land	0.2	0.0
	Barren Land	0.0	0.0
	Low-Density Mixed	2.8	0.4
	Medium-Density Mixed	1.4	0.2
	High-Density Mixed	0.0	0.0
	Low-Density Open Space	5.0	0.6
Other Sources	Farm Animals and Waterfowl	0.1	0.0
	Stream Bank	0.0	0.0
	Groundwater	32.5	4.1
	Dryfall	12.9	1.6
	Septic Systems	734.2	93.0
	Total	789.5	100

Table 104: Estimated annual loads of nitrogen by subwatershed in the Lindy's Lake watershed

Category	Description	Full Watershed	Northeast	Northwest	South
		kg	kg	kg	kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0
	Forest	0.2	0.0	0.2	0.0
	Wetland	0.1	0.1	0.0	0.0
	Open Land	0.2	0.0	0.0	0.2
	Barren Land	0.0	0.0	0.0	0.0
	Low-Density Mixed	2.8	0.1	1.3	1.6
	Medium-Density Mixed	1.4	0.0	0.4	0.4
	High-Density Mixed	0.0	0.0	0.0	0.0
	Low-Density Open Space	5.0	0.6	1.4	2.7
Other Sources	Farm Animals	0.1	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0
	Groundwater	32.5	3.4	11.0	17.3
	Dryfall	12.9	.	.	.
	Septic Systems	734.2	108.3	192.7	433.2
	Total (kg)	789.5	112.5	206.9	455.4
	kg/acre	13.1	14.6	10.2	14.1

Due to the relatively high number of septic systems in Lindy's Lake's watershed, the nitrogen load is estimated to be dominated by nitrogen originating from septic systems. Runoff-based nitrogen loading is relatively low but is largely contributed to by runoff from urbanized areas. As the largest subwatershed, the South subwatershed is estimated to contribute the highest overall annual nitrogen load, while the Northeast subwatershed is estimated to yield the highest annual load per acre.

Table 105: Estimated annual loads of phosphorus in the total Lindy's Lake watershed

Category	Description	Total Phosphorus kg	Total Phosphorus %
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.01	0.0
	Wetland	0.01	0.0
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.31	0.2
	Medium-Density Mixed	0.14	0.1
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.54	0.4
Other Sources	Farm Animals and Waterfowl	0.03	0.0
	Stream Bank	0.00	0.0
	Groundwater	0.95	0.7
	Dryfall	0.06	0.1
	Septic Systems	125.14	98.4
	Total	127.19	100.0

Table 106: Estimated annual loads of phosphorus by subwatershed in the Lindy's Lake watershed

Category	Description	Full Watershed kg	Northeast kg	Northwest kg	South kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00
	Forest	0.01	0.00	0.01	0.00
	Wetland	0.01	0.01	0.00	0.00
	Open Land	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.31	0.01	0.14	0.17
	Medium-Density Mixed	0.14	0.00	0.04	0.04
	High-Density Mixed	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.54	0.07	0.15	0.29
Other Sources	Farm Animals and Watefowl	0.03	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00
	Groundwater	0.95	0.10	0.32	0.51
	Dryfall	0.06	.	.	.
	Septic Systems	125.14	26.04	32.76	66.35
	Total (kg)	127.19	26.23	33.42	67.36
	kg/acre	2.11	3.41	1.65	2.09

As with nitrogen, septic system influence was estimated to be the dominant source of phosphorus for Lindy's Lake. Runoff from urbanized areas was estimated to yield the highest runoff-based load. The Southern subwatershed was estimated to yield the highest overall estimated annual phosphorus load, while the Northeastern subwatershed was estimated to yield the highest load per acre.

As the deepest lake in the study, Lindy's Lake was observed to be anoxic for a large portion of its water column during the peak of the summer season, as well as to a lesser extent in the fall. During both of these events, deep-water phosphorus was measured to be notably higher than that measured from the surface, with this difference being particularly large during the summer. As such, the lake was estimated to remain anoxic forapproximately 3.5 months during an average year, with approximately 40% of the lake's area being affected. When the lesser oxic loading was also accounted for, internal phosphorus loading was calculated to occur at a rate of approximately 25.18 kg/yr. If a season were to occur with no increased anoxic loading, the lake would yield approximately 7.16 kg/yr of phosphorus.

Table 107 compares the average estimated phosphorus loads entering Lindy's Lake from external and internal sources, as well as the total estimated annual phosphorus load, totaling approximately 152.37 kg/yr. This total load is dominated by watershed-based loads, which contribute approximately 84% of the annual total.

Table 107: Total estimated annual phosphorus loads for Lindy's Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	127.19
Internal	25.18
Total	**152.37**

Table 108: Estimated annual loads of sediment in the total Lindy's 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	0.120	25.0
	Medium-Density Mixed	0.080	16.7
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.210	43.8
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.070	14.6
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.480	100.0

Table 109: Estimated annual loads of sediment by subwatershed in the Lindy's Lake watershed

Category	Description	Full Watershed kg x 1000	Northeast kg x 1000	Northwest kg x 1000	South kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000
	Forest	0.000	0.000	0.000	0.000
	Wetland	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.120	0.000	0.050	0.060
	Medium-Density Mixed	0.080	0.000	0.020	0.020
	High-Density Mixed	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.210	0.030	0.050	0.110
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000
	Stream Bank	0.070	0.008	0.031	0.011
	Groundwater	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.480	0.038	0.151	0.201
	kg/acre	7.960	4.935	7.475	6.223

A majority of Lindy's Lake's annual estimated sediment load is modeled to originate as runoff from urbanized land. While the Southern subwatershed yields a higher sediment load than the other two subwatersheds, the Northwest subwatershed yields the highest amount of sediment per acre. This subwatershed also featured a slightly higher amount of modeled streambank erosion than the other two subwatersheds.

Table 110: Estimated annual loads of bacteria for the full Lindy's Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	3.60E+07	0.1
	Urban Areas	1.52E+11	99.3
	Other Wildlife	9.69E+08	0.6
	Total	1.53E+11	100

Table 111: Estimated annual loads of bacteria by subwatershed for the Lindy's Lake watershed

Category	Description	Full Watershed %	Northeast %	Northwest %	South %
Fecal Coliform	Farm Animals and Waterfowl	0.1	0	0	0
	Urban Areas	99.3	98.7	98.4	100.0
	Other Wildlife	0.6	1.3	1.6	0.0
	Total (organisms)	1.53E+11	1.40E+10	4.97E+10	8.97E+10

Most of the annual bacterial load in the Lindy's Lake watershed is estimated to originate from urbanized areas. As with sediment, the Southern subwatershed is estimated to yield the highest amount of bacteria of the three subwatersheds.

LAKE LOOKOVER

Lake Lookover's watershed spans an area of approximately 775.4 acres, while the lake itself has a surface area of approximately 15 acres. The watershed consists largely of forested land and wetlands, with urbanized land present directly adjacent to the lake. Immediately upstream of the lake is the outlet to Bearfort Waters, which is itself fed by Longhouse Creek. The outlet of Lake Lookover continues north before entering Mt. Laurel Lake. Descriptions of the lake's subwatersheds are as follows:

- **Longhouse Creek:** This is Lake Lookover's largest subwatershed, spanning an area of approximately 568.3 acres. The watershed also features lake's the main inlet. The area is largely covered by wetlands and forested land.
- **Northwest:** This 35.4-acre subwatershed contains the entire western shoreline of Lake Lookover, and consists mostly of forested land, with some urban land use present closer to the shoreline.
- **Northeast:** This 40.3-acre subwatershed largely consists of forested land with some wetlands, but also contains a length of Clinton Road and the urbanized area along it (approximately 7.2 acres).
- **Southeast:** This 132-acre subwatershed contains a portion of the lake's eastern shoreline and the adjacent urbanized area, while the large area east of Clinton Road consists largely of forested land and wetlands.

Table 112. Land-use by subwatershed in the Lake Lookover watershed.

Source	Full Watershed	Longhouse Creek	Northwest	Northeast	Southeast
	Area (acres)				
Open Water	17.3	17.3	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0
Forest	569.3	413.7	26.4	27.7	101.6
Wetland	143.1	113.2	0.0	5.4	25.0
Open Land	1.2	1.2	0.2	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	5.2	1.2	1.2	2.5	0.2
Medium-Density Mixed	1.0	0.0	0.2	1.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	38.3	21.7	7.4	3.7	5.2
Total	775.4	568.3	35.4	40.3	132

Table 112 continued: Land-use by subwatershed in the Lake Lookover watershed

Source	Full Watershed	Longhouse Creek	Northwest	Northeast	Southeast
			Area (%)		
Open Water	2.2	3.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0
Forest	73.4	72.8	74.6	68.7	77.0
Wetland	18.5	19.9	0.0	13.4	18.9
Open Land	0.2	0.2	0.6	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	0.7	0.2	3.4	6.2	0.2
Medium-Density Mixed	0.1	0.0	0.6	2.5	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	4.9	3.8	20.9	9.2	3.9
Total	100	100	100	100	100

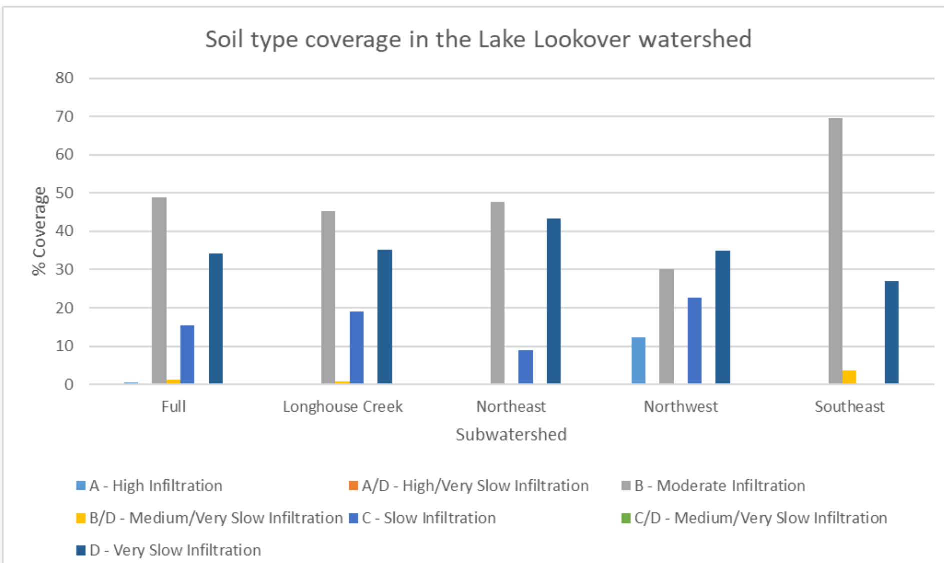


Figure 49. Percent coverage of Lake Lookover's watershed and subwatersheds by different hydrologic soil groups

Lake Lookover's watershed soils differ from some of the other watersheds assessed in this study by containing relatively high coverage with soil Type B ("moderate infiltration"), while the Northwest subwatershed features some coverage by soil Type A ("high infiltration"). While the watershed also contains a significant amount of Type D soil ("very slow infiltration"), the increased rate of infiltration afforded by the areas of Type B and Type A soils may serve to reduce the rate of runoff in Lake Lookover's watershed. Each subwatershed featured a relatively low average percent slope; however, the Longhouse Creek subwatershed featured a relatively high maximum slope of approximately 57.7%. This suggests that this subwatershed may contain some steep areas that are prone to increased soil erosion.

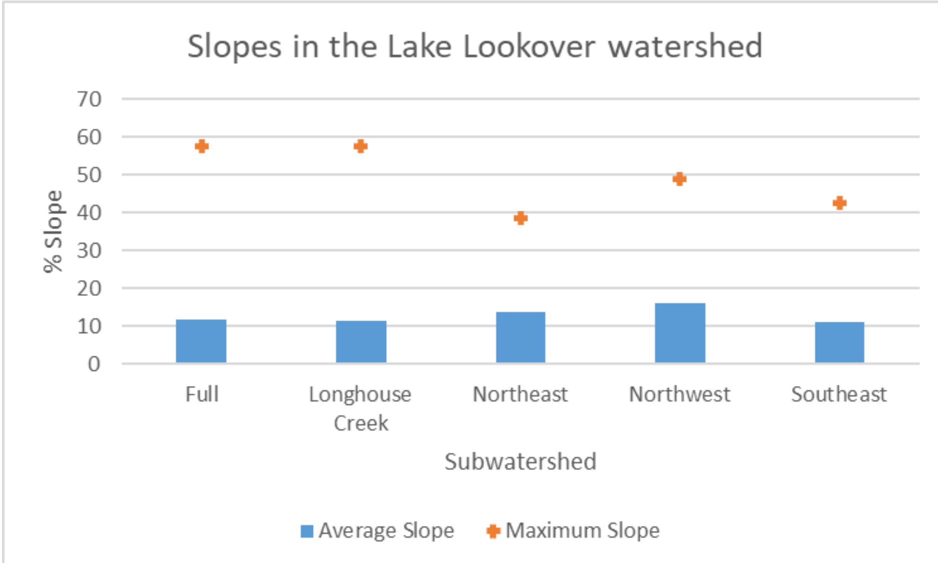


Figure 50. Variation in average and maximum percent slope between subwatersheds in the Lake Lookover watershed.

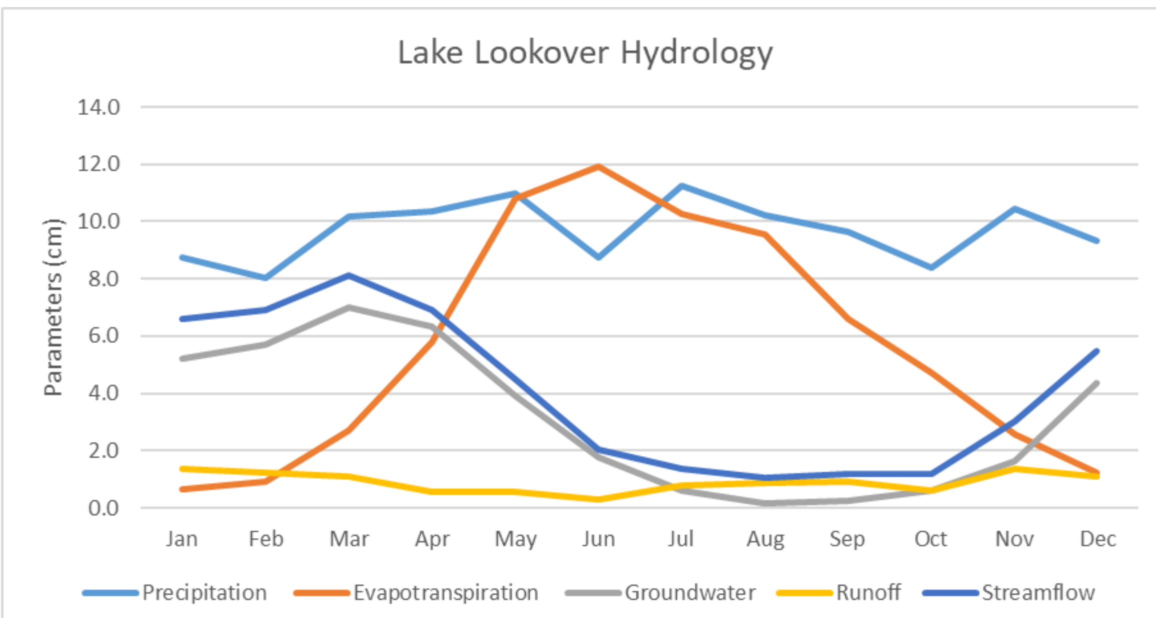


Figure 51. Estimated seasonal changes in hydrology in the Lake Lookover watershed

Table 113. Total hydrological parameters in the full Lake Lookover watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.2	1.4	6.6	2.7
Feb	8.0	0.9	5.7	1.2	6.9	3.1
Mar	10.2	2.7	7.0	1.1	8.1	3.4
Apr	10.4	5.8	6.3	0.6	6.9	3.0
May	11.0	10.8	3.9	0.6	4.5	1.9
Jun	8.8	11.9	1.8	0.3	2.1	0.9
Jul	11.2	10.3	0.6	0.8	1.4	0.6
Aug	10.2	9.5	0.2	0.9	1.0	0.4
Sep	9.7	6.6	0.3	0.9	1.2	0.5
Oct	8.4	4.7	0.6	0.6	1.2	0.5
Nov	10.4	2.6	1.6	1.4	3.0	1.3
Dec	9.3	1.2	4.4	1.1	5.5	2.3
Total	116.4	67.8	37.6	10.8	48.4	1.7

Some variability existed between the Lake Lookover subwatersheds in regard to runoff; in particular, the Northwest and Northeast subwatersheds featured somewhat lower runoff throughout the year. When direct precipitation and evapotranspiration to the lake itself are considered, Lake Lookover is estimated to receive approximately 1547882 m³ or 408.9 million gallons of water each year.

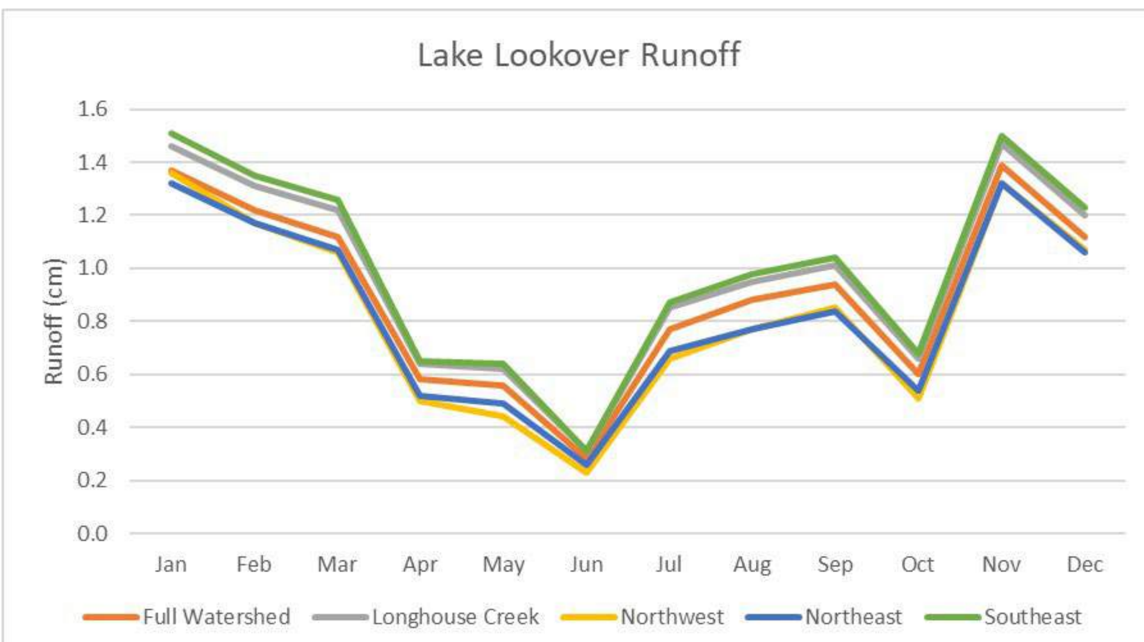


Figure 52. Average monthly runoff occurring in each subwatershed in the Lake Lookover watershed

As no bathymetric data for Lake Lookover was available, the lake's volume was estimated using depths collected in the field to be approximately 73,214 m³ or 19.3 million gallons of water. Using this and the estimated annual hydraulic load, Lake Lookover is estimated to flush completely approximately 21.1 times a year, with a hydraulic retention time of approximately 17.3 days. When examined on a monthly basis, the lake's annualized flushing rate is estimated to be at its lowest during August.

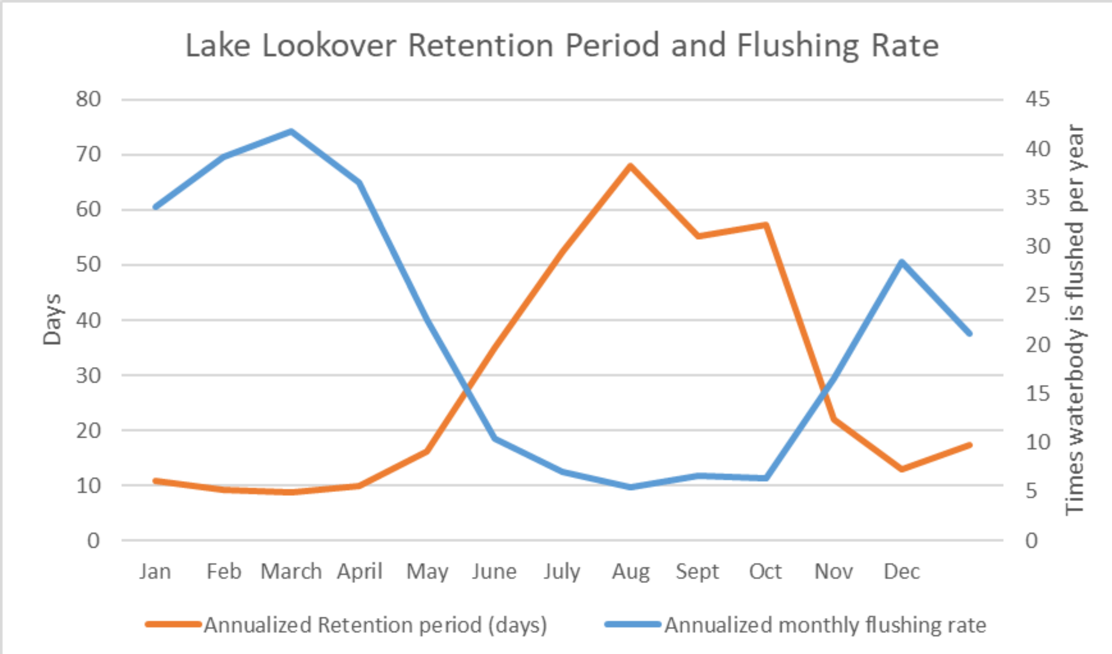


Figure 53. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Lake Lookover, based on variations in hydraulic loads.

Table 114: Estimated annual loads of nitrogen in the total Lake Lookover watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	32.4	4.02
	Wetland	25.6	3.18
	Open Land	0.6	0.07
	Barren Land	0.0	0.00
	Low-Density Mixed	0.6	0.07
	Medium-Density Mixed	0.5	0.07
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	4.1	0.51
Other Sources	Farm Animals and Waterfowl	0.1	0.01
	Stream Bank	0.0	0.00
	Groundwater	375.5	46.63
	Dryfall	127.9	15.88
	Septic Systems	238.0	29.56
	Total	805.2	100

The estimated annual nitrogen load for Lake Lookover is dominated by nitrogen originating from groundwater and septic systems within the watershed, with dryfall also contributing a significant load. Runoff from forested areas and wetlands also contributes nitrogen via runoff, this is likely simply due to the large areas of these land use types within the watershed. The Longhouse Creek subwatershed is estimated to yield the highest annual nitrogen load, while the Northwest subwatershed yields the largest load per acre. This is likely due to the relatively high number of septic systems in the northwest subwatershed compared to those present in the other subwatersheds.

Table 115. Estimated annual loads of nitrogen by subwatershed in the Lake Lookover watershed

Category	Description	Full Watershed kg	Longhouse Creek kg	Northwest kg	Northeast kg	Southeast kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0
	Forest	32.4	25.7	2.0	1.5	7.3
	Wetland	25.6	20.0	0.0	1.1	4.7
	Open Land	0.6	0.6	0.1	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	0.6	0.1	0.1	0.3	0.0
	Medium-Density Mixed	0.5	0.0	0.1	0.6	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	4.1	2.0	0.8	0.5	0.6
Other Sources	Farm Animals and Waterfowl	0.1	0.0	0.0	0.0	0.0
	Stream Bank	0.0	1.0	0.0	0.0	0.0
	Groundwater	375.5	266.1	19.8	20.2	63.6
	Dryfall	127.9	.	.	.	.
	Septic Systems	238.0	15.0	137.0	39.8	55.7
	Total (kg)	805.2	330.5	159.9	63.9	132.0
	kg/acre	1.0	0.6	4.5	1.6	1.0

Table 116. Estimated annual loads of Phosphorus in the total Lake Lookover Lake watershed

Category	Description	Total Phosphorus kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	1.67	5.4
	Wetland	0.97	3.2
	Open Land	0.01	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.04	0.1
	Medium-Density Mixed	0.04	0.1
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.32	1.0
Other Sources	Farm Animals and Waterfowl	0.03	0.1
	Stream Bank	1.00	3.3
	Groundwater	7.03	22.9
	Dryfall	0.64	2.1
	Septic Systems	18.99	61.8
	Total	30.73	100.0

Table 117. Estimated annual loads of phosphorus by subwatershed in the Lake Lookover watershed

Category	Description	Full Watershed kg	Longhouse Creek kg	Northwest kg	Northeast kg	Southeast kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00
	Forest	1.67	1.06	0.19	0.18	0.48
	Wetland	0.97	0.64	0.00	0.07	0.28
	Open Land	0.01	0.01	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.04	0.01	0.01	0.03	0.00
	Medium-Density Mixed	0.04	0.00	0.01	0.06	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.32	0.13	0.08	0.05	0.07
Other Sources	Farm Animals and Waterfowl	0.03	0.00	0.00	0.00	0.00
	Stream Bank	1.00	0.00	0.00	0.00	0.00
	Groundwater	7.03	4.23	0.52	0.53	1.66
	Dryfall	0.64	.	.	.	.
	Septic Systems	18.99	0.00	22.68	0.84	3.36
	Total (kg)	30.73	6.08	23.49	1.76	5.85
	kg/acre	0.04	0.01	0.66	0.04	0.04

The annual estimated watershed-based phosphorus load for Lake Lookover largely originates from septic systems, which were estimated to yield approximately 62% of the full watershed-based load. The Northwest subwatershed yielded both the highest overall annual phosphorus load and the largest load per acre.

During the field events in 2022, Lake Lookover was not observed to become anoxic, and water samples collected near the bottom of the water column did not yield higher phosphorus concentrations than those collected at the surface. The lake's internal phosphorus load was therefore calculated using a reduced oxic loading coefficient and was estimated to be approximately 5.56 kg/year.

Table 118 below displays the external and internal loads of phosphorus for Lake Lookover, as well as the grand total, which is estimated to be approximately 36.29 kg/year. Watershed-based loading was modeled to be the largest driver of phosphorus loading in Lake Lookover, contributing to approximately 85% of the total annual load.

Table 118. Total estimated annual phosphorus loads for Lake Lookover from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	30.73
Internal	5.56
Total	**36.29**

Table 119. Estimated annual loads of sediment in the total Lake Lookover watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.210	12.4
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.010	0.6
	Medium-Density Mixed	0.010	0.6
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.070	4.1
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	1.395	82.3
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	1.695	100.0

The total estimated yearly sediment load for Lake Lookover largely originated from streambank erosion, as well as from runoff from forested land. The Southeast subwatershed is estimated to yield the highest annual load of sediment, while the Northeast subwatershed yields the highest load per acre.

Table 120. Estimated annual loads of sediment by subwatershed in the Lake Lookover watershed

Category	Description	Full Watershed kg x 1000	Longhouse Creek kg x 1000	Northwest kg x 1000	Northeast kg x 1000	Southeast kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000
	Forest	0.210	0.040	0.080	0.100	0.090
	Wetland	0.000	0.000	0.000	0.020	0.030
	Open Land	0.000	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.010	0.000	0.010	0.010	0.000
	Medium-Density Mixed	0.010	0.000	0.010	0.030	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.070	0.010	0.040	0.020	0.030
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000
	Stream Bank	1.395	0.204	0.006	0.005	0.237
	Groundwater	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	1.695	0.254	0.146	0.185	0.387
	kg/acre	2.186	0.447	4.124	4.591	2.932

Table 121. Estimated annual loads of bacteria in the total Lake Lookover watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.08E+08	0.1
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	5.13E+08	0.2
	Other Wildlife	2.05E+11	99.7
	Total	2.06E+11	100

Lake Lookover's total estimated annual load of bacteria is modeled to almost entirely originate from wildlife in the watershed's forested area. The Longhouse Creek subwatershed yielded the highest bacterial load of the four subwatersheds due to its large area.

Table 122. Estimated annual bacterial loads by subwatershed in the Lake Lookover watershed

Category	Description	Full Watershed	Longhouse Creek	Northwest	Northeast	Southeast
		%	%	%	%	%
Fecal Coliform	Farm Animals and Waterfowl	0.1	0	0	0	0
	WWTP	0	0	0	0	0
	Septic Systems	0	0	0	0	0
	Urban Areas	0.2	1.3	35.5	27.4	1.3
	Other Wildlife	99.7	98.7	64.5	72.6	98.7
	Total (organisms)	2.06E+11	1.50E+11	1.46E+10	1.36E+10	3.67E+10

LOWER MOUNT GLEN LAKE

Lower Mount Glen Lake's watershed spans an area of approximately 599 acres, while the lake itself has a surface area of approximately 14.8 acres. A majority of the watershed's area consists of forested land, low-density open space, and wetlands. The watershed contains Upper Mount Glen Lake and Lindy's Lake and both of their respective watersheds. The outlet of Lower Mount Glen Lake travels north before converging with West Brook. Descriptions of the lake's subwatersheds are as follows:

- **East:** This 11.5-acre subwatershed is largely forested, however approximately 42.6% of the area is also urbanized, with most present along Larsen Road.
- **North:** This 21.7-acre subwatershed contains the northwestern shoreline of the lake and the nearby urbanized areas along Broadway, as well as forested areas to the northwest.
- **Southwest:** This 15.7-acre subwatershed contains the urbanized areas along Hudson Dr. and Broadway, as well as a smaller strip of forested land between the two streets.
- **Upper:** This is the largest of Lower Mount Glen's subwatersheds at approximately 550.5 acres. The area is largely covered with forested land and wetlands; however, approximately 196.9 acres of urbanized landcover is also present. This subwatershed contains Upper Mount Glen Lake and Lindy's Lake.

Table 123. Land-use by subwatershed in the Lower Mount Glen Lake watershed

Source	Full Watershed	East	North	Southwest	Upper
			Area (acres)		
Open Water	29.2	0.0	0.0	0.0	29.2
Hay/Pasture	0.2	0.0	0.0	0.2	0.0
Cropland	0.0	0.0	0.0	0.0	0.0
Forest	280.0	6.4	13.1	4.9	255.5
Wetland	68.4	0.0	0.0	0.0	68.4
Open Land	1.0	0.2	0.2	0.0	0.5
Barren Land	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	70.7	0.7	1.2	1.7	66.7
Medium-Density Mixed	12.1	0.5	0.5	0.0	11.1
High-Density Mixed	0.2	0.0	0.0	0.0	0.2
Low-Density Open Space	137.6	3.7	6.7	8.9	118.9
Total	599.4	11.5	21.7	15.7	550.5

Table 123 continued. Land-use by subwatershed in the Lower Mount Glen Lake watershed

Source	Full Watershed	East	North	Southwest	Upper
			Area (%)		
Open Water	4.9	0.0	0.0	0.0	5.3
Hay/Pasture	0.0	0.0	0.0	1.3	0.0
Cropland	0.0	0.0	0.0	0.0	0.0
Forest	46.7	55.7	60.4	31.2	46.4
Wetland	11.4	0.0	0.0	0.0	12.4
Open Land	0.2	1.7	0.9	0.0	0.1
Barren Land	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	11.8	6.1	5.5	10.8	12.1
Medium-Density Mixed	2.0	4.3	2.3	0.0	2.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	23.0	32.2	30.9	56.7	21.6
Total	100	100	100	100	100

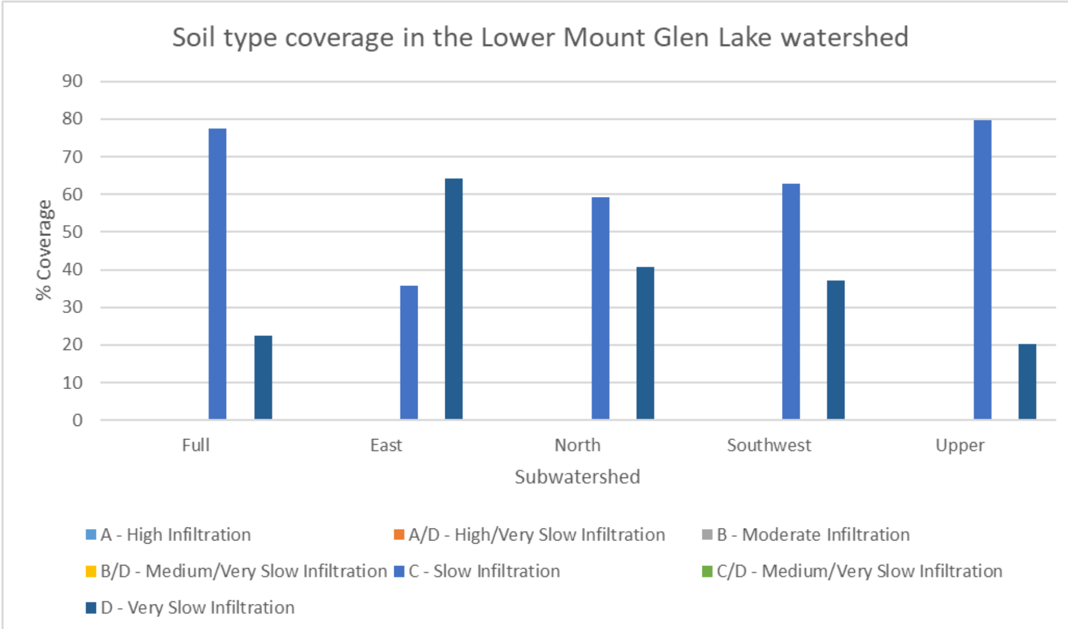


Figure 54. Percent coverage of Lower Mount Glen Lake watershed and subwatersheds by different hydrologic soil groups.

Lower Mount Glen Lake's soils consist entirely of slow and very slow infiltration soils. The Eastern watershed features the highest area of Type D ("very slow infiltration") soils, suggesting that this subwatershed is slightly more prone to runoff than the other subwatersheds, which feature higher amounts of Type C ("slow infiltration"). Overall, however, the full watershed is likely prone to somewhat high runoff due to the high prevalence of these soil types. The average percent slope within the watershed is approximately 10%, however the Eastern subwatershed features a maximum slope of approximately 60%.

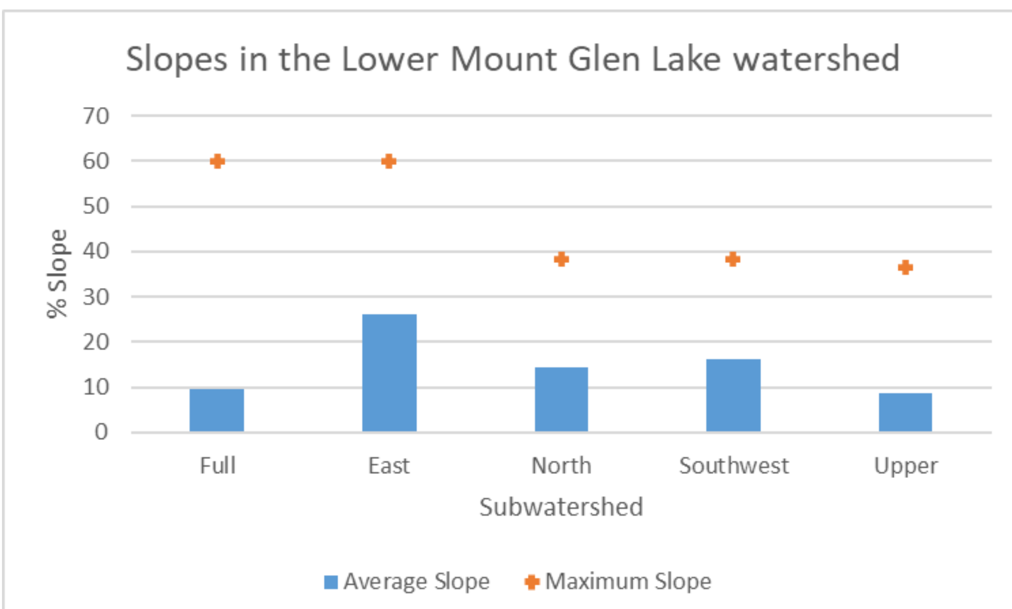


Figure 55. Variation in average and maximum percent slope between subwatersheds in the Lower Mount Glen Lake watershed.

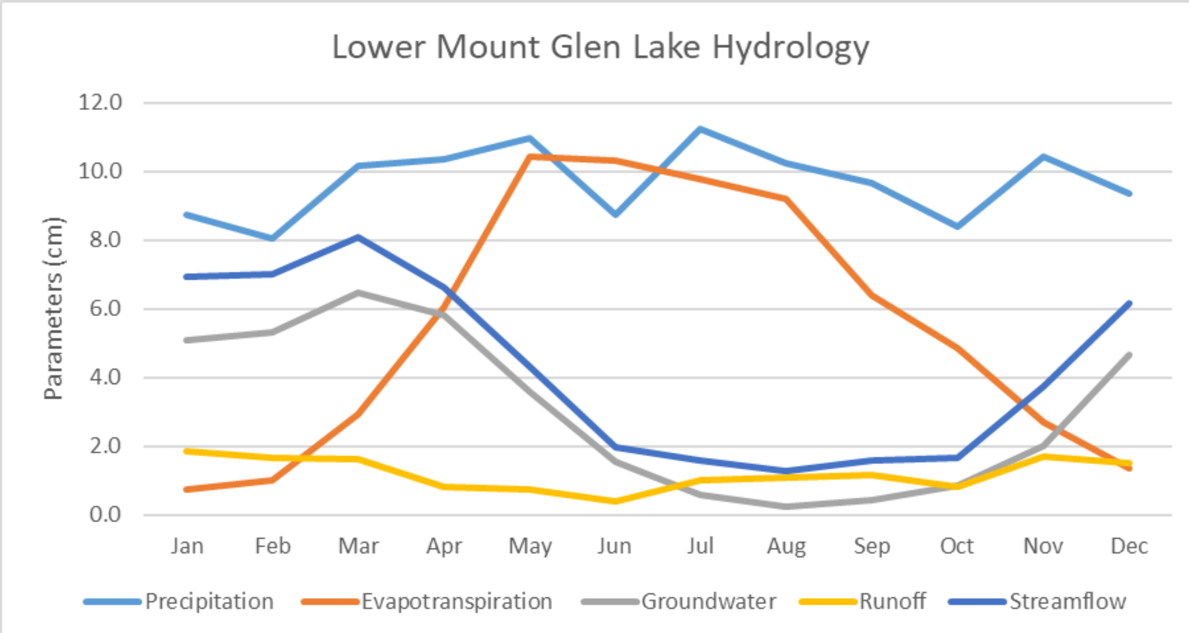


Figure 56. Estimated seasonal changes in hydrology in the Lower Mount Glen Lake watershed

Table 124. Total hydrological parameters in the full Lower Mount Glen Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.1	1.8	6.9	2.2
Feb	8.0	1.0	5.3	1.7	7.0	2.5
Mar	10.2	2.9	6.5	1.6	8.1	2.6
Apr	10.4	6.0	5.8	0.8	6.6	2.2
May	11.0	10.4	3.6	0.7	4.3	1.4
Jun	8.8	10.3	1.6	0.4	2.0	0.6
Jul	11.2	9.8	0.6	1.0	1.6	0.5
Aug	10.2	9.2	0.2	1.1	1.3	0.4
Sep	9.7	6.4	0.4	1.1	1.6	0.5
Oct	8.4	4.8	0.8	0.8	1.6	0.5
Nov	10.4	2.7	2.0	1.7	3.7	1.2
Dec	9.3	1.3	4.7	1.5	6.2	2.0
Total	116.4	65.7	36.6	14.3	50.9	1.4

For the most part, very little variability exists between the four subwatersheds in regard to runoff, however the Southwest subwatershed is modeled to yield notably less runoff than the other subwatersheds. When total precipitation and evapotranspiration to the lake itself are factored, Lower Mount Glen Lake is estimated to receive approximately 1,264,031 m³ or 333.9 million gallons of water each year.

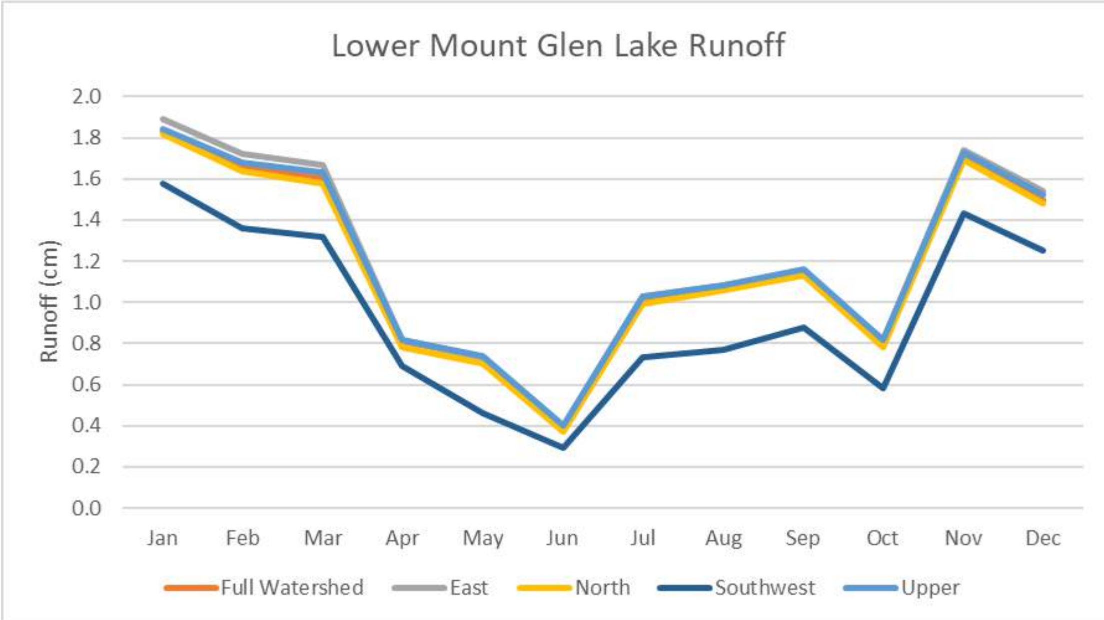


Figure 57. Average monthly runoff occurring in each subwatershed in the Lower Mount Glen Lake watershed

As no bathymetric data was available for Lower Mount Glen Lake, the lake's volume was estimated based on depths collected in the field to be approximately 142,278 m³ or 37.6 million gallons. Using this result and the estimated hydraulic load, the lake's flushing rate was estimated to be approximately 8.9 times a year, with a hydraulic residence time of approximately 41.1 days. The lake's annualized flushing rate is estimated to occur during the month of August in an average year.

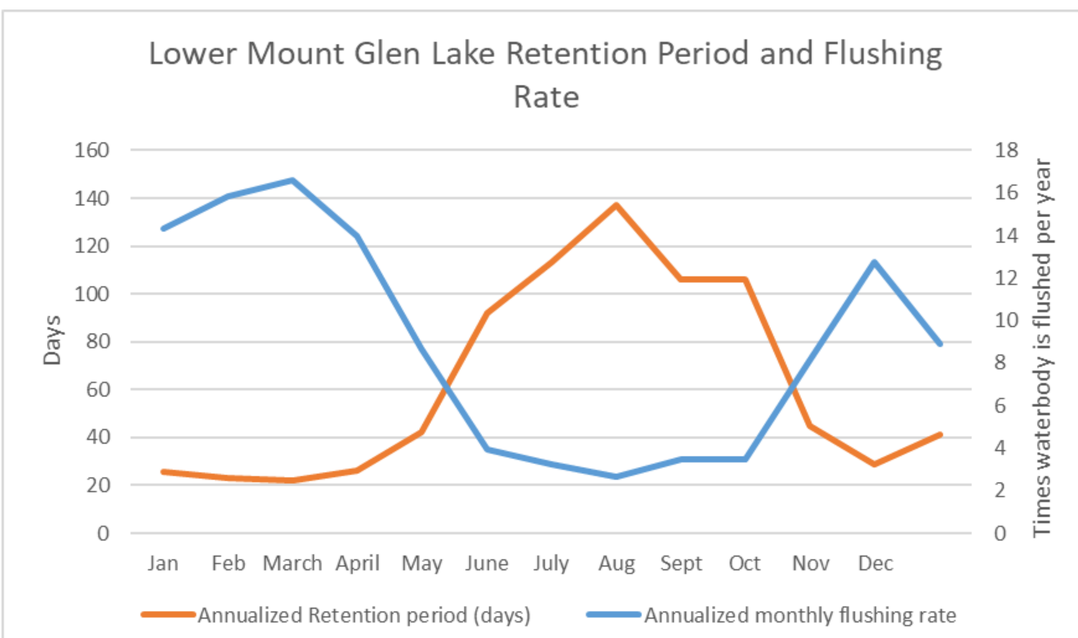


Figure 58. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Lower Mount Glen Lake, based on variations in hydraulic loads.

Table 125. Estimated annual loads of nitrogen in the total Lower Mount Glen Lake watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	0.1	0.01
	Cropland	0.0	0.00
	Forest	23.7	1.47
	Wetland	13.7	0.85
	Open Land	0.5	0.03
	Barren Land	0.0	0.00
	Low-Density Mixed	9.5	0.59
	Medium-Density Mixed	6.5	0.40
	High-Density Mixed	0.1	0.01
	Low-Density Open Space	18.5	1.15
Other Sources	Farm Animals and Waterfowl	1.1	0.07
	Stream Bank	6.0	0.37
	Groundwater	271.6	16.85
	Dryfall	99.4	6.17
	Septic Systems	1161.6	72.05
	Total	1612.3	100

As with many of the other lakes in the study, Lower Mount Glen Lake's estimated annual nitrogen load largely originates in septic systems within the watershed. Groundwater was also estimated to yield a relatively high load of nitrogen, while runoff-based nitrogen loading was largely contributed by runoff from forested land, wetlands, and low-density open space. The Upper subwatershed was estimated to yield the largest overall annual load of nitrogen due to its size and number of septic systems, while the Southwest subwatershed was estimated to yield the highest amount of nitrogen per acre.

Table 126. Estimated annual loads of nitrogen by subwatershed in the Lower Mount Glen Lake watershed

Category	Description	Full Watershed	East	North	Southwest	Upper
		kg	kg	kg	kg	kg
Runoff	Hay/Pasture	0.1	0.0	0.0	0.2	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0
	Forest	23.7	0.7	1.5	0.4	21.5
	Wetland	13.7	0.0	0.0	0.0	13.6
	Open Land	0.5	0.1	0.1	0.0	0.2
	Barren Land	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	9.5	0.1	0.1	0.2	9.2
	Medium-Density Mixed	6.5	0.3	0.3	0.0	5.5
	High-Density Mixed	0.1	0.0	0.0	0.0	0.1
	Low-Density Open Space	18.5	0.4	0.6	0.9	16.4
Other Sources	Farm Animals and Waterfowl	1.1	0.0	0.0	0.0	0.0
	Stream Bank	6.0	0.0	0.0	0.0	0.0
	Groundwater	271.6	5.8	10.6	8.2	246.3
	Dryfall	99.4	.	.	.	.
	Septic Systems	1161.6	52.6	105.1	105.1	911.6
	Total (kg)	1612.3	59.9	118.4	114.9	1224.5
	kg/acre	2.7	5.2	5.5	7.3	2.2

Table 127. Estimated annual loads of Phosphorus in the total Lower Mount Glen Lake watershed

Category	Description	Total Phosphorus kg	%
Runoff	Hay/Pasture	0.04	0.0
	Cropland	0.00	0.0
	Forest	1.01	0.7
	Wetland	0.47	0.3
	Open Land	0.02	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.64	0.4
	Medium-Density Mixed	0.41	0.3
	High-Density Mixed	0.01	0.0
	Low-Density Open Space	1.26	0.9
Other Sources	Farm Animals and Waterfowl	0.37	0.3
	Stream Bank	5.00	3.5
	Groundwater	6.93	4.8
	Dryfall	0.50	0.3
	Septic Systems	126.43	88.4
	Total	143.09	100.0

Table 128. Estimated annual loads of phosphorus by subwatershed in the Lower Mount Glen Lake watershed

Category	Description	Full Watershed kg	East kg	North kg	Southwest kg	Upper kg
Runoff	Hay/Pasture	0.04	0.00	0.00	0.07	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00
	Forest	1.01	0.06	0.11	0.03	0.88
	Wetland	0.47	0.00	0.00	0.00	0.45
	Open Land	0.02	0.01	0.02	0.00	0.01
	Barren Land	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.64	0.01	0.01	0.02	0.60
	Medium-Density Mixed	0.41	0.03	0.03	0.00	0.34
	High-Density Mixed	0.01	0.00	0.00	0.00	0.01
	Low-Density Open Space	1.26	0.04	0.07	0.10	1.07
Other Sources	Farm Animals and Waterfowl	0.37	0.00	0.00	0.00	0.00
	Stream Bank	5.00	0.00	0.00	0.00	4.00
	Groundwater	6.93	0.15	0.28	0.21	6.07
	Dryfall	0.50	.	.	.	.
	Septic Systems	126.43	7.56	9.24	9.24	106.74
	Total (kg)	143.09	7.86	9.76	9.67	120.17
	kg/acre	0.24	0.68	0.45	0.62	0.22

Estimated phosphorus loads in the Lake Lower Mount Glen Lake watershed follow a similar pattern to those of nitrogen, with septic systems in the watershed yielding approximately 88% of the estimated annual load. The Upper subwatershed yields the highest estimated overall load, while the East subwatershed yields the largest load per acre.

Lower Mount Glen Lake was measured to feature anoxia at the bottom of the water column during the summer sampling event. Discrete samples from the bottom of the water column also yielded higher total phosphorus concentrations than the surface did. Internal load modeling accordingly assumed that increased loading of phosphorus occurred for two months at a depth of 3 meters. The calculated yearly internal load for Lower Mount Glen Lake was approximately 11.54 kg. If a year were to occur with no anoxic loading occurring in Lower Mount Glen Lake, the yearly internal load would be approximately 5.51 kg/L.

Table 129 below displays the external and internal loads of phosphorus for Lower Mount Glen Lake, as well as the grand total, which is estimated to be approximately 154.63 kg/year. Watershed-based phosphorus loading is modeled to dominate the total phosphorus load, contributing approximately 93% per year.

Table 129. Total estimated annual phosphorus loads for Lower Mount Glen Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	143.09
Internal	11.54
Total	**154.63**

Table 130. Estimated annual loads of sediment in the total Lower Mount Glen Lake watershed

Category	Description	Sediment	
		kgx1000	%
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.050	1.1
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.060	1.3
	Medium-Density Mixed	0.060	1.3
	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	4.189	93.5
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	4.479	100.0

The total estimated yearly sediment load for Lower Mount Glen Watershed largely originated from stream bank erosion, with most of this occurring in the Upper subwatershed, which yields the highest overall sediment load. The East subwatershed is modeled to yield the largest sediment load per acre. Runoff-based sediment loading was dominated by sediment originating from urbanized areas.

Table 131. Estimated annual loads of sediment by subwatershed in the Lower Mount Glen Lake watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	North kg x 1000	Southwest kg x 1000	Upper kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000
	Forest	0.050	0.020	0.030	0.010	0.030
	Wetland	0.000	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.010	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.060	0.000	0.010	0.010	0.040
	Medium-Density Mixed	0.060	0.020	0.020	0.000	0.030
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.120	0.020	0.030	0.040	0.070
Other Sources	Farm Animals	0.000	0.000	0.000	0.000	0.000
	Stream Bank	4.189	0.005	0.001	0.018	2.606
	Groundwater	0.000	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000	0.000
	Total (kgx1000)	4.479	0.065	0.101	0.078	2.776
	kg/acre	7.47	5.65	4.65	4.97	5.04

Table 132. Estimated annual loads of bacteria in the total Lower Mount Glen Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	5.03E+08	0.2
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.27E+11	69.3
	Other Wildlife	9.99E+10	30.5
	Total	3.27E+11	100

Approximately 69% of the Lower Mount Glen Lake watershed's bacterial load is estimated to originate from urbanized areas, while most of the remaining portion is estimated to originate from wildlife in the forested areas of the watershed. The Upper subwatershed is estimated to yield the highest bacterial load of the four subwatersheds.

Table 133. Estimated annual bacterial loads by subwatershed in the Lower Mount Glen Lake watershed

Category	Description	Full Watershed	East	North	Southwest	Upper
		%	%	%	%	%
Fecal Coliform	Farm Animals and Waterfowl	0.2	0.0	0.0	0.0	0.0
	WWTP	0.0	0.0	0.0	0.0	0.0
	Septic Systems	0.0	0.0	0.0	0.0	0.0
	Urban Areas	69.3	71.3	63.6	90.6	68.6
	Other Wildlife	30.5	28.7	36.4	9.4	31.4
	Total (organisms)	3.27E+11	7.98E+09	1.28E+10	1.88E+10	2.90E+11

UPPER MOUNT GLEN LAKE

Upper Mount Glen Lake's watershed spans an area of approximately 513 acres, while the lake itself has a surface area of approximately 9.9 acres. The watershed is approximately 48.2% forested and 36.6% urbanized, with wetlands comprising approximately 13% of the area. The lake features an inlet from the west originating at Lindy's Lake, while two other inlets enter the lake from the south. The Lake's outlet travels north for a short distance before entering Lower Mount Glen Lake. Descriptions of the lake's subwatersheds are as follows:

- **East:** This 22.9-acre subwatershed is largely forested with some urbanized areas along Upper Mount Glen Lake Dr. and Otterhole Road.
- **Lindy's Lake:** This 96.7-acre subwatershed contains Lindy's Lake and its entire watershed, as well as patches of urbanized land and forest immediately south of Lindy's Lake's Dam. The subwatershed is over 80% urbanized.
- **North:** This subwatershed contains the intersection of Broadway and Rosemont Ave. The watershed is classified as approximately 88% urbanized, with smaller amounts of wetland and forested land also present.
- **Norvin Green:** This is the largest of Upper Mount Glen Lake's subwatersheds, at 309.6 acres. Approximately 89% of the area consists of forested land and wetlands, with most of the remaining area comprising of urbanized areas along Otterhole Road.
- **South:** This 50.6-acre subwatershed contains the largely developed area between Post Brook Rd. and Sanders Ct. The subwatershed also contains approximately 15 acres of forested land and wetlands.
- **Southwest:** This approximately 15-acre subwatershed comprises of the largely developed area around Mountainside Road.

Table 134. Land-use by subwatershed in the Upper Mount Glen Lake watershed

Source	Full Watershed	East	Lindy's	North	Norvin Green	South	Southwest
	Area (acres)						
Open Water	11.5	0.0	11.1	0.0	0.4	0.0	0.0
Hay/Pasture	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
Forest	246.9	15.8	2.0	0.5	211.8	14.8	1.5
Wetland	66.0	1.0	1.2	0.1	63.5	0.2	0.0
Open Land	0.5	0.0	0.5	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	65.0	1.0	28.2	1.4	11.9	11.6	7.2
Medium-Density Mixed	10.6	0.2	3.5	0.0	1.7	1.0	3.2
High-Density Mixed	0.2	0.0	0.0	0.0	0.0	0.0	0.2
Low-Density Open Space	111.9	4.9	50.2	3.1	20.3	23.0	3.0
Total	512.6	22.9	96.7	5.1	309.6	50.6	15.1

Table 134 continued. Land-use by subwatershed in the Upper Mount Glen Lake watershed

Source	Full Watershed	East	Lindy's	North	Norvin Green	South	Southwest
	Area (%)						
Open Water	2.2	0.0	11.5	0.0	0.1	0.0	0.0
Hay/Pasture	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
Forest	48.2	69.0	2.1	9.8	68.4	29.2	9.9
Wetland	12.9	4.4	1.2	2.0	20.5	0.4	0.0
Open Land	0.1	0.0	0.5	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	12.7	4.4	29.2	27.5	3.8	22.9	47.7
Medium-Density Mixed	2.1	0.9	3.6	0.0	0.5	2.0	21.2
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Low-Density Open Space	21.8	21.4	51.9	60.8	6.6	45.5	19.9
Total	100	100	100	100	100	100	100

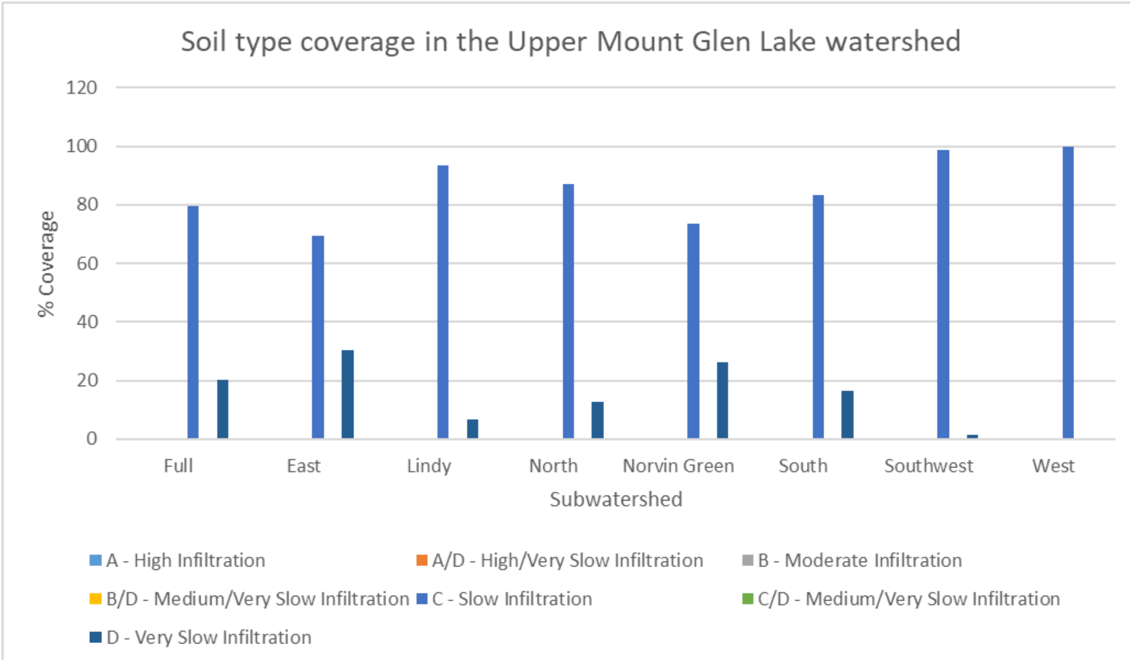


Figure 59. Percent coverage of Upper Mount Glen Lake watershed and subwatersheds by different hydrologic soil groups.

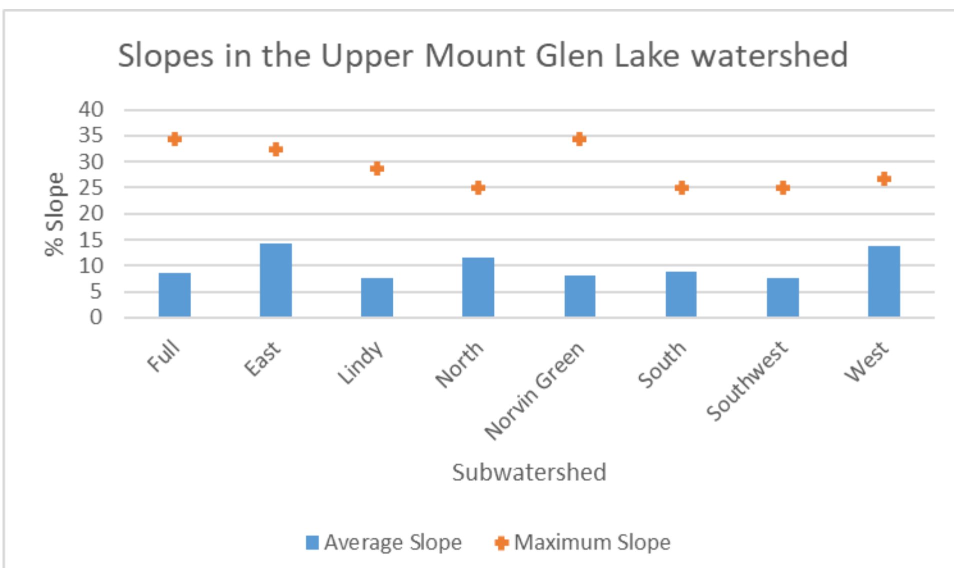


Figure 60. Variation in average and maximum percent slope between subwatersheds in the Upper Mount Glen Lake watershed.

Upper Mount Glen Lake Watershed is entirely covered with soil groups C and D, both of which feature slow infiltration rates. The East subwatershed was modeled to contain the largest percentage of soil group D, suggesting that this subwatershed may be prone to increased runoff. The average slope for the lake's full watershed was modeled to be approximately 8%, with a maximum slope of approximately 34% occurring in the Norvin Green subwatershed. The East subwatershed featured the highest average slope at approximately 14%.

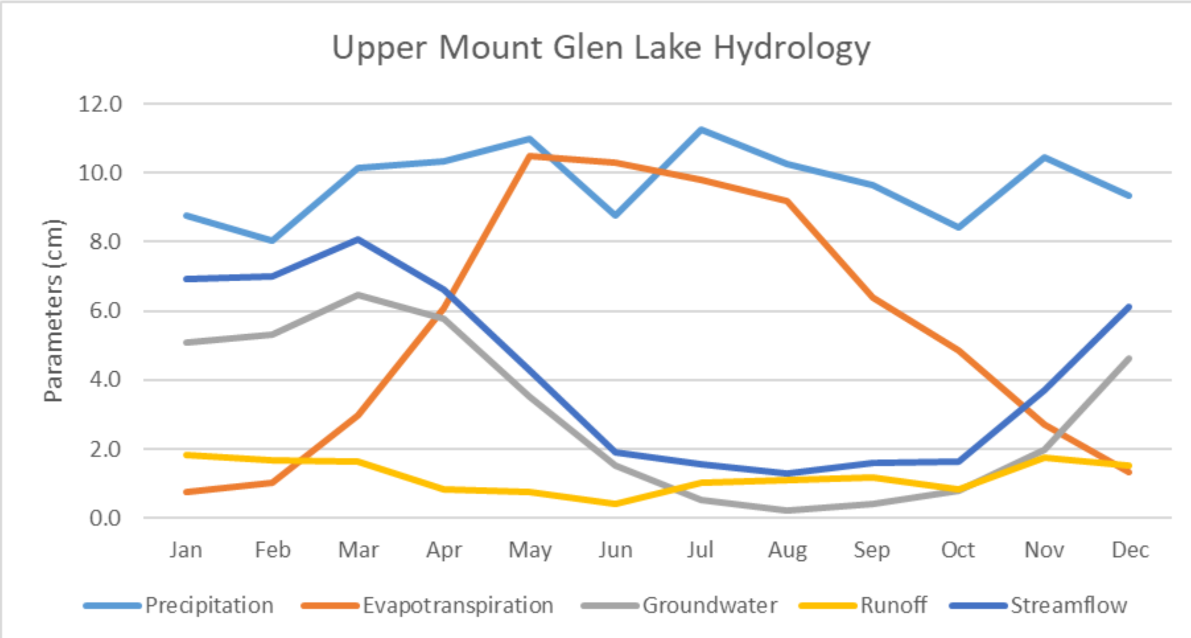


Figure 61. Estimated seasonal changes in hydrology in the Upper Mount Glen Lake watershed

Table 135. Total hydrological parameters in the full Upper Mount Glen Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.1	1.8	6.9	1.9
Feb	8.0	1.0	5.3	1.7	7.0	2.1
Mar	10.2	3.0	6.5	1.6	8.1	2.2
Apr	10.4	6.1	5.8	0.8	6.6	1.9
May	11.0	10.5	3.5	0.7	4.3	1.2
Jun	8.8	10.3	1.5	0.4	1.9	0.5
Jul	11.2	9.8	0.5	1.0	1.6	0.4
Aug	10.2	9.2	0.2	1.1	1.3	0.4
Sep	9.7	6.4	0.4	1.2	1.6	0.4
Oct	8.4	4.9	0.8	0.8	1.6	0.4
Nov	10.4	2.7	2.0	1.7	3.7	1.0
Dec	9.3	1.3	4.6	1.5	6.1	1.7
Total	116.4	65.9	36.2	14.5	50.7	1.2

While most of Upper Mount Glen Lake's subwatersheds are relatively similar in terms of runoff over the course of an average year, the Southwest subwatershed yields about 26% higher runoff than the other subwatersheds during the earlier portions of the year and remains the highest yielding subwatershed throughout the season. When total precipitation and evapotranspiration to the lake itself are factored, Upper Mount Glen Lake is estimated to receive approximately 1,071,581 m³ or 283.1 million gallons of water each year.

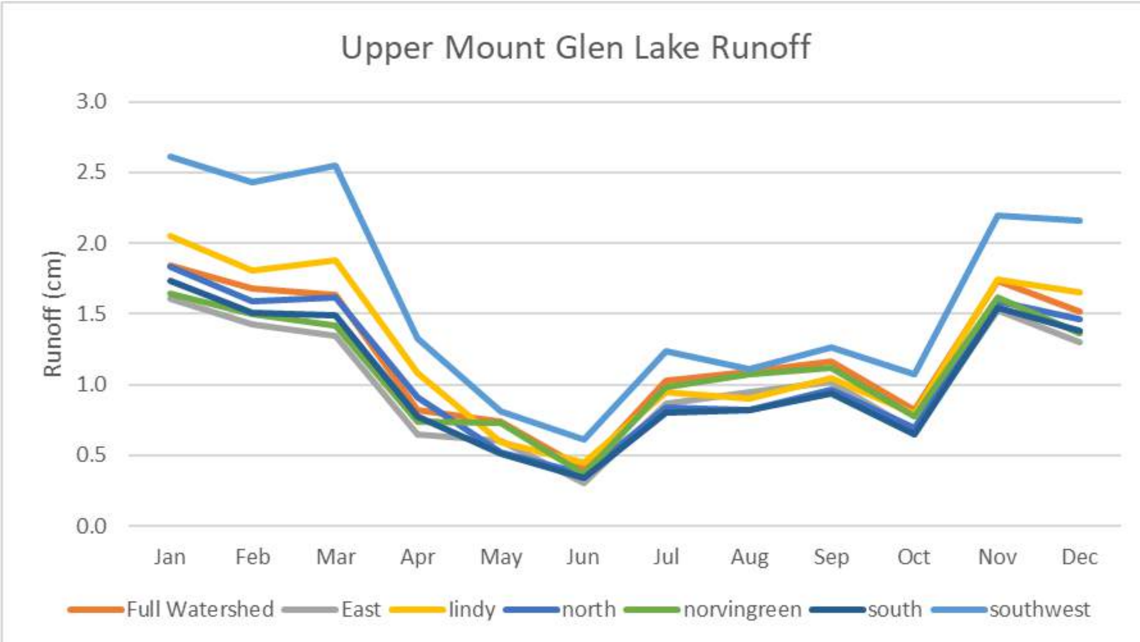


Figure 62. Average monthly runoff occurring in each subwatershed in the Upper Mount Glen Lake Watershed

As bathymetric data for Upper Mount Glen Lake was not available, the lake's volume was estimated using depths measured in the field. Upper Mount Glen Lake has an estimated volume of approximately 31,239 m^3 or 8.25 million gallons of water. The lake is estimated to have a relatively high flushing rate of approximately 32.4 times a year, with a retention time of approximately 10.7 days. The lowest annualized flushing rates during an average year are estimated to occur in August and October

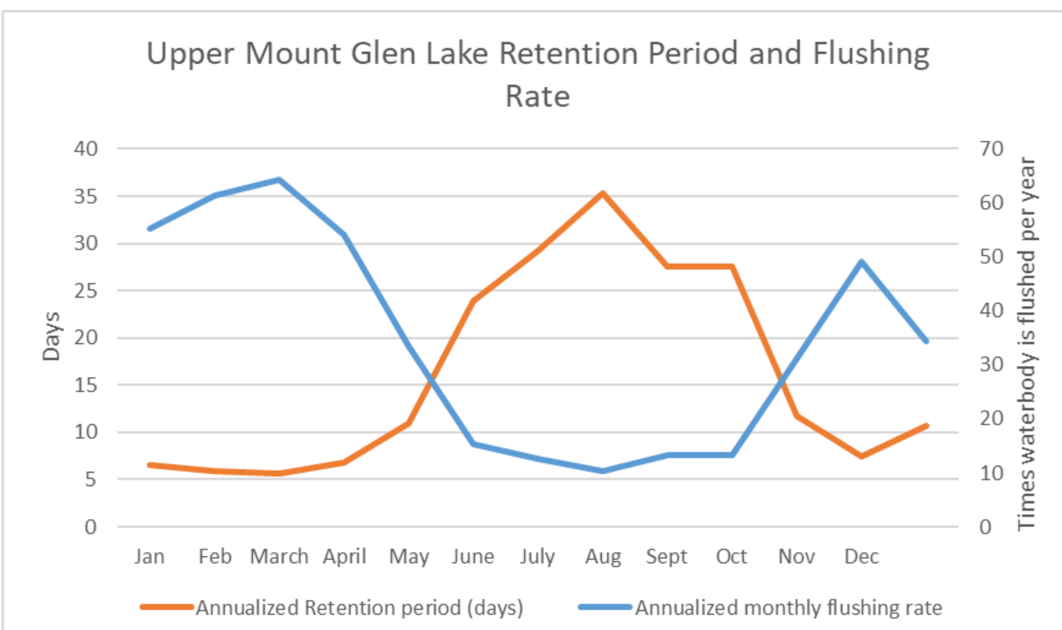


Figure 63. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Upper Mount Glen Lake, based on variations in hydraulic

Table 136. Estimated annual loads of nitrogen in the total Upper Mount Glen Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.0	0.0
	Cropland	0.0	0.0
	Forest	21.8	1.1
	Wetland	13.8	0.7
	Open Land	0.2	0.0
	Barren Land	0.0	0.0
	Low-Density Mixed	9.6	0.5
	Medium-Density Mixed	6.6	0.3
	High-Density Mixed	0.2	0.0
	Low-Density Open Space	16.4	0.8
Other Sources	Farm Animals and Waterfowl	1.0	0.0
	Stream Bank	4.0	0.2
	Groundwater	247.2	12.1
	Dryfall	84.6	4.1
	Septic Systems	1642.0	80.2
	Total	2047.4	100

As with many of the other lakes in the study, Upper Mount Glen Lake's estimated annual nitrogen load largely originates in septic systems within the watershed. Groundwater was also estimated to yield a relatively high load of nitrogen, while runoff-base nitrogen loading was largely contributed by urbanized and forested areas. The Lindy's subwatershed was estimated to yield the largest overall load of nitrogen, while the North subwatershed yielded the largest yearly load of nitrogen per acre.

Table 137. Estimated annual loads of nitrogen by subwatershed in the Upper Mount Glen Lake watershed

Category	Description	Full Watershed kg	East kg	Lindys kg	North kg	Norvin Green kg	South kg	Southwest kg
Runoff	Hay/Pasture	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
	Forest	21.8	1.4	0.2	0.1	14.8	1.1	0.1
	Wetland	13.8	0.2	0.3	0.1	13.2	0.1	0.0
	Open Land	0.2	0.0	0.2	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	9.6	0.1	4.0	0.5	1.7	1.7	1.4
	Medium-Density Mixed	6.6	0.1	2.6	0.0	0.7	0.6	2.6
	High-Density Mixed	0.2	0.0	0.0	0.0	0.0	0.0	0.2
	Low-Density Open Space	16.4	0.7	7.1	1.2	2.9	3.3	0.6
Other Sources	Farm Animals and Waterfowl	1.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	4.0	0.0	1.0	0.0	1.0	0.0	0.0
	Groundwater	247.2	11.5	44.8	6.6	139.5	24.5	6.5
	Dryfall	84.6	.	.	.	.	.	.
	Septic Systems	1642.0	52.6	831.7	92.4	221.2	195.9	164.0
	Total (kg)	2047.4	66.6	891.8	100.8	395.0	226.9	175.4
	kg/acre	4.0	2.9	9.2	19.8	1.3	4.5	11.6

Table 138. Estimated annual loads of phosphorus in the total Upper Mount Glen Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	1.38	0.7
	Wetland	0.70	0.3
	Open Land	0.01	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.96	0.5
	Medium-Density Mixed	0.63	0.3
	High-Density Mixed	0.01	0.0
	Low-Density Open Space	1.66	0.8
Other Sources	Farm Animals and Waterfowl	0.35	0.2
	Stream Bank	6.00	2.9
	Groundwater	9.40	4.5
	Dryfall	0.42	0.2
	Septic Systems	186.28	89.6
	Total	207.80	100.0

Table 139. Estimated annual loads of phosphorus by subwatershed in the Upper Mount Glen Lake watershed

Category	Description	Full Watershed	East	Lindys	North	Norvin Green	South	Southwest
		kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	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
	Forest	1.38	0.12	0.01	0.01	0.95	0.08	0.01
	Wetland	0.70	0.01	0.01	0.00	0.64	0.00	0.00
	Open Land	0.01	0.00	0.01	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.96	0.02	0.27	0.06	0.17	0.18	0.15
	Medium-Density Mixed	0.63	0.01	0.16	0.00	0.06	0.06	0.27
	High-Density Mixed	0.01	0.00	0.00	0.00	0.00	0.00	0.02
	Low-Density Open Space	1.66	0.08	0.48	0.13	0.29	0.35	0.06
Other Sources	Farm Animals and Waterfowl	0.35	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	6.00	0.00	1.00	0.00	1.00	0.00	0.00
	Groundwater	9.40	0.30	1.14	0.17	3.29	0.64	0.26
	Dryfall	0.42	.	.	.	.	.	.
	Septic Systems	186.28	5.88	81.96	15.12	20.13	9.24	4.20
	Total (kg)	207.80	6.42	85.04	15.49	26.53	10.55	4.97
	kg/acre	0.41	0.28	0.88	3.04	0.09	0.21	0.33

Estimated phosphorus loads in the Upper Mount Glen watershed follow a similar pattern to those of nitrogen, with septic systems in the watershed yielding approximately 90% of the estimated annual load. The Lindy's subwatershed yields the highest estimated overall load, while the North subwatershed yields the highest load per acre.

During field events in 2022, Upper Mount Glen Lake was not observed to become anoxic. As such, internal phosphorus loading was calculated using a reduced oxic load and resulted in an estimated annual internal load of 3.67 kg.

Table 140 below displays and compares phosphorus loads from external and internal sources for Upper Mount

Glen Lake, as well as the total combined yearly load, which is approximately 211.47 kg/yr. Phosphorus entering the lake from the watershed was the dominant source, contributing approximately 98% of the total phosphorus load.

Table 140. Total estimated annual phosphorus loads for Upper Mount Glen Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	207.80
Internal	3.67
Total	**211.47**

Table 141. Estimated annual loads of sediment in the total Upper Mount Glen Lake watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.250	1.2
	Wetland	0.020	0.1
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.330	1.6
	Medium-Density Mixed	0.330	1.6
	High-Density Mixed	0.010	0.0
	Low-Density Open Space	0.570	2.8
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	19.011	92.6
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	20.521	100.0

The total estimated yearly sediment load for Upper Mount Glen Watershed largely originated from stream bank erosion. The Norvin Green subwatershed yielded the overall highest load of sediment, while the South subwatershed yielded the highest load per acre.

Table 142. Estimated annual loads of sediment by subwatershed in the Upper Mount Glen Lake watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	Lindy kg x 1000	North kg x 1000	Norvin Green kg x 1000	South kg x 1000	Southwest kg x 1000
Runoff	Hay/Pasture	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
	Forest	0.250	0.040	0.000	0.000	0.190	0.020	0.000
	Wetland	0.020	0.000	0.000	0.000	0.010	0.000	0.000
	Open Land	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
	Low-Density Mixed	0.330	0.010	0.020	0.020	0.050	0.070	0.050
	Medium-Density Mixed	0.330	0.010	0.020	0.000	0.030	0.030	0.150
	High-Density Mixed	0.010	0.000	0.000	0.000	0.000	0.000	0.010
	Low-Density Open Space	0.570	0.030	0.040	0.050	0.090	0.140	0.020
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	19.011	0.016	0.572	0.006	2.798	1.308	0.016
	Groundwater	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
	Total (kgx1000)	20.521	0.106	0.652	0.076	3.168	1.568	0.246
	kg/acre	40.031	4.629	6.744	14.902	10.231	30.988	16.291

Table 143. Estimated annual loads of bacteria in the total Upper Mount Glen Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	4.67E+08	0.2
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	1.89E+11	68.1
	Other Wildlife	8.80E+10	31.7
	Total	2.77E+11	100

Approximately 68% of the Upper Mount Glen Lake watershed's bacterial load is estimated to originate from urbanized areas, while most of the remaining 32% is estimated to originate from wildlife in the forested areas of the watershed. The Lindy's subwatershed was estimated to yield the highest bacterial load.

Table 144. Estimated annual bacterial loads by subwatershed in the Upper Mount Glen Lake watershed

Category	Description	Full Watershed %	East %	Lindy's %	North %	Norvin Green %	South %	Southwest %
Fecal Coliform	Farm Animals and Waterfowl	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	WWTP	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	68.1	41.5	99.7	98.3	11.1	92.7	98.9
	Other Wildlife	31.7	58.5	0.3	1.7	88.9	7.3	1.1
	Total (organisms)	2.77E+11	9.64E+09	2.24E+11	2.60E+10	8.50E+10	7.20E+10	4.93E+10

MT. LAUREL LAKE

Mt. Laurel Lake is located immediately south of Upper Greenwood Lake and consists of two basins, separated by a bridge along the Warwick Turnpike. The lake's watershed spans an area of approximately 1,269 acres, while the lake itself features a surface area of approximately 35 acres. The watershed consists of almost 85% forested land and wetlands. The lake's main inlet flows from the Lake Lookover dam and enters the southwest corner of upper Mt. Laurel Lake (the southern basin). The lake's outflow immediately enters Upper Greenwood Lake to the north. Descriptions of the Lake's subwatersheds are as follows:

- **Islands:** This approximately 3-acre subwatershed contains portions of the islands bordering the northern portion of the lake. Approximately 71% of this area is classified as urbanized land, while the remaining land is classified as forested.
- **Larchmont:** This approximately 25-acre subwatershed is located in the northeastern portion of the northern basin. Approximately 56% of the area is classified as urbanized land, while approximately 40% of the area is forested, and the remaining land is classified as open land.
- **Longhouse:** This is the largest of Mt. Laurel Lake's subwatersheds at approximately 904 acres. This area includes Lake Lookover and Bearfort Waters, as well as approximately 630 acres of forested land and approximately 159 acres of wetland.
- **Northeast:** This approximately 62-acre subwatershed contains approximately 30 acres of urbanized land cover, 28 acres of forested land, and 3.5 acres of wetland, with less than an acre each of open land and hay/pasture also present.
- **Northwest:** This approximately 26-acre subwatershed is largely urbanized, containing portions of Clinton Road and Warwick Turnpike.
- **Southeast:** This approximately 249-acre subwatershed consists largely of forested land and wetlands, as well as some of the urbanized area adjacent to Brook Road.

Table 145. Land-use by subwatershed in the Mt. Laurel Lake watershed.

Source	Full Watershed	Islands	Larchmont	Longhouse	Northeast	Northwest	Southeast
	Area (acres)						
Open Water	25.8	0.0	0.0	24.7	0.0	0.0	1.1
Hay/Pasture	3.7	0.0	0.0	3.5	0.2	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	845.1	1.0	9.9	629.9	27.9	7.2	169.3
Wetland	228.6	0.0	0.0	159.1	3.5	0.2	65.7
Open Land	3.7	0.0	1.2	1.7	0.5	0.0	0.5
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	37.6	1.5	3.7	16.3	11.4	3.2	1.5
Medium-Density Mixed	7.9	0.2	2.5	3.2	1.2	0.7	0.2
High-Density Mixed	0.2	0.0	0.0	0.0	0.2	0.0	0.0
Low-Density Open Space	116.6	0.7	7.7	66.0	17.1	14.8	10.6
Total	1269.2	3.4	25.0	904.4	62.0	26.1	248.9

Table 145 continued. Land-use by subwatershed in the Mt. Laurel Lake watershed.

Source	Full Watershed	Islands	Larchmont	Longhouse	Northeast	Northwest	Southeast
				Area (%)			
Open Water	2.0	0.0	0.0	2.7	0.0	0.0	0.4
Hay/Pasture	0.3	0.0	0.0	0.4	0.3	0.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	66.6	29.4	39.6	69.6	45.0	27.6	68.0
Wetland	18.0	0.0	0.0	17.6	5.6	0.8	26.4
Open Land	0.3	0.0	4.8	0.2	0.8	0.0	0.2
Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	3.0	44.1	14.8	1.8	18.4	12.3	0.6
Medium-Density Mixed	0.6	5.9	10.0	0.4	1.9	2.7	0.1
High-Density Mixed	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Low-Density Open Space	9.2	20.6	30.8	7.3	27.6	56.7	4.3
Total	100	100	100	100	100	100	100

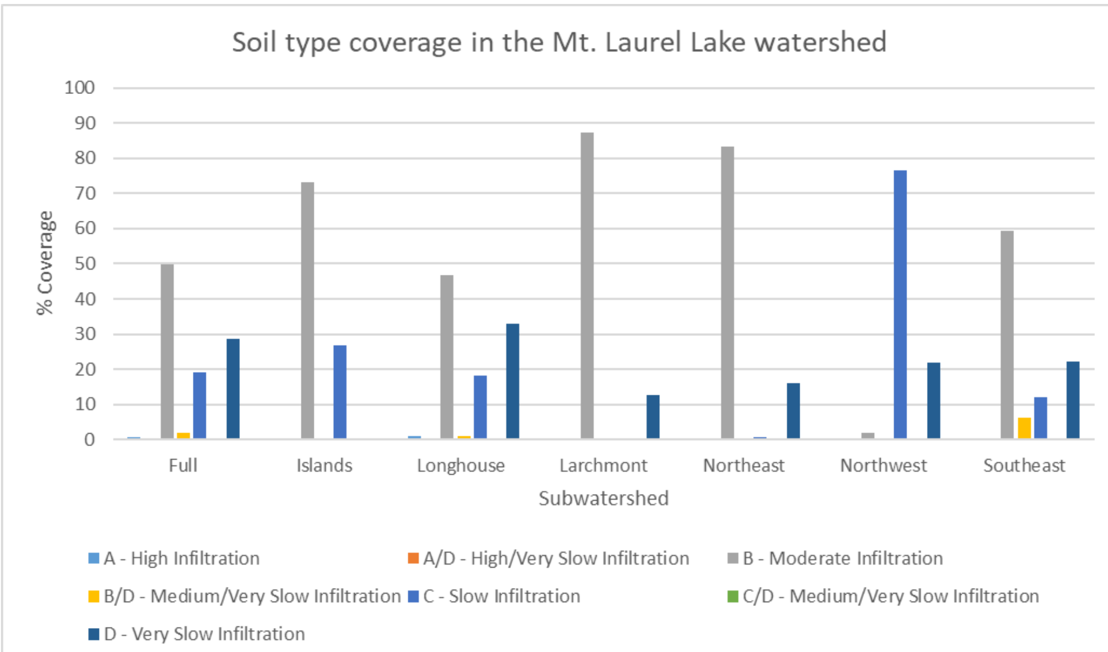


Figure 64. Percent coverage of Mt. Laurel Lake watershed and subwatersheds by different hydrologic soil groups.

Mt. Laurel Lake's full watershed is dominated by soil group B; however, groups C and D have a notable presence. The Northwest subwatershed in particular is modeled to contain a high coverage (about 76%) of soil group C, with group D making up about 21% percent of the area. As such, this subwatershed may be more prone to runoff than those with a larger concentration of soil group B. The lake's full watershed features an average slope of approximately 11%, with a maximum slope of approximately 58% occurring in the Longhouse subwatershed.

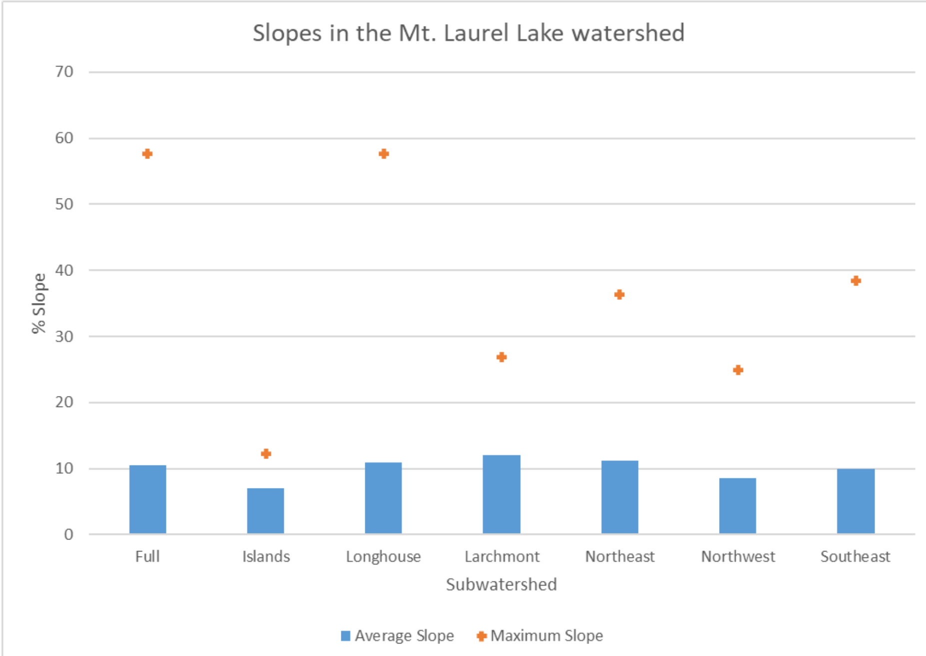


Figure 65. Variation in average and maximum percent slope between subwatersheds in the Mt. Laurel Lake watershed.

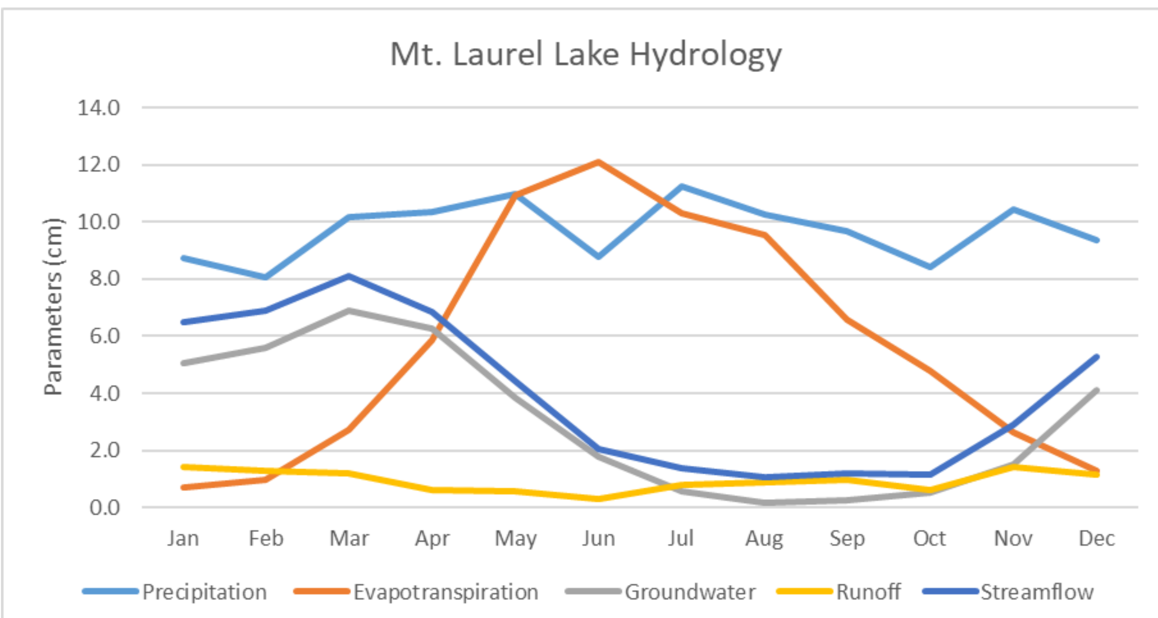


Figure 66. Estimated seasonal changes in hydrology in the Mt. Laurel Lake watershed

Table 146. Total hydrological parameters in the full Mt. Laurel Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.1	1.4	6.5	4.4
Feb	8.0	1.0	5.6	1.3	6.9	5.1
Mar	10.2	2.7	6.9	1.2	8.1	5.5
Apr	10.4	5.9	6.3	0.6	6.9	4.8
May	11.0	10.9	3.9	0.6	4.4	3.0
Jun	8.8	12.1	1.8	0.3	2.1	1.4
Jul	11.2	10.3	0.6	0.8	1.4	0.9
Aug	10.2	9.5	0.2	0.9	1.1	0.7
Sep	9.7	6.6	0.2	1.0	1.2	0.8
Oct	8.4	4.8	0.5	0.6	1.2	0.8
Nov	10.4	2.6	1.5	1.4	2.9	2.0
Dec	9.3	1.3	4.1	1.2	5.3	3.6
Total	116.4	68.4	36.6	11.2	47.8	2.7

Some variability existed between the Mt. Laurel Lake subwatersheds in regard to runoff. The Islands subwatershed featured the highest runoff earlier in the season, while the Southeast subwatershed featured the highest runoff during dryer months. When direct precipitation and evapotranspiration to the lake itself are considered, Mt. Laurel Lake is estimated to receive approximately 2,522,002 m³ or 666.2 million gallons of water each year.

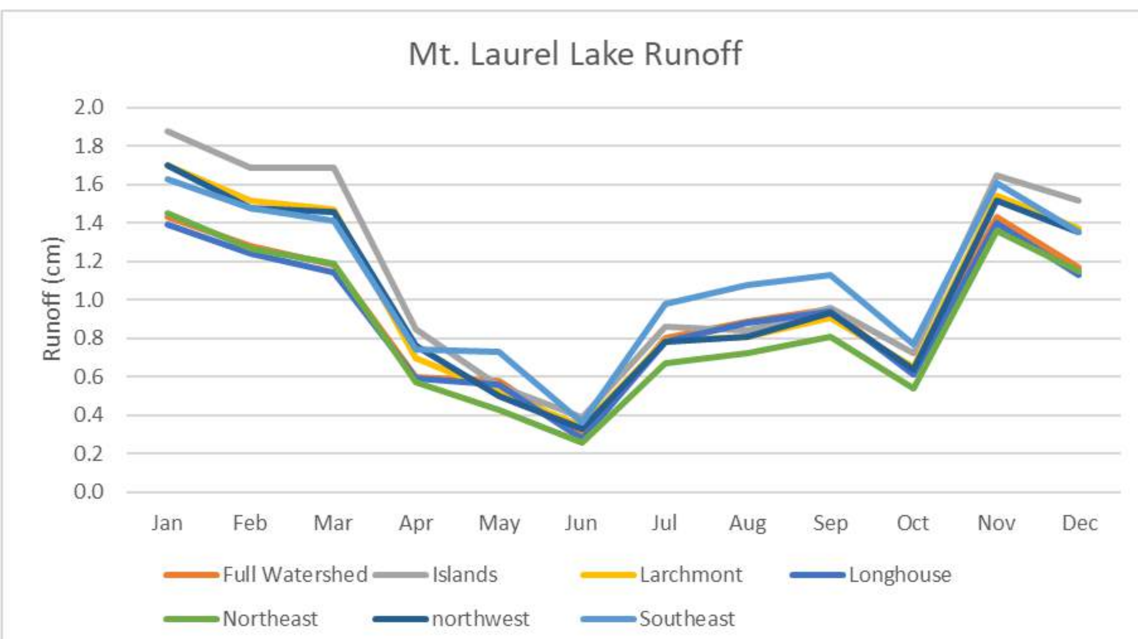


Figure 67. Average monthly runoff occurring in each subwatershed in the Mt. Laurel Lake watershed

As no bathymetric data for Mt. Laurel Lake was available, the lake's volume was estimated using depths collected in the field to be approximately 149,649 m³ or 39.5 million gallons of water. Using this and the estimated annual hydraulic load, Mt. Laurel Lake is estimated to flush completely approximately 16.9 times a year, with a hydraulic retention time of approximately 21.7 days. When examined on a monthly basis, the lake's annualized flushing rate is estimated to be at its lowest during August.

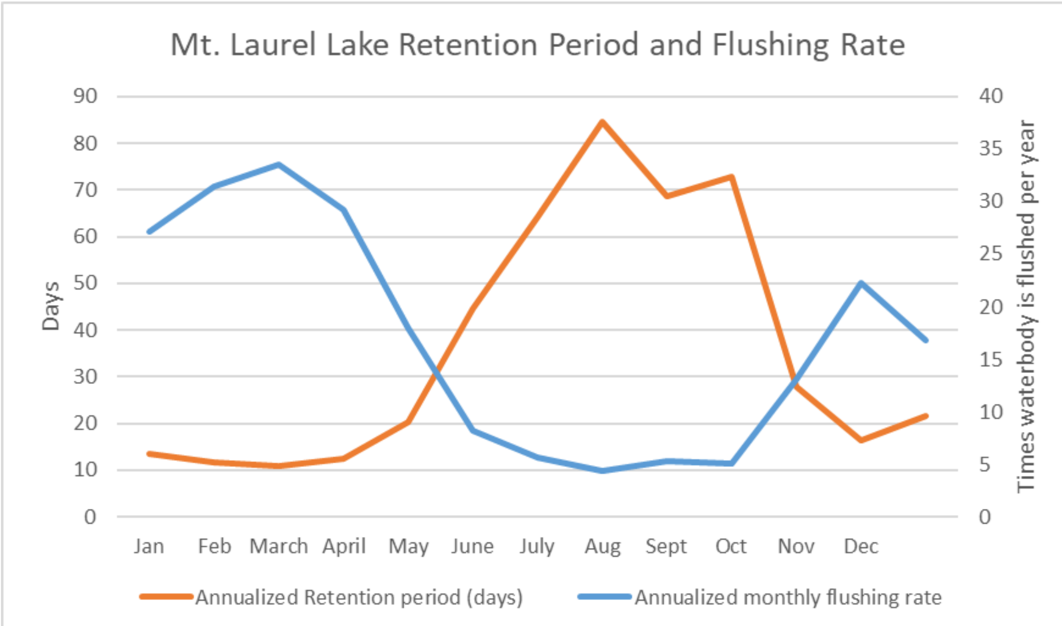


Figure 68. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Mt. Laurel Lake, based on variations in hydraulic loads.

Table 147. Estimated annual loads of nitrogen in the total Mt. Laurel Lake watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	1.6	0.08
	Cropland	0.0	0.00
	Forest	47.4	2.50
	Wetland	40.8	2.15
	Open Land	2.0	0.10
	Barren Land	0.0	0.00
	Low-Density Mixed	4.7	0.25
	Medium-Density Mixed	4.7	0.25
	High-Density Mixed	0.2	0.01
	Low-Density Open Space	14.6	0.77
Other Sources	Farm Animals and Waterfowl	2.4	0.13
	Stream Bank	10.0	0.53
	Groundwater	595.4	31.35
	Dryfall	211.1	11.12
	Septic Systems	964.3	50.77
	Total	1899.3	100

The estimated annual nitrogen load for Mt. Laurel Lake is dominated by nitrogen originating from groundwater and septic systems within the watershed, with dryfall also contributing a significant load. Runoff from forested areas and wetlands also contribute notable nitrogen loads; this is likely simply due to the large areas of these land-use types within the watershed. As the largest subwatershed, the Longhouse subwatershed yielded the highest overall estimated annual nitrogen load, while the Islands subwatershed yielded the largest amount of nitrogen per acre, likely due to the disproportionally high number of septic systems within 15 m of the waterbody.

Table 148. Estimated annual loads of nitrogen by subwatershed in the Mt. Laurel Lake watershed

Category	Description	Full Watershed kg	Islands kg	Larchmont kg	Longhouse kg	Northeast kg	Northwest kg	Southeast kg
Runoff	Hay/Pasture	1.6	0.0	0.0	1.5	0.1	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	47.4	0.1	0.5	35.4	1.4	0.5	12.8
	Wetland	40.8	0.0	0.0	28.3	0.4	0.1	12.1
	Open Land	2.0	0.0	0.5	0.9	0.2	0.0	0.3
	Barren Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	4.7	0.3	0.5	1.9	1.7	0.4	0.2
	Medium-Density Mixed	4.7	0.1	1.4	2.2	0.4	0.4	0.1
	High-Density Mixed	0.2	0.0	0.0	0.0	0.1	0.0	0.0
	Low-Density Open Space	14.6	0.1	1.0	7.7	2.5	1.9	1.2
Other Sources	Farm Animals and Waterfowl	2.4	0.0	0.0	0.0	0.0	0.0	4.5
	Stream Bank	10.0	0.0	0.0	6.0	0.0	0.0	0.0
	Groundwater	595.4	1.7	12.1	432.3	30.5	12.2	110.4
	Dryfall	210.9	.	.	.	.	.	.
	Septic Systems	964.3	20.7	119.4	417.0	288.3	100.3	43.9
	Total (kg)	1899.1	22.9	135.5	933.1	325.5	115.8	185.4
	kg/acre	1.5	6.7	5.4	1.0	5.2	4.4	0.7

Table 149. Estimated annual loads of phosphorus in the total Mt. Laurel Lake watershed

Category	Description	Total Phosphorus kg	%
Runoff	Hay/Pasture	0.46	0.5
	Cropland	0.00	0.0
	Forest	2.25	2.4
	Wetland	1.50	1.6
	Open Land	0.11	0.1
	Barren Land	0.00	0.0
	Low-Density Mixed	0.34	0.4
	Medium-Density Mixed	0.32	0.3
	High-Density Mixed	0.01	0.0
	Low-Density Open Space	1.07	1.1
Other Sources	Farm Animals and Waterfowl	0.86	0.9
	Stream Bank	3.00	3.1
	Groundwater	10.48	11.0
	Dryfall	1.06	1.1
	Septic Systems	74.18	77.6
	Total	95.63	100.0

Table 150. Estimated annual loads of phosphorus by subwatershed in the Mt. Laurel Lake watershed

Category	Description	Full Watershed kg	Islands kg	Larchmont kg	Longhouse kg	Northeast kg	Northwest kg	Southeast kg
Runoff	Hay/Pasture	0.46	0.00	0.00	0.42	0.04	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	2.25	0.00	0.04	1.65	0.12	0.04	1.17
	Wetland	1.50	0.00	0.00	1.01	0.03	0.00	0.57
	Open Land	0.11	0.00	0.08	0.02	0.03	0.00	0.02
	Barren Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.34	0.03	0.05	0.14	0.18	0.04	0.02
	Medium-Density Mixed	0.32	0.01	0.14	0.15	0.05	0.04	0.01
	High-Density Mixed	0.01	0.00	0.00	0.00	0.01	0.00	0.00
	Low-Density Open Space	1.07	0.01	0.11	0.56	0.27	0.21	0.12
Other Sources	Farm Animals and Waterfowl	0.86	0.00	0.00	0.00	0.00	0.00	1.13
	Stream Bank	3.00	0.00	0.00	2.00	0.00	0.00	0.00
	Groundwater	10.48	0.04	0.32	7.61	0.8	0.32	2.60
	Dryfall	1.05	.	.	.	.	.	.
	Septic Systems	74.18	10.92	13.44	23.65	28.56	17.64	6.71
	Total (kg)	95.63	11.01	14.18	37.21	30.09	18.29	12.35
	kg/acre	0.08	3.24	0.57	0.04	0.49	0.70	0.05

The annual estimated watershed-based phosphorus load for Mt. Laurel Lake largely originates from septic systems, which were estimated to yield approximately 78% of the full watershed-based load. As with estimated nitrogen loads, the Longhouse subwatershed yielded the highest overall estimated annual load, whereas the Islands subwatershed yielded the largest load per acre.During the field events in 2022, Mt. Laurel Lake was not observed to become anoxic, and water samples collected near the bottom of the water column only slightly higher phosphorus concentrations than those at the surface during the summer event. The lake's internal phosphorus load was therefore calculated using a reduced oxic loading coefficient and was estimated to be approximately 13.00 kg/year.

Table 151 below displays the external and internal loads of phosphorus for Mt. Laurel Lake, as well as the grand total, which is estimated to be approximately 108.63 kg/year. Watershed-based loading was modeled to be the largest driver of phosphorus loading in Mt. Laurel Lake, contributing to approximately 88% of the total annual load.

Table 151. Total estimated annual phosphorus loads for Mt. Laurel Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	95.63
Internal	13.00
Total	**108.63**

Table 152. Estimated annual loads of sediment in the total Mt. Laurel Lake watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.020	0.4
	Cropland	0.000	0.0
	Forest	0.210	4.3
	Wetland	0.020	0.4
	Open Land	0.030	0.6
	Barren Land	0.000	0.0
	Low-Density Mixed	0.050	1.0
	Medium-Density Mixed	0.070	1.4
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.160	3.3
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	4.314	88.5
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	4.874	100.0

The total estimated yearly sediment load for Mt. Laurel Lake largely originated from eroding stream banks, as well as runoff from forested land. The Longhouse subwatershed is estimated to yield the highest annual load of sediment, while the Islands and Larchmont subwatersheds yield the highest load per acre.

Table 153. Estimated annual loads of sediment by subwatershed in the Mt. Laurel Lake watershed

Category	Description	Full Watershed kg x 1000	Islands kg x 1000	Larchmont kg x 1000	Longhouse kg x 1000	Northeast kg x 1000	Northwest kg x 1000	Southeast kg x 1000
Runoff	Hay/Pasture	0.020	0.000	0.000	0.020	0.010	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.210	0.000	0.010	0.150	0.050	0.010	0.460
	Wetland	0.020	0.000	0.000	0.000	0.010	0.000	0.000
	Open Land	0.030	0.000	0.070	0.000	0.020	0.000	0.010
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.050	0.010	0.020	0.020	0.070	0.020	0.010
	Medium-Density Mixed	0.070	0.010	0.080	0.030	0.020	0.020	0.010
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.160	0.000	0.040	0.090	0.100	0.090	0.040
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	4.314	0.005	0.012	2.445	0.015	0.015	0.185
	Groundwater	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
	Total (kgx1000)	4.874	0.025	0.232	2.755	0.295	0.155	0.715
	kg/acre	3.840	7.353	9.280	3.046	4.758	5.939	2.873

Table 154. Estimated annual loads of bacteria in the total Mt. Laurel Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	1.15E+09	0.3
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	5.22E+10	14.7
	Other Wildlife	3.01E+11	84.9
	Total	3.54E+11	100

Mt. Laurel Lake's total estimated annual load of bacteria is modeled to originate largely from wildlife in the watershed's forested area. The Longhouse subwatershed yielded the highest bacterial load of the six subwatersheds due to its large area.

Table 155. Estimated annual bacterial loads by subwatershed in the Mt. Laurel Lake watershed

Category	Description	Full Watershed %	Islands %	Larchmont %	Longhouse %	Northeast %	Northwest %	Southeast %
Fecal Coliform	Farm Animals and Waterfowl	0.3	0.0	0.0	0.0	0.0	0.0	13.9
	WWTP	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	14.7	94.2	87.4	8.0	79.8	93.2	1.9
	Other Wildlife	84.9	5.8	12.6	92.0	20.2	6.8	84.2
	Total (organisms)	3.54E+11	6.06E+09	2.80E+10	2.44E+11	4.93E+10	3.74E+10	7.17E+10

MOUNTAIN SPRINGS LAKE

Mountain Springs Lake's watershed spans an area of approximately 45.2 acres, while the lake itself features a surface area of approximately 2.0 acres. The watershed consists of approximately 90% forested land with smaller amounts of wetlands and urbanized land. The lake's main inlet is relatively minor, originating from a small private pond near the northern edge of the watershed and entering the northern corner of the lake. The lake's outlet travels southeast for a short distance before its confluence with Apshawa Brook, eventually entering Butler Reservoir. Descriptions of the lake's subwatersheds are as follows:

- **East:** This approximately 3-acre subwatershed has similar amounts of forested land and urban-classified land, containing lengths of Teal Rd. and Lookout Ln.
- **North:** This is the largest of Mountain Springs Lake's subwatersheds at 22.2 acres. The area is largely forested, containing the lake's inlet and the private pond it originates from.
- **West:** This 19.5-acre subwatershed is also largely forested, containing a length of Teal Road.

Table 156. Land-use by subwatershed in the Mountain Springs Lake watershed

Source	Full Watershed	East	North	West
	Area (acres)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	40.5	1.7	19.8	18.8
Wetland	1.7	0.0	1.7	0.0
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	0.5	0.2	0.2	0.0
Medium-Density Mixed	0.0	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	2.5	1.2	0.5	0.7
Total	45.2	3.1	22.2	19.5

Table 156 continued. Land-use by subwatershed in the Mountain Springs Lake watershed

Source	Full Watershed	East	North	West
	Area (%)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	89.6	54.8	89.2	96.4
Wetland	3.8	0.0	7.7	0.0
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	1.1	6.5	0.9	0.0
Medium-Density Mixed	0.0	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	5.5	38.7	2.3	3.6
Total	100	100	100	100

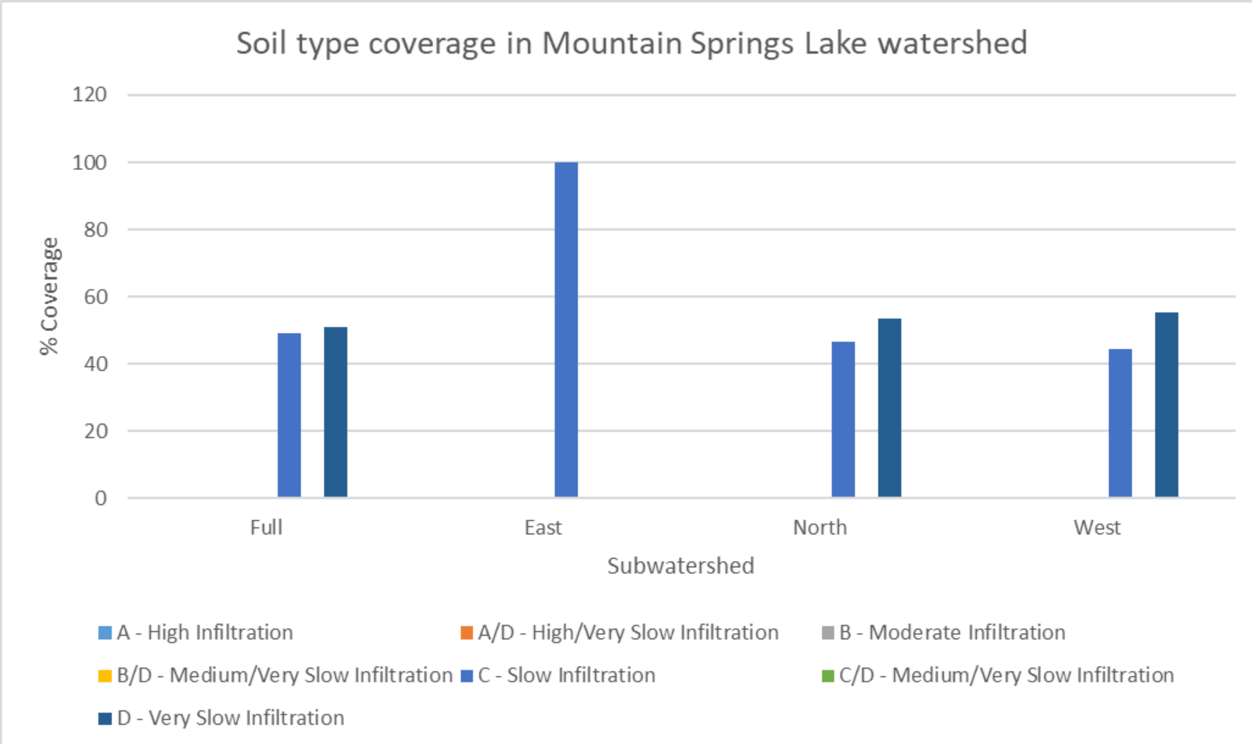


Figure 69. Percent coverage of Mountain Springs Lake watershed and subwatersheds by different hydrologic soil groups.

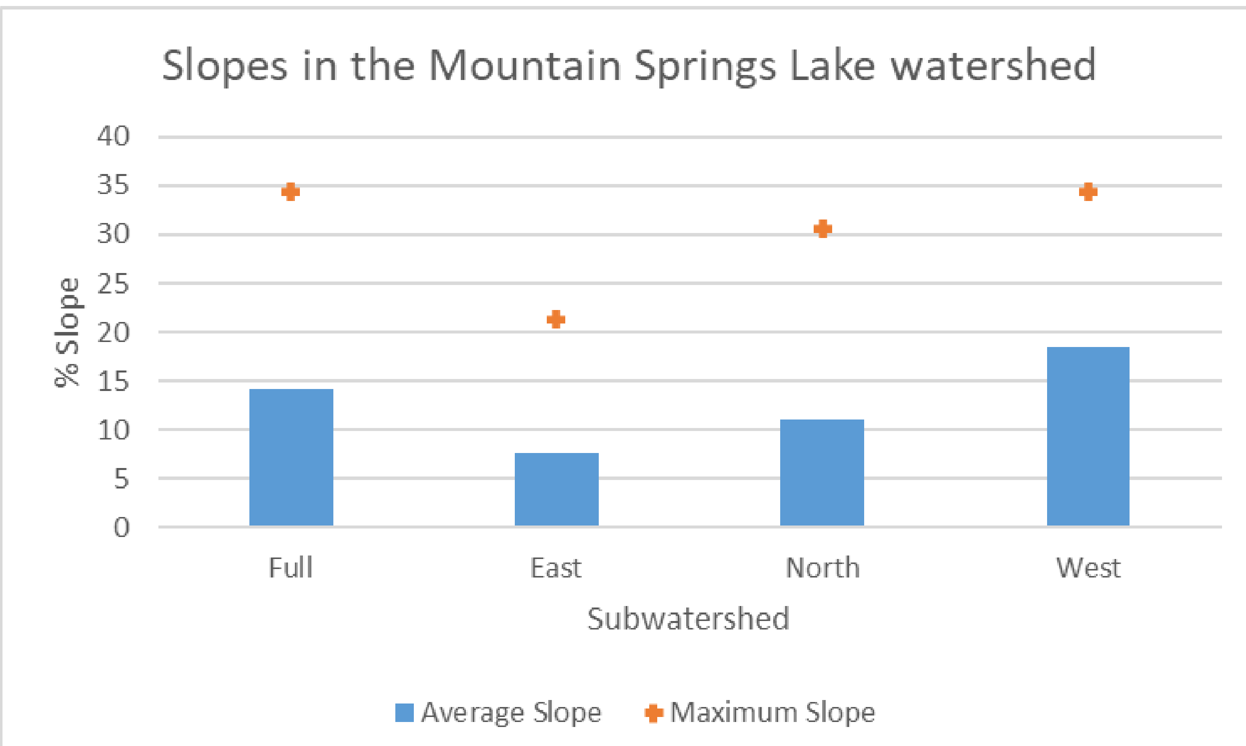


Figure 70. Variation in average and maximum percent slope between subwatersheds in the Mountain Springs Lake watershed.

Soils in the Mountain Springs Lake watershed are almost equally divided between soil groups C and D, suggesting that the watershed may yield an increased amount of runoff. While the North and West subwatersheds feature similar soil compositions, it is notable that the East subwatershed features total coverage with group C soils, suggesting this subwatershed may yield slightly less runoff than the other two (based on soils alone). The average slope in the full watershed is approximately 14%, while the maximum slope is approximately 34%, occurring in the West watershed. This watershed also features the highest average slope.

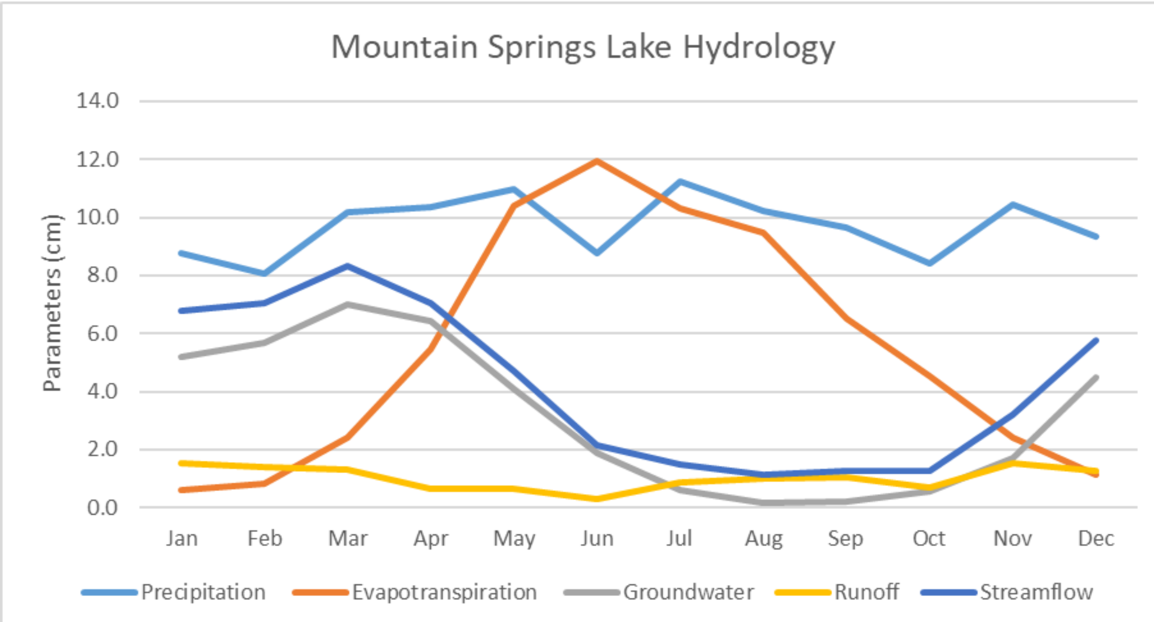


Figure 71. Estimated seasonal changes in hydrology in the Mountain Springs Lake Watershed

Table 157. Total hydrological parameters in the full Mountain Springs Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.6	5.2	1.6	6.8	0.2
Feb	8.0	0.8	5.7	1.4	7.0	0.2
Mar	10.2	2.4	7.0	1.3	8.3	0.2
Apr	10.4	5.4	6.4	0.7	7.1	0.2
May	11.0	10.4	4.1	0.6	4.7	0.1
Jun	8.8	11.9	1.9	0.3	2.2	0.1
Jul	11.2	10.3	0.6	0.9	1.5	0.0
Aug	10.2	9.5	0.2	1.0	1.2	0.0
Sep	9.7	6.5	0.2	1.1	1.3	0.0
Oct	8.4	4.5	0.6	0.7	1.3	0.0
Nov	10.4	2.4	1.7	1.5	3.2	0.1
Dec	9.3	1.1	4.5	1.3	5.8	0.1
Total	116.4	66.1	37.9	12.2	50.1	0.1

Some variability existed between the Mountain Springs Lake subwatersheds in regard to runoff. The Western subwatershed featured the highest runoff throughout the year, possibly due to having the overall steepest slopes in the watershed, as well as poorly draining soils. When direct precipitation and evapotranspiration to the lake itself are considered, Mountain Springs Lake is estimated to receive approximately 95,750 m³ or 25.3 million gallons of water each year.

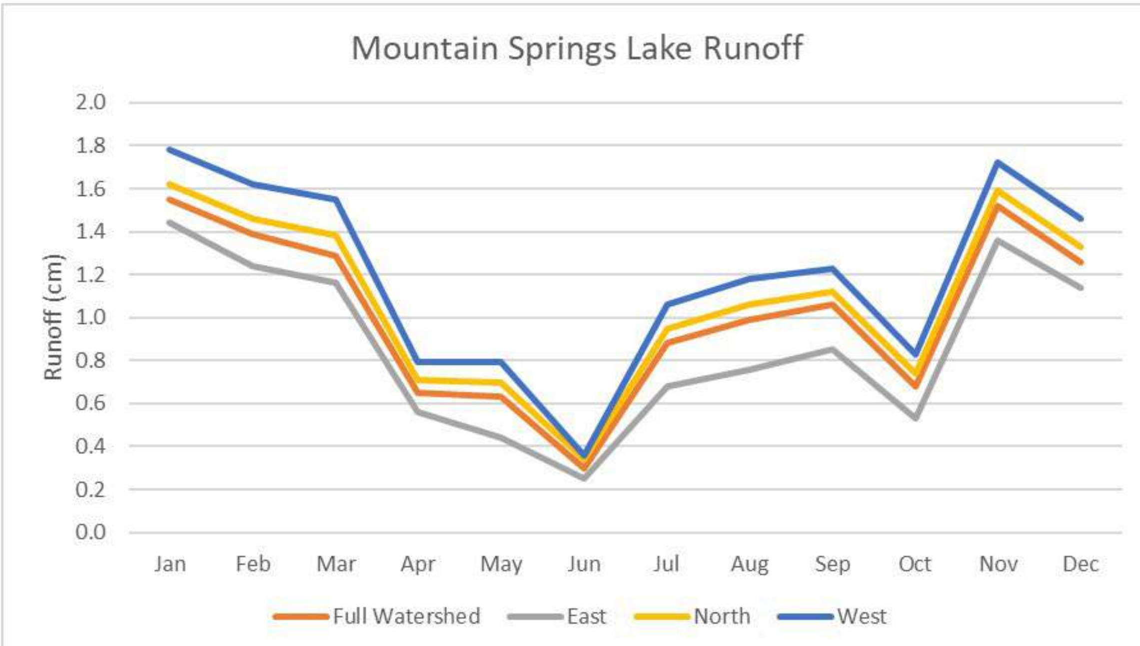


Figure 72. Average monthly runoff occurring in each subwatershed in the Mountain Springs Lake watershed

As no bathymetric data for Mountain Springs Lake was available, the lake's volume was estimated using depths collected in the field to be approximately 11,028 m³ or 2.9 million gallons of water. Using this and the estimated annual hydraulic load, Mountain Springs Lake is estimated to flush completely approximately 8.7 times a year, with a hydraulic retention time of approximately 42 days. When examined on a monthly basis, the lake's annualized flushing rate is estimated to be at its lowest during August.

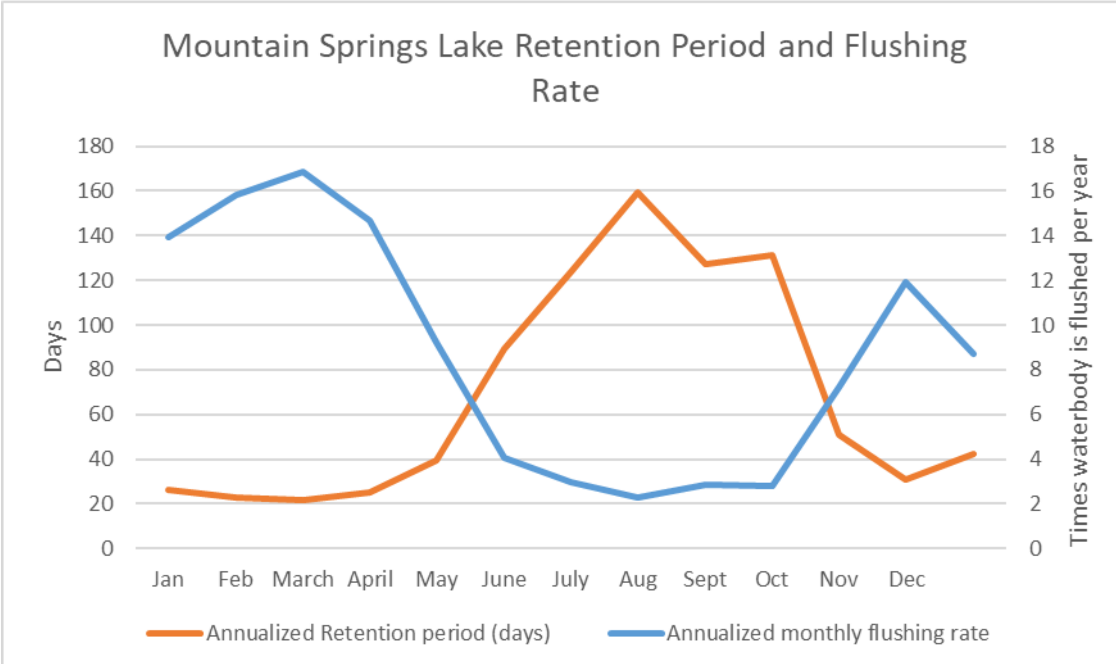


Figure 73. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Mountain Springs Lake, based on variations in hydraulic loads

Table 158. Estimated annual loads of nitrogen in the total Mountain Springs Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	3.8	4.61
	Wetland	0.4	0.51
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	0.1	0.08
	Medium-Density Mixed	0.0	0.00
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	0.4	0.42
Other Sources	Farm Animals and Waterfowl	0.2	0.24
	Stream Bank	0.0	0.00
	Groundwater	23.3	28.08
	Dryfall	7.6	9.20
	Septic Systems	47.2	56.85
	Total	83.0	100

The estimated annual nitrogen load for Mountain Springs Lake is dominated by nitrogen originating from septic systems within the watershed, as well as from groundwater. Runoff-based nitrogen loads largely originated from forested areas. The largest annual load was estimated to originate from the Western subwatershed, while the Eastern subwatershed yielded the highest load per acre.

Table 159. Estimated annual loads of nitrogen by subwatershed in the Mountain Springs Lake watershed

Category	Description	Full Watershed	East	North	West
		kg	kg	kg	kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0
	Forest	3.8	0.1	1.8	2.2
	Wetland	0.4	0.0	0.4	0.0
	Open Land	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0
	Low-Density Mixed	0.1	0.0	0.1	0.0
	Medium-Density Mixed	0.0	0.0	0.0	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0
	Low-Density Open Space	0.4	0.1	0.1	0.1
Other Sources	Farm Animals and Waterfowl	0.2	0.1	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0
	Groundwater	23.3	1.7	10.9	10.0
	Dryfall	7.6	.	.	.
	Septic Systems	47.2	11.1	10.8	23.9
	Total (kg)	83.0	13.2	24.0	36.2
	kg/acre	1.8	4.2	1.1	1.9

Table 160. Estimated annual loads of phosphorus in the total Mountain Springs Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.34	8.1
	Wetland	0.02	0.5
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.01	0.2
	Medium-Density Mixed	0.00	0.0
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.04	0.9
Other Sources	Farm Animals and Waterfowl	0.08	1.9
	Stream Bank	0.00	0.0
	Groundwater	0.63	14.9
	Dryfall	0.04	0.9
	Septic Systems	3.06	72.5
	Total	4.21	100.0

Table 161. Estimated annual loads of phosphorus by subwatershed in the Mountain Springs Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.34	8.1
	Wetland	0.02	0.5
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.01	0.2
	Medium-Density Mixed	0.00	0.0
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.04	0.9
Other Sources	Farm Animals and Waterfowl	0.08	1.9
	Stream Bank	0.00	0.0
	Groundwater	0.63	14.9
	Dryfall	0.04	0.9
	Septic Systems	3.06	72.5
	Total	4.21	100.0

As with many other lakes in the township, Mountain Springs Lake's watershed-based annual phosphorus load is estimated to originate largely from septic systems, which account for approximately 73% of the total watershed-based load. The Western subwatershed was modeled to yield both the highest overall annual phosphorus load, as well as the highest load per acre.

Mountain Springs Lake was observed to only feature a relatively small amount of anoxia during the July sampling event, and this was only measured to occur immediately over the bottom sediments in the deepest areas. Furthermore, discrete samples did not yield any large differences in phosphorus between the surface of the water column and deeper waters. Modeling of the lake's internal load was therefore performed using only the reduced oxic loading rate, yielding an annual estimate of 0.74 kg.

Table 162 below displays the external and internal loads of phosphorus for Mountain Springs Lake, as well as the grand total, which is estimated to be approximately 4.95 kg/year. Watershed-based loading was modeled to be the largest driver of phosphorus loading in Mountain Springs Lake, contributing to approximately 85% of the total annual load.

Table 162. Total estimated annual phosphorus loads for Mountain Springs Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	4.21
Internal	0.74
Total	**4.95**

Table 163. Estimated annual loads of sediment in the total Mountain Springs Lake watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.130	91.5
	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	0.000	0.0
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.010	7.0
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.002	1.4
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.142	100.0

Mountain Springs Lake is estimated to receive a relatively small annual sediment load, at only approximately 142 kg/year. A large majority of this sediment (>90%) is estimated to enter the lake as runoff from forested land. Similar to phosphorus, the West subwatershed was estimated to yield both the highest overall annual sediment load and the largest load per acre.

Table 164. Estimated annual loads of sediment by subwatershed in the Mountain Springs Lake watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	North kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000
	Forest	0.130	0.000	0.020	0.080
	Wetland	0.000	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.000	0.000	0.000	0.000
	Medium-Density Mixed	0.000	0.000	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.010	0.000	0.000	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000
	Stream Bank	0.002	0.003	0.001	0.001
	Groundwater	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.142	0.003	0.021	0.081
	kg/acre	3.142	0.968	0.946	4.154

Table 165. Estimated annual loads of bacteria in the total Mountain Springs Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	3.18E+07	0.2
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	4.25E+08	2.9
	Other Wildlife	1.45E+10	96.9
	Total	1.49E+10	100

Mountain Springs Lake's total estimated annual load of bacteria is modeled to originate largely from wildlife in the watershed's forested area. The Northern subwatershed yielded the highest bacterial load of the three subwatersheds.

Table 166. Estimated annual bacterial loads by subwatershed in the Mountain Springs Lake watershed

Category	Description	Full Watershed %	East %	North %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.2	1.4	0.0	0.0
	WWTP	0.0	0.0	0.0	0.0
	Septic Systems	0.0	0.0	0.0	0.0
	Urban Areas	2.9	71.0	0.8	0.9
	Other Wildlife	96.9	27.6	99.2	99.1
	Total (organisms)	1.49E+10	2.24E+09	7.11E+09	6.76E+09

PINECLIFF LAKE

Pinecliff Lake's watershed spans an area of approximately 3,801 acres, while the lake itself covers an area of approximately 144 acres. The watershed is approximately 66% forested, with a notable contingent (approximately 24%) classified as urbanized land. The lake's main inlet, Belcher's Creek, enters the lake at its southern end, leaving the lake at its northeastern corner before traveling northeast and eventually entering Greenwood Lake. Bubbling Springs Pond and its entire watershed is contained in Pinecliff Watershed. Descriptions of Pinecliff Lake's subwatersheds are as follows:

- **Bearfort Mountain:** This approximately 371-acre subwatershed is situated to the west of Pinecliff Lake. The area consists largely of forested land, wetlands, and non-urbanized open land, with a smaller amount of urbanized landcover immediately near the lake. This subwatershed contains one of the lake's smaller inlets.
- **Capstan:** This approximately 97-acre subwatershed is located on the southeastern corner of the lake. Approximately 93% of the area consists of forested land, with small amounts of open land, wetlands, and urbanized land also present.
- **Dam:** This approximately 23-acre subwatershed is located in the northeastern corner of the lake, containing the northern end of Pinecliff Lake Dr. and the surrounding urbanized area, as well as the lake's dam.
- **East:** This approximately 131-acre subwatershed contains a large portion of the urbanized area along the eastern shoreline, extending across Union Valley Rd. to the developed area along Ridge Road. This

subwatershed is approximately 78% urbanized, with the remaining land classified as forested land or wetlands.

- **Inlet:** This is the largest subwatershed at approximately 2,801 acres, containing portions of the Union Valley Rd. and Macopin Rd., as well as Belcher's Creek and the entirety of the Bubbling Springs watershed. The area consists of approximately 75% forested land and wetlands with approximately 664 acres of urbanized land.
- **North:** This approximately 43-acre subwatershed contains the developed areas on the northern length of Bearfort Rd., as well as a forested area to the northwest. This subwatershed contains 22.5 acres of urbanized land and 20.8 acres of forested land.
- **Northwest:** This approximately 114-acre subwatershed contains lengths of Bearfort Rd. and Terrace Rd., as well as the urbanized areas closer to the lake. These amount to approximately 24 acres of urbanized land, while the remainder of the land is entirely forested.
- **Stowaway:** This is the smallest of Pinecliff's subwatersheds at 15.3 acres, containing lengths of Anchor Ave. and Stowaway Rd. The area is approximately 25.5% urbanized, with the remaining area consisting of forested land and wetlands.
- **Sylvan:** This approximately 48.6-acre subwatershed is located on the eastern side of Pinecliff Lake, containing the northern end of Ridge Road and the adjacent urbanized areas, which make up approximately 89% of the total area. The remaining area is classified as forested land.
- **West:** This approximately 157-acre subwatershed contains the southern end of Bearfort Rd. and a length of Binnacle Ave., as well as the urbanized areas adjacent to these roads. A majority of the subwatershed, however, is mountainous, forested land, which comprises approximately 88% of the total area. This area also contains approximately 16 acres of urbanized land.

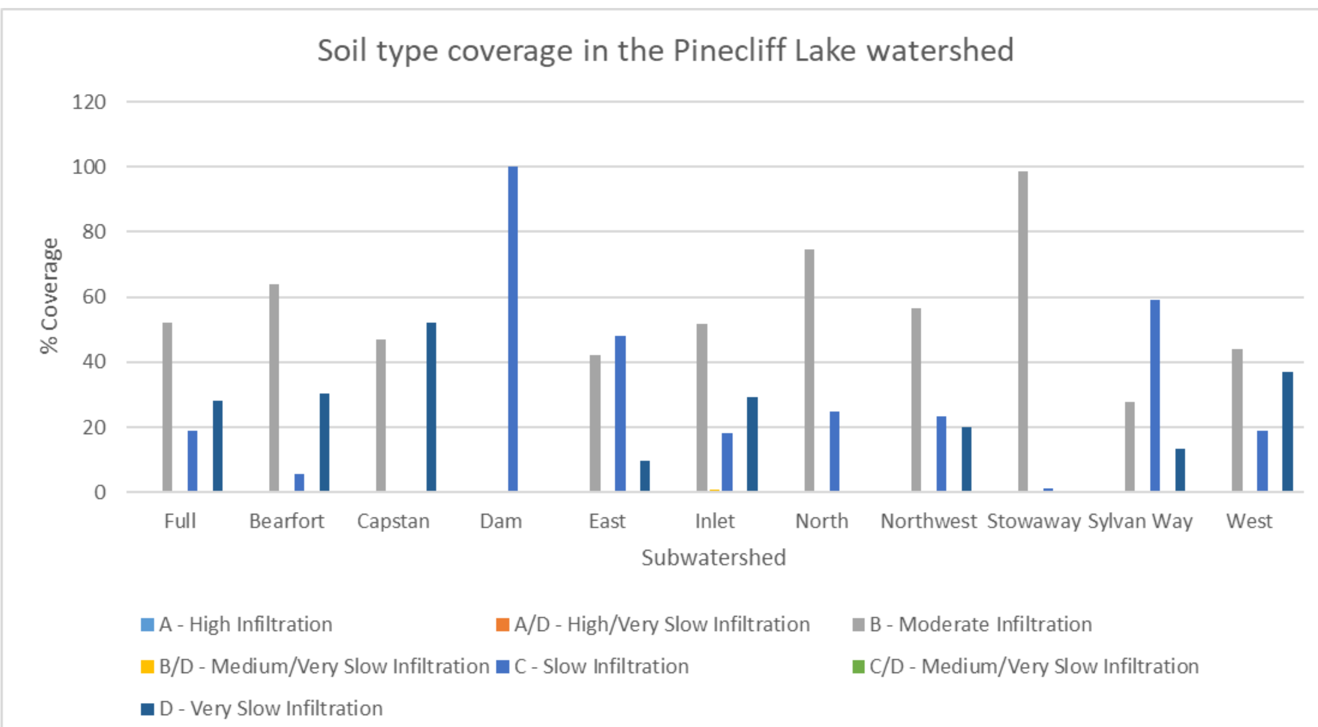


Figure 73. Percent coverage of Pinecliff Lake watershed and subwatersheds by different hydrologic soil groups.

Pinecliff Lake's full watershed features approximately 50% coverage with hydrologic soil group B, with this being the dominant soil type in several subwatersheds, almost completely covering the Stowaway subwatershed. Soil groups C and D also make up a notable portion of the full watershed, and the Dam subwatershed features 100% coverage with soil group C. This subwatershed and others with larger amounts of group C and D soils are prone to greater amounts of runoff. The average slope in the lake's full watershed is approximately 14%, with the maximum slope of approximately 62% occurring in the inlet subwatershed. The Capstan, Northwest, and West subwatersheds all feature greater average slopes than Pinecliff Lake's other subwatersheds, with these all averaging an approximately 24% slope. These subwatersheds may be more prone to soil erosion.

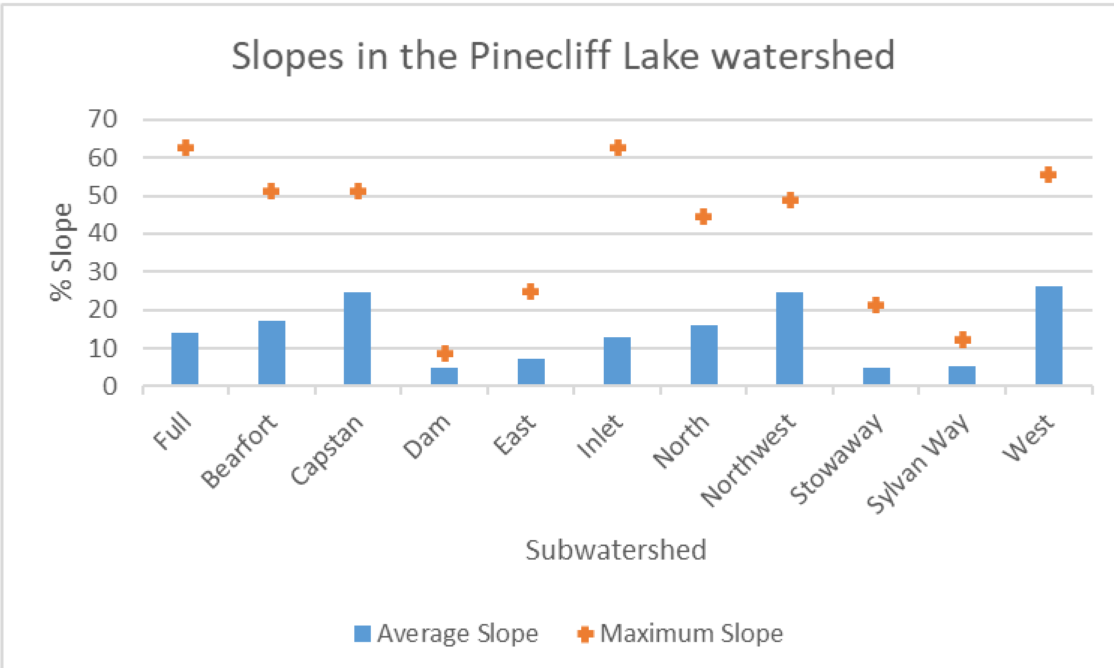


Figure 74. Variation in average and maximum percent slope between subwatersheds in the Pinecliff Lake watershed.

Table 167. Land-use by subwatershed in the Pinecliff Lake watershed.

Source	Full Watershed	Bearfort Mt.	Capstan	Dam	East	Inlet	North	Northwest	Stowaway	Sylvan	West
						Area (%)					
Open Water	0.3	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.7	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.4	0.3
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	65.7	91.3	93.4	0.9	21.1	63.4	48.0	79.3	53.6	11.1	88.4
Wetland	9.1	6.9	0.7	0.0	0.9	11.2	0.0	0.0	20.9	0.0	0.0
Open Land	0.3	0.3	1.5	0.0	0.0	0.2	0.0	0.0	0.0	0.0	1.1
Barren Land	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	8.0	0.0	1.0	44.5	20.9	8.4	20.6	4.7	7.8	23.5	1.4
Medium-Density Mixed	2.1	0.0	0.0	17.6	5.9	2.0	2.8	0.4	4.6	21.8	0.4
High-Density Mixed	0.2	0.0	0.0	0.9	0.5	0.2	0.0	0.0	0.0	7.2	0.0
Low-Density Open Space	13.5	1.5	3.3	36.1	50.7	13.1	28.6	15.6	13.1	36.0	8.4
Total	100	100	100	100	100	100	100	100	100	100	100

Table 167 continued. Land-use by subwatershed in the Pinecliff Lake watershed.

Source	Full Watershed	Bearfort Mt.	Capstan	Dam	East	Inlet	North	Northwest	Stowaway	Sylvan	West
					Area (acres)						
Open Water	13.3	0.0	0.0	0.0	0.0	13.3	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	25.5	0.0	0.0	0.0	0.0	24.7	0.0	0.0	0.0	0.2	0.5
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	2497.5	338.5	90.4	0.2	27.7	1776.7	20.8	90.7	8.2	5.4	138.6
Wetland	344.5	25.7	0.7	0.0	1.2	313.8	0.0	0.0	3.2	0.0	0.0
Open Land	11.1	1.2	1.5	0.0	0.0	6.7	0.0	0.0	0.0	0.0	1.7
Barren Land	2.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Low-Density Mixed	303.9	0.0	1.0	10.1	27.4	236.2	8.9	5.4	1.2	11.4	2.2
Medium-Density Mixed	81.1	0.0	0.0	4.0	7.7	55.8	1.2	0.5	0.7	10.6	0.7
High-Density Mixed	8.6	0.0	0.0	0.2	0.7	4.4	0.0	0.0	0.0	3.5	0.0
Low-Density Open Space	513.2	5.4	3.2	8.2	66.5	367.7	12.4	17.8	2.0	17.5	13.1
Total	3800.7	370.8	96.8	22.7	131.2	2801.3	43.3	114.4	15.3	48.6	156.8

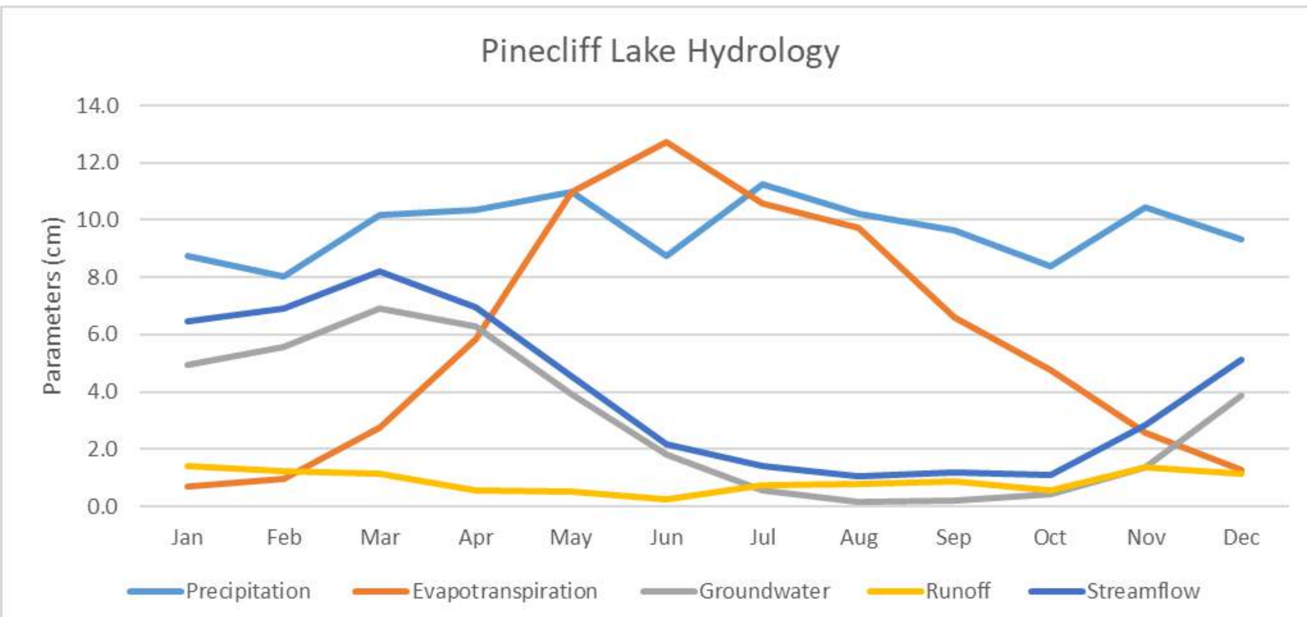


Figure 75. Estimated seasonal changes in hydrology in the Pinecliff Lake watershed

Table 168. Total hydrological parameters in the full Pinecliff Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.0	1.4	6.5	13.1
Feb	8.0	1.0	5.6	1.3	6.9	15.4
Mar	10.2	2.8	6.9	1.2	8.2	16.6
Apr	10.4	5.8	6.3	0.6	7.0	14.6
May	11.0	11.0	3.9	0.5	4.5	9.2
Jun	8.8	12.7	1.8	0.3	2.2	4.5
Jul	11.2	10.6	0.6	0.7	1.4	2.9
Aug	10.2	9.7	0.2	0.8	1.1	2.2
Sep	9.7	6.6	0.2	0.9	1.2	2.5
Oct	8.4	4.8	0.5	0.6	1.1	2.3
Nov	10.4	2.6	1.4	1.4	2.8	5.9
Dec	9.3	1.3	3.9	1.1	5.1	10.4
Total	116.4	69.4	36.1	10.7	48.0	8.3

Some variability existed between the Pinecliff Lake subwatersheds in regard to runoff. The Sylvan subwatershed yielded the highest runoff for a majority of the year, likely due to the overall high percentage of urbanized land-use in this subwatershed. Notably, the Capstan subwatershed yielded the lowest estimated runoff values throughout the year, likely a product of the comparatively high percentage of forested land in this subwatershed. When direct precipitation and evapotranspiration to the lake itself are considered, Pinecliff Lake is estimated to receive approximately 7,469,326 m² or 1,973.2 million gallons of water during an average year.

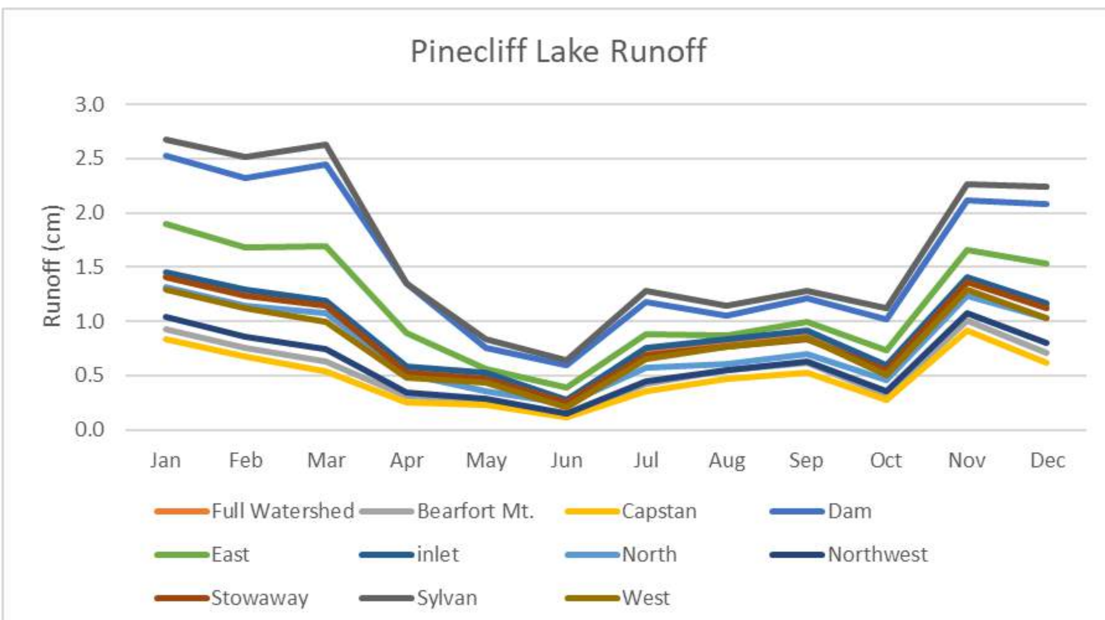


Figure 76. Average monthly runoff occurring in each subwatershed in the Pinecliff Lake watershed

As no bathymetric data for Pinecliff Lake was available, the lake's volume was estimated using depths collected in the field to be approximately 943,003 m³ or 249.1 million gallons of water. Using this and the estimated annual hydraulic load, Pinecliff Lake is estimated to flush completely approximately 7.9 times a year, with a hydraulic retention time of approximately 46 days. When examined on a monthly basis, the lake's annualized flushing rate is estimated to be at its lowest during August.

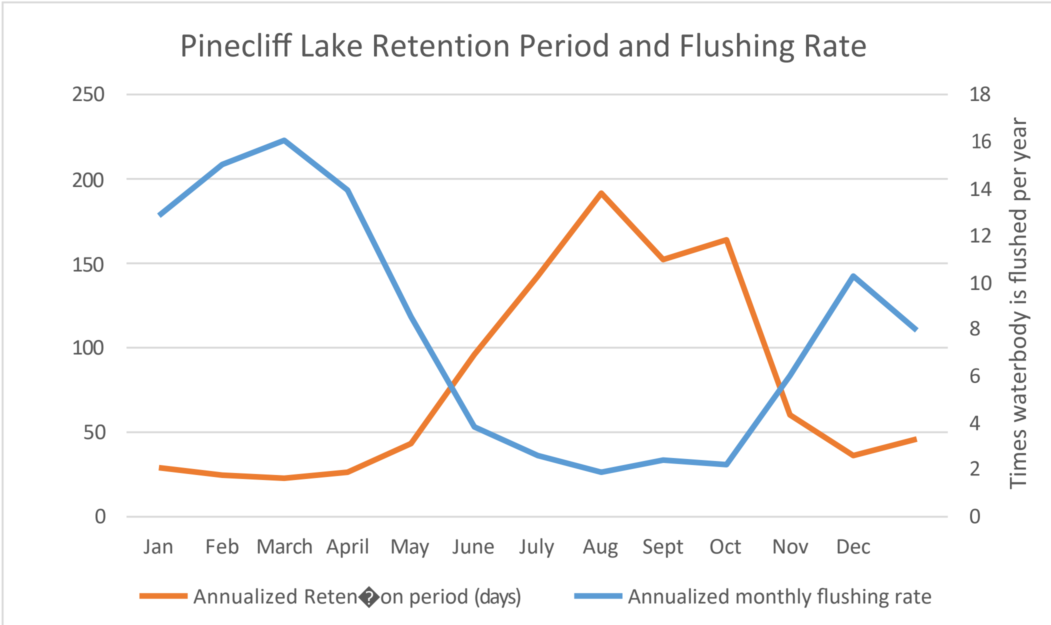


Figure 77. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Pinecliff Lake, based on variations in hydraulic loads.

Table 169. Estimated annual loads of nitrogen in the total Pinecliff Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	11.8	0.1
	Cropland	0.0	0.0
	Forest	149.7	1.8
	Wetland	63.0	0.7
	Open Land	6.4	0.1
	Barren Land	0.4	0.0
	Low-Density Mixed	43.2	0.5
	Medium-Density Mixed	44.9	0.5
	High-Density Mixed	4.8	0.1
	Low-Density Open Space	73.0	0.9
Other Sources	Farm Animals and Waterfowl	46.4	0.5
	Stream Bank	108.0	1.3
	Groundwater	1815.0	21.5
	Point Sources	3254.2	38.5
	Dryfall	638.5	7.6
	Septic Systems	2183.2	25.9
	Total	8442.3	100

The estimated annual nitrogen load for Pinecliff Lake is dominated by nitrogen originating from point sources, generally present as wastewater treatment plant outflows. Septic systems in the watershed and groundwater are also estimated to be a relatively large source of nitrogen. While the Inlet subwatershed is estimated to yield the highest overall annual nitrogen load, the Dam subwatershed is estimated to yield the largest amount per acre.

Table 170. Estimated annual loads of nitrogen by subwatershed in the Pinecliff Lake watershed

Category	Description	Full Watershed	Bearfort Mt.	Capstan	Dam	East	Inlet	North	Northwest	Stowaway	Sylvan	West
		kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg
Runoff	Hay/Pasture	11.8	0.0	0.0	0.0	0.0	11.3	0.0	0.0	0.0	0.2	0.2
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	149.7	16.7	5.7	0.0	2.1	103.3	0.7	6.6	0.4	0.4	15.0
	Wetland	63.0	2.9	0.1	0.0	0.2	56.1	0.0	0.0	0.4	0.0	0.0
	Open Land	6.4	0.6	0.9	0.0	0.0	2.8	0.0	0.0	0.0	0.0	1.3
	Barren Land	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
	Low-Density Mixed	43.2	0.0	0.2	1.8	3.8	33.4	1.3	0.7	0.1	1.7	0.3
	Medium-Density Mixed	44.9	0.0	0.0	1.9	5.1	29.9	0.4	0.3	0.4	7.5	0.4
	High-Density Mixed	4.8	0.0	0.0	0.1	0.5	2.4	0.0	0.0	0.0	2.5	0.0
	Low-Density Open Space	73.0	0.6	0.7	1.5	9.1	52.0	1.8	2.4	0.2	2.6	1.6
Other Sources	Farm Animals and Waterfowl	46.4	0.0	0.0	0.0	0.0	45.7	0.0	0.0	0.0	0.0	0.0
	Stream Bank	108.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	1815.0	218.2	58.9	10.6	56.3	77.0	22.3	65.3	7.5	20.4	86.9
	Point Sources	3254.2	0.0	0.0	0.0	0.0	1269.6	0.0	0.0	0.0	0.0	0.0
	Dryfall	638.5	.	.	.	.	.	.	.	.	.	.
	Septic Systems	2183.2	54.9	26.9	180.0	828.2	273.3	237.3	277.1	39.8	129.0	200.7
	Total (kg)	8442.3	293.8	93.4	196.0	905.2	1957.0	263.9	352.4	48.8	164.1	306.4
	kg/acre	2.2	0.8	1.0	8.6	6.9	0.7	6.1	3.1	3.2	3.4	2.0

Table 171. Estimated annual loads of Phosphorus in the total Pinecliff Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	3.89	1.6
	Cropland	0.00	0.0
	Forest	11.26	4.5
	Wetland	2.89	1.2
	Open Land	0.55	0.2
	Barren Land	0.01	0.0
	Low-Density Mixed	3.52	1.4
	Medium-Density Mixed	3.46	1.4
	High-Density Mixed	0.37	0.1
	Low-Density Open Space	5.95	2.4
Other Sources	Farm Animals and Waterfowl	11.89	4.8
	Stream Bank	47.00	18.9
	Groundwater	35.98	14.5
	Point Sources	8.28	3.3
	Dryfall	3.19	1.3
	Septic Systems	110.36	44.4
	Total	248.60	100.0

Table 172. Estimated annual loads of phosphorus by subwatershed in the Pinecliff Lake watershed

Category	Description	Full Watershed kg	Bearfort Mt. kg	Capstan kg	Dam kg	East kg	Inlet kg	North kg	Northwest kg	Stowaway kg	Sylvan kg	West kg
Runoff	Hay/Pasture	3.89	0.00	0.00	0.00	0.00	2.98	0.00	0.00	0.00	0.08	0.10
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	11.26	1.41	1.25	0.00	0.17	5.96	0.11	1.68	0.04	0.02	3.38
	Wetland	2.89	0.16	0.01	0.00	0.01	2.05	0.00	0.00	0.03	0.00	0.00
	Open Land	0.55	0.01	0.08	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.18
	Barren Land	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	3.52	0.00	0.02	0.20	0.41	2.18	0.14	0.08	0.01	0.18	0.03
	Medium-Density Mixed	3.46	0.00	0.00	0.20	0.52	1.84	0.04	0.03	0.04	0.77	0.04
	High-Density Mixed	0.37	0.00	0.00	0.01	0.05	0.15	0.00	0.00	0.00	0.25	0.00
	Low-Density Open Space	5.95	0.06	0.07	0.16	0.99	3.39	0.20	0.26	0.02	0.28	0.17
Other Sources	Farm Animals and Waterfowl	11.89	0.00	0.00	0.00	0.00	11.65	0.00	0.00	0.00	0.00	0.00
	Stream Bank	47.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	35.98	5.15	1.48	0.28	1.47	27.00	0.58	1.71	0.20	0.53	2.27
	Point Sources	8.28	0.00	0.00	0.00	0.00	20.18	0.00	0.00	0.00	0.00	0.00
	Dryfall	3.19	.	.	.	.	.	.	.	.	.	.
	Septic Systems	110.36	5.96	4.81	15.96	54.59	8.65	15.96	31.08	6.72	7.56	11.76
	Total (kg)	248.60	12.75	7.72	16.81	58.21	86.29	17.03	34.84	7.06	9.67	17.93
	kg/acre	0.07	0.03	0.08	0.74	0.44	0.03	0.39	0.30	0.46	0.20	0.11

As with many other lakes in the study, Pinecliff Lake's watershed-based annual phosphorus load is estimated to originate largely from septic systems, which account for approximately 44% of the total watershed-based load. Eroding stream banks and groundwater are also notable sources. The Inlet subwatershed is estimated to yield the highest overall annual phosphorus load, while the Dam subwatershed is estimated to yield the highest load per acre.

Pinecliff Lake was not observed to feature any anoxia over the course of the 2022 season. Deep phosphorus concentrations, however, were measured to be much higher than surface concentrations during the July event. In the absence of anoxia, this elevated deep-water concentration may be the product of decomposing organic debris settling to the bottom of the water column. Due to the lack of measured anoxia, Pinecliff Lake's internal phosphorus load was calculated using the reduced oxic load of 0.6 mg TP/m²/day, yielding an annual estimate of approximately 53.35 kg.

Table 173 below displays the external and internal loads of phosphorus for Pinecliff Lake, as well as the grand total, which is estimated to be approximately 301.95 kg/year. Watershed-based loading was modeled to be the largest driver of phosphorus loading in Pinecliff Lake, contributing to approximately 82% of the total annual load.

Table 173. Total estimated annual phosphorus loads for Pinecliff Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	248.60
Internal	53.35
Total	**301.95**

Table 174. Estimated annual loads of sediment in the total Pinecliff watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.390	0.4
	Cropland	0.000	0.0
	Forest	2.980	2.9
	Wetland	0.210	0.2
	Open Land	0.240	0.2
	Barren Land	0.000	0.0
	Low-Density Mixed	0.780	0.7
	Medium-Density Mixed	1.090	1.0
	High-Density Mixed	0.120	0.1
	Low-Density Open Space	1.320	1.3
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	96.978	93.2
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	104.108	100.0

Table 175. Estimated annual loads of sediment by subwatershed in the Pinecliff Lake watershed

Category	Description	Full Watershed kg x 1000	Bearfort Mt. kg x 1000	Capstan kg x 1000	Dam kg x 1000	East kg x 1000	Inlet kg x 1000	North kg x 1000	Northwest kg x 1000	Stowaway kg x 1000	Sylvan kg x 1000	West kg x 1000
Runoff	Hay/Pasture	0.390	0.000	0.000	0.000	0.000	0.090	0.000	0.000	0.000	0.010	0.020
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	2.980	0.520	0.880	0.000	0.060	0.430	0.070	1.270	0.020	0.000	2.500
	Wetland	0.210	0.020	0.000	0.000	0.000	0.040	0.000	0.000	0.010	0.000	0.000
	Open Land	0.240	0.000	0.050	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.140
	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	0.780	0.000	0.010	0.070	0.160	0.140	0.050	0.030	0.000	0.070	0.010
	Medium-Density Mixed	1.090	0.000	0.000	0.110	0.280	0.170	0.020	0.020	0.020	0.360	0.020
	High-Density Mixed	0.120	0.000	0.000	0.010	0.030	0.010	0.000	0.000	0.000	0.120	0.000
	Low-Density Open Space	1.320	0.020	0.030	0.060	0.380	0.220	0.070	0.100	0.010	0.100	0.070
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	96.978	0.511	0.044	0.024	0.044	15.952	0.017	0.013	0.004	0.030	0.007
	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)	104.108	1.071	1.014	0.274	0.954	17.082	0.227	1.433	0.064	0.690	2.767
	kg/acre	27.392	2.888	10.475	12.070	7.271	6.098	5.242	12.526	4.183	14.198	17.647

Table 176. Estimated annual bacterial loads by subwatershed in the Pinecliff Lake watershed

Description	Full Watershed %	Bearfort Mt. %	Capstan %	Dam %	East %	Inlet %	North %	Northwest %	Stowaway %	Sylvan %	West %
Farm Animals and Waterfowl	8.5	0	0	0	0	12.7	0	0	0	0	0
WWTP	9.9	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	33.1	0.1	1.2	99.9	95.9	35.7	81.4	26.5	52.3	98.8	7.3
Other Wildlife	48.5	99.9	98.8	0.1	4.1	51.6	18.6	73.5	47.7	1.2	92.7
Total (organisms)	1.84E+12	1.21E+11	3.27E+10	8.11E+10	2.41E+11	1.23E+12	3.98E+10	4.40E+10	6.10E+09	1.60E+11	5.33E+10

Pinecliff Lake's annual sediment load is largely estimated to originate from streambank erosion, with most of this occurring in the Inlet subwatershed. This subwatershed is estimated to yield the highest overall sediment load, while the West subwatershed is estimated to yield the largest annual load per acre.

Table 177. Estimated annual loads of bacteria in the total Pinecliff Lake watershed

Description	Fecal Coliform Organisms	%
Farm Animals and Waterfowl	1.56E+11	8.5
WWTP	1.82E+11	9.9
Septic Systems	0.00E+00	0.0
Urban Areas	6.07E+11	33.1
Other Wildlife	8.91E+11	48.5
Total	1.84E+12	100

Pinecliff Lake's total estimated annual load of bacteria is modeled to originate largely from both wildlife in the watershed's forested areas, as well as from urbanized areas. The Inlet subwatershed yielded the highest bacterial load of the nine subwatersheds.

POST BROOK FARMS LAKE

Post Brook Farms Lake's watershed spans an area of approximately 65.5 acres, while the lake itself features a surface area of approximately 7.7 acres. The watershed consists of approximately 64% forested land and wetlands, with the remaining land classified as urbanized land. The lake features only relatively minor inlets, with an ephemeral input entering the lake at the northwest corner and another small stream entering along the western shoreline. The lake's dam and outlet are located in the southwestern corner, and the outlet stream travels south before entering Algonquin Waters. Descriptions of the lake's subwatersheds are as follows:

- **East:** This approximately 9.1-acre subwatershed spans almost the entire eastern shoreline of the lake, and is mostly (approximately 85%) forested, with the remaining area classified as urbanized land.
- **North:** This approximately 8.9-acre subwatershed contains the lake's beach, as well as the small ephemeral inlet. It also contains lengths of Schofield Rd. and Osage Dr. The area is classified as over 80% urbanized land.
- **Northwest:** This subwatershed contains the small inlet stream entering the western side of the lake and spans an area of approximately 13.7 acres. The area is mostly urbanized with small amounts of forested land also present.
- **South:** This is the largest of Post Brook Farms Lake's subwatersheds at approximately 30.4 acres, draining to the lake to the east of the dam. The area is entirely classified as forested land and wetlands.
- **West:** This small (approximately 3.6 acres) subwatershed contains a length of Osage Dr. and the adjacent urbanized areas. The area is mostly classified as urbanized land, with some forested land also present.

Table 178. Land-use by subwatershed in the Post Brook Farms Lake watershed.

Source	Full Watershed	East	North	Northwest	South	West
	Area (acres)					
Open Water	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
Cropland	0.0	0.0	0.0	0.0	0.0	0.0
Forest	31.9	7.7	0.5	2.5	20.0	1.2
Wetland	10.1	0.0	0.0	0.0	10.4	0.0
Open Land	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
Low-Density Mixed	7.7	0.2	2.7	4.0	0.0	0.7
Medium-Density Mixed	0.5	0.0	0.0	0.5	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	15.3	1.2	5.7	6.7	0.0	1.7
Total	65.5	9.1	8.9	13.7	30.4	3.6

Table 178 continued. Land-use by subwatershed in the Post Brook Farms Lake watershed.

Source	Full Watershed	East	North	Northwest	South	West
	Area (%)					
Open Water	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
Cropland	0.0	0.0	0.0	0.0	0.0	0.0
Forest	48.7	84.6	5.6	18.2	65.8	33.3
Wetland	15.4	0.0	0.0	0.0	34.2	0.0
Open Land	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
Low-Density Mixed	11.8	2.2	30.3	29.2	0.0	19.4
Medium-Density Mixed	0.8	0.0	0.0	3.6	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0
Low-Density Open Space	23.4	13.2	64.0	48.9	0.0	47.2
Total	100	100	100	100	100	100

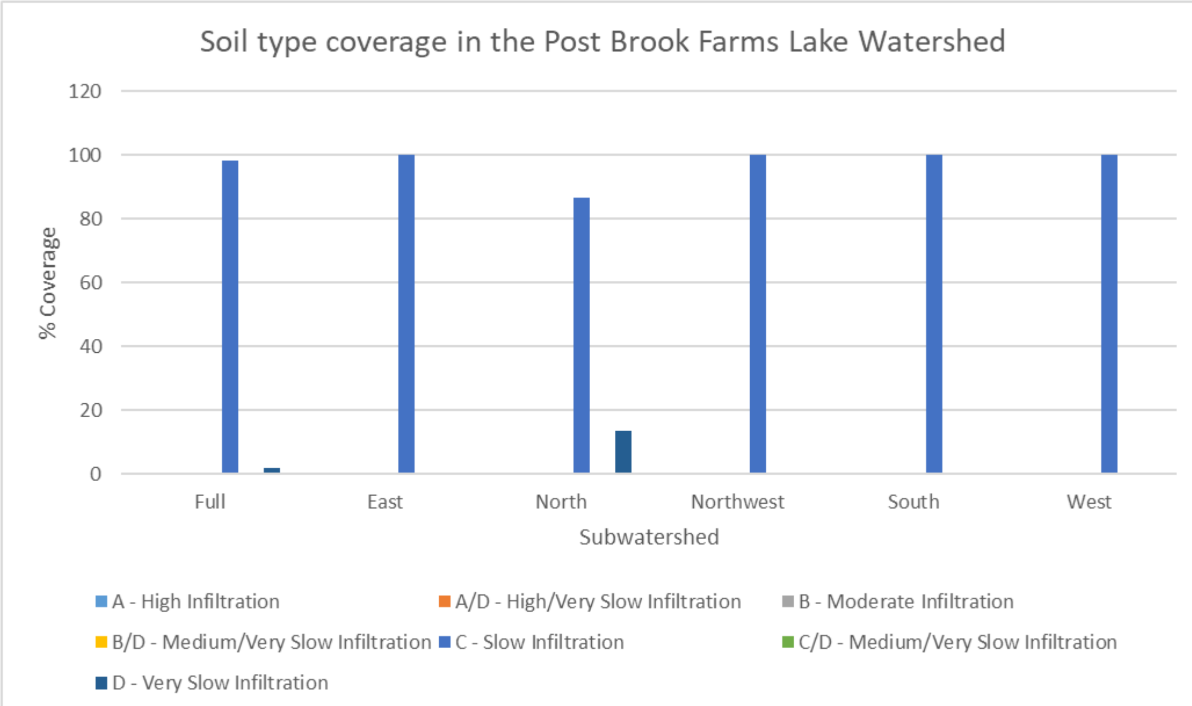


Figure 78. Percent coverage of Post Brook Farms Lake's watershed and subwatersheds by different hydrologic soil groups.

The full Post Brook Farms Lake watershed is almost entirely covered with soil group C, with a small amount of soil group D occurring in the North subwatershed. The watershed as a whole likely yields increased runoff due to slow groundwater infiltration, particularly in the North subwatershed. Slopes in the watershed are relatively gradual on average, with the full watershed averaging approximately 7% and the highest average in the East subwatershed at approximately 10%. The maximum slope of approximately 19% is located in the North subwatershed.

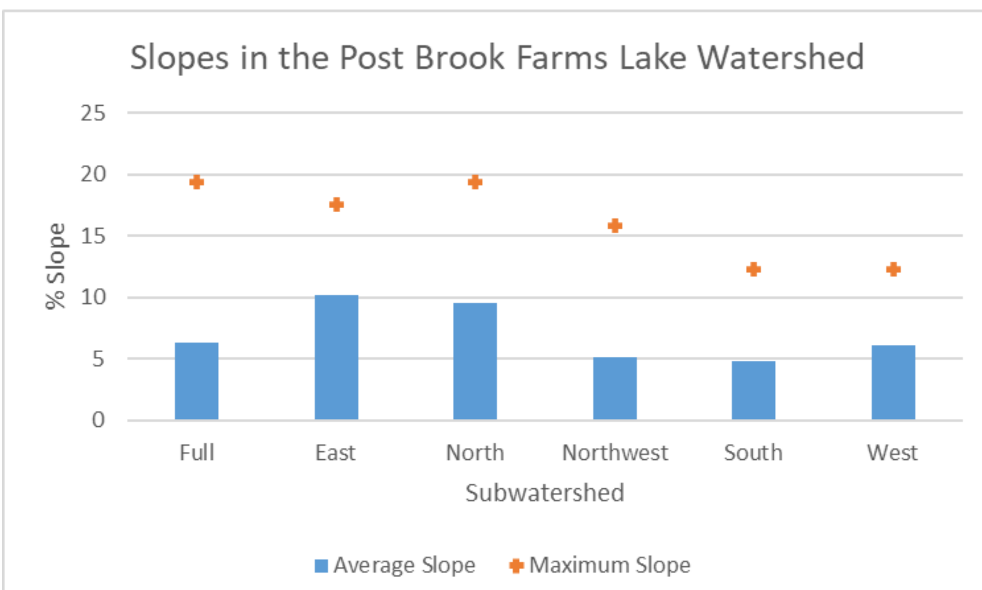


Figure 79. Variation in average and maximum percent slope between subwatersheds in the Post Brook Farms Lake watershed.

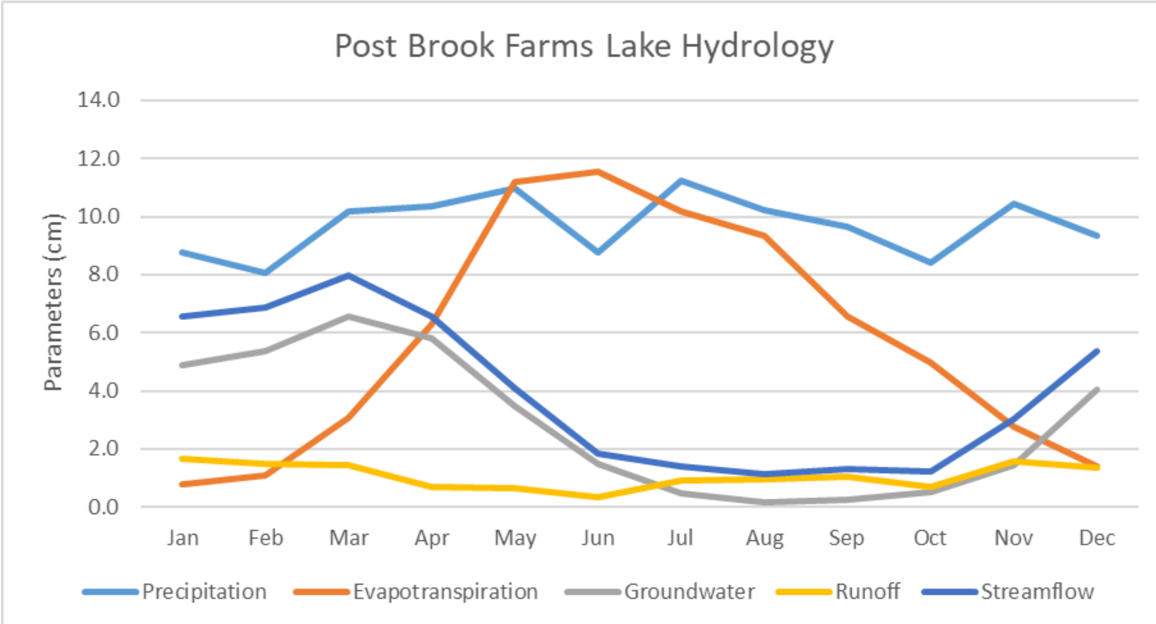


Figure 80. Estimated seasonal changes in hydrology in the Post Brook Farms Lake watershed

Table 179. Total hydrological parameters in the full Post Brook Farms Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.8	4.9	1.7	6.6	0.2
Feb	8.0	1.1	5.4	1.5	6.9	0.3
Mar	10.2	3.1	6.6	1.4	8.0	0.3
Apr	10.4	6.3	5.8	0.7	6.6	0.2
May	11.0	11.2	3.5	0.6	4.1	0.1
Jun	8.8	11.5	1.5	0.3	1.8	0.1
Jul	11.2	10.2	0.5	0.9	1.4	0.0
Aug	10.2	9.4	0.1	1.0	1.1	0.0
Sep	9.7	6.6	0.3	1.0	1.3	0.0
Oct	8.4	5.0	0.5	0.7	1.2	0.0
Nov	10.4	2.8	1.4	1.6	3.0	0.1
Dec	9.3	1.4	4.0	1.4	5.4	0.2
Total	116.4	69.2	34.5	12.8	47.3	0.1

The Southern subwatershed was modeled to yield a higher runoff than the other subwatersheds during the warmer months. Additionally, the Eastern subwatershed yielded a notably lower runoff compared to the other subwatersheds. When direct precipitation and evapotranspiration to the lake itself are considered, Post Brook Farms Lake is estimated to receive approximately 139,854 m^3 or 37.0 million gallons of water each year.

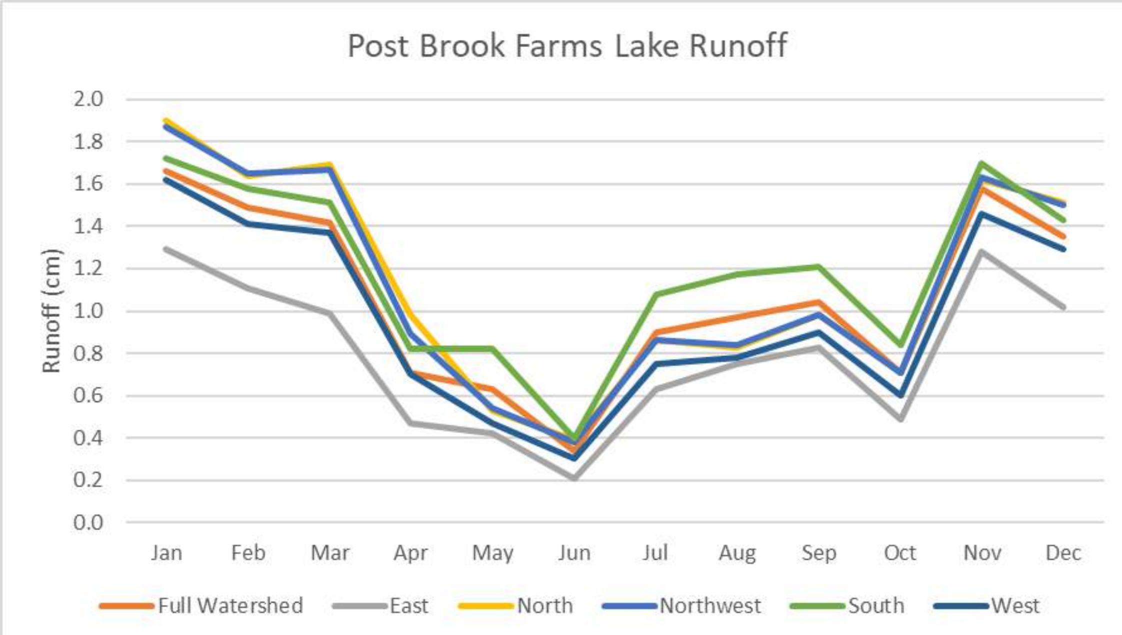


Figure 81. Average monthly runoff occurring in each subwatershed in the Post Brook Farms Lake watershed

As no bathymetric data for Post Brook Farms Lake was available, the lake's volume was estimated using depths collected in the field to be approximately 47,419 m³ or 12.5 million gallons of water. Using this and the estimated annual hydraulic load, Post Brook Farms is estimated to flush completely approximately 3.0 times a year, with a hydraulic retention time of approximately 123.8 days. When examined on a monthly basis, the lake's annualized flushing rate is estimated to be at its lowest during the months of June, August, and October.

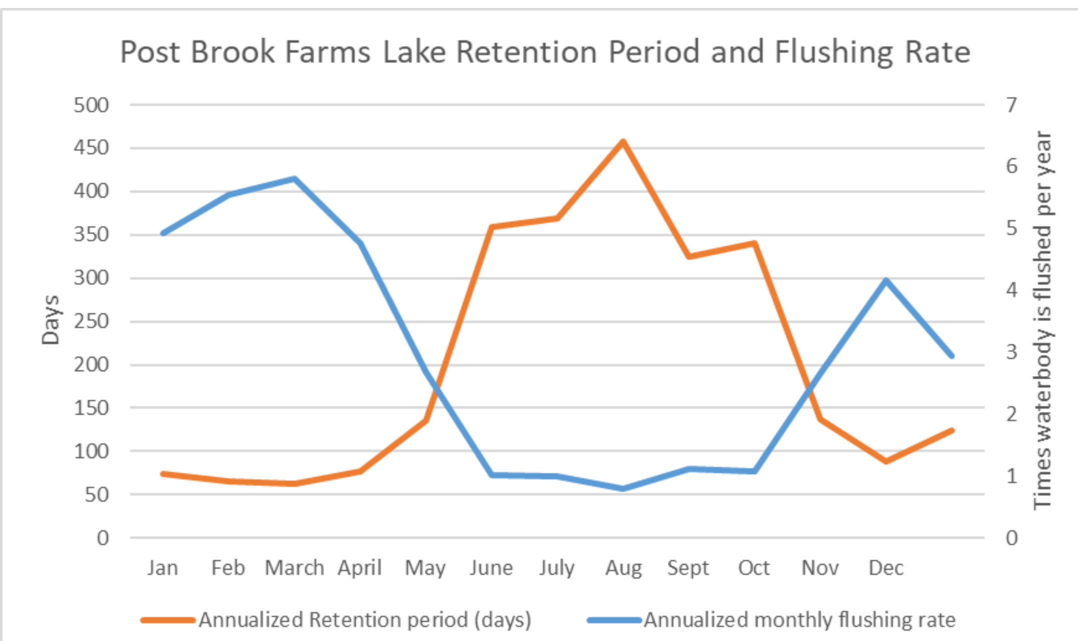


Figure 82. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Post Brook Farms Lake, based on variations in hydraulic loads.

Table 180. Estimated annual loads of nitrogen in the total Post Brook Farms Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	2.3	0.81
	Wetland	1.9	0.68
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	1.1	0.40
	Medium-Density Mixed	0.3	0.10
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	2.3	0.81
Other Sources	Farm Animals and Waterfowl	0.2	0.05
	Stream Bank	0.0	0.00
	Groundwater	31.0	11.08
	Dryfall	11.8	4.23
	Septic Systems	229.3	81.85
	Total	280.2	100

The estimated annual nitrogen load for Post Brook Farms Lake is dominated by nitrogen originating from septic systems within the watershed, as well as from groundwater and dryfall. Runoff-based nitrogen loads largely originated from forested areas and low-density urbanized open space. The largest annual load was estimated to originate from the Northwest subwatershed, while the Western subwatershed yielded the highest load per acre.

Table 181. Estimated annual loads of nitrogen by subwatershed in the Post Brook Farms Lake watershed

Category	Description	Full Watershed kg	East kg	North kg	Northwest kg	South kg	West kg
Runoff	Hay/Pasture	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
	Forest	2.3	0.5	0.1	0.2	1.4	0.1
	Wetland	1.9	0.0	0.0	0.0	1.9	0.0
	Open Land	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
	Low-Density Mixed	1.1	0.0	0.4	0.5	0.0	0.1
	Medium-Density Mixed	0.3	0.0	0.0	0.3	0.0	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Density Open Space	2.3	0.1	0.9	0.9	0.0	0.2
Other Sources	Farm Animals and Waterfowl	0.2	0.0	0.0	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0	0.0	0.0
	Groundwater	31.0	5.0	4.0	6.3	10.5	1.8
	Dryfall	11.8	.	.	.	.	.
	Septic Systems	229.3	12.7	52.6	129.0	0.0	36.6
	Total (kg)	280.2	18.4	58.0	137.1	13.9	38.9
	kg/acre	4.3	2.0	6.5	10.0	0.5	10.8

Table 182. Estimated annual loads of phosphorus in the total Post Brook Farms Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.16	0.6
	Wetland	0.10	0.4
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.12	0.4
	Medium-Density Mixed	0.03	0.1
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.24	0.9
Other Sources	Farm Animals and Waterfowl	0.05	0.2
	Stream Bank	0.00	0.0
	Groundwater	1.26	4.6
	Dryfall	0.06	0.2
	Septic Systems	25.20	92.6
	Total	27.22	100.0

Table 183. Estimated annual loads of phosphorus by subwatershed in the Post Brook Farms Lake watershed

Category	Description	Full Watershed	East	North	Northwest	South
		kg	kg	kg	kg	kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00
	Forest	0.16	0.04	0.00	0.01	0.09
	Wetland	0.10	0.00	0.00	0.00	0.11
	Open Land	0.00	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.12	0.00	0.05	0.05	0.00
	Medium-Density Mixed	0.03	0.00	0.00	0.03	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.24	0.01	0.10	0.09	0.00
Other Sources	Farm Animals and Waterfowl	0.05	0.00	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00	0.00
	Groundwater	1.26	0.13	0.11	0.26	0.28
	Dryfall	0.06	.	.	.	.
	Septic Systems	25.20	6.72	5.88	5.88	0.00
	Total (kg)	27.22	6.90	6.14	6.32	0.48
	kg/acre	0.42	0.76	0.69	0.46	0.02

Post Brook Farm Lake's watershed-based annual phosphorus load is estimated to originate largely from septic systems, which account for approximately 93% of the total watershed-based load. The Western subwatershed was modeled to yield both the highest overall annual phosphorus load, as well as the highest load per acre.

The water column in Post Brook Farms Lake was measured to be anoxic below approximately 2 meters in depth during the summer sampling event. This coincided with a deep-water sample featuring a notably higher total phosphorus concentration than the surface sample. Both of these measurements suggest that the lake may have been experiencing a degree of increased internal phosphorus loading. As such, the lake was modeled to release an increased rate of phosphorus from the bottom sediments for approximately two months out of a 153-day growing season. When the lower oxic loading rate is also taken into account for areas outside of the effected depth and during the remainder of the growing season, Post Brook Farms Lake was estimated to yield an internal phosphorus load of approximately 6.99 kg/yr. If a year without anoxia and increased internal phosphorus loading occurred, the lake would receive an estimated 2.84 kg of phosphorus over the course of the year.

Table 184 below displays the external and internal loads of phosphorus for Post Brook Farms Lake, as well as the grand total, which is estimated to be approximately 34.21 kg/year. Watershed-based loading was modeled to be the largest driver of phosphorus loading in Post Brook Farms Lake, contributing to approximately 80% of the total annual load.

Table 184. Total estimated annual phosphorus loads for Post Brook Farms Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	27.22
Internal	6.99
Total	**34.21**

Table 185. Estimated annual loads of sediment in the total Post Brook Farms Lake watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.040	18.9
	Wetland	0.000	0.0
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.050	23.6
	Medium-Density Mixed	0.020	9.4
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.090	42.5
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.012	5.7
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.212	100.0

Post Brook Farms Lake is estimated to receive a relatively small annual sediment load, at only approximately 212 kg/year. A large majority of this sediment (approximately 76%) is estimated to enter the lake as runoff from urbanized areas. The Northwest subwatershed was estimated to yield the highest overall annual sediment load, while the North subwatershed was estimated to yield the largest load per acre.

Table 186. Estimated annual loads of sediment by subwatershed in the Post Brook Farms Lake watershed

Category	Description	Full Watershed kg x 1000	East kg x 1000	North kg x 1000	Northwest 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
	Cropland	0.000	0.000	0.000	0.000	0.000	0.000
	Forest	0.040	0.010	0.000	0.000	0.020	0.000
	Wetland	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
	Barren Land	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.050	0.000	0.020	0.020	0.000	0.000
	Medium-Density Mixed	0.020	0.000	0.000	0.020	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.090	0.000	0.040	0.030	0.000	0.010
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000	0.000	0.000
	Stream Bank	0.012	0.002	0.011	0.013	0.000	0.004
	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)	0.212	0.012	0.071	0.083	0.020	0.014
	kg/acre	3.237	1.319	7.978	6.058	0.658	3.889

Table 187. Estimated annual loads of bacteria in the total Post Brook Farms watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	7.19E+07	0.2
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.11E+10	64.8
	Other Wildlife	1.14E+10	35.0
	Total	3.26E+10	100

Post Brook Farms Lake's total estimated annual load of bacteria is modeled to originate largely from urbanized areas in the watershed. The Northwest subwatershed yielded the highest bacterial load of the five subwatersheds.

Table 188. Estimated annual bacterial loads by subwatershed in the Post Brook Farms Lake watershed

Category	Description	Full Watershed %	East %	North %	Northwest %	South %	West %
Fecal Coliform	Farm Animals and Waterfowl	0.2	0.0	0.0	0.0	0.0	0.0
	WWTP	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	64.8	16.3	99.2	96.7	0.0	90.4
	Other Wildlife	35.0	83.7	0.8	3.3	100.0	9.6
	Total (organisms)	3.26E+10	3.27E+09	2.11E+10	2.65E+10	7.14E+09	4.58E+09

SHADY LAKE

Shady Lake's watershed covers an area of approximately 51 acres, while the lake itself features a surface area of approximately 5.2 acres. Approximately 56% of the watershed is classified as forested land, while urban land represents approximately 43% of the area. The only inlet entering the lake originates in a small pond to the immediate north of the lake; this pond was not observed to have any inlets except for a small spring seep. The lake's dam and outlet are located on the eastern end of the lake, and the outlet stream passes through two other small waterbodies before its confluence with another branch of Posts Brook. Descriptions of the lake's subwatersheds are as follows:

- **East:** This approximately 8.5-acre subwatershed is situated along the northeastern edge of shady Lake, containing lengths of Poplar Grove Terrace and Rock Rd. and the adjacent developed land. This developed land represented approximately 53% of the area, with the remaining land classified as forested.
- **North:** This is the largest of Shady Lake's subwatersheds at approximately 39.5 acres. The area is approximately 62% forested, with urbanized land making up the majority of the remaining land, as well as small amounts of open water and wetlands. This subwatershed contains the small pond that drains immediately into Shady Lake.
- **South:** This is the smallest of Shady Lake's subwatersheds at approximately 3.7 acres. This area is classified entirely as urbanized land, containing the area immediately adjacent to the southern length of Poplar Grove Terrace.

Table 189. Land-use by subwatershed in the Shady Lake watershed.

Source	Full Watershed	East	North	South
	Area (acres)			
Open Water	0.7	0.0	0.7	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	28.4	4.0	24.5	0.0
Wetland	0.2	0.0	0.2	0.0
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	2.2	0.5	1.0	1.0
Medium-Density Mixed	0.0	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	19.5	4.0	13.1	2.7
Total	51.0	8.5	39.5	3.7

Table 189 continued. Land-use by subwatershed in the Shady Lake watershed.

Source	Full Watershed	East	North	South
		Area (%)		
Open Water	1.3	0.0	1.7	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	55.7	47.1	62.1	0.0
Wetland	0.4	0.0	0.5	0.0
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	4.3	5.9	2.5	27.0
Medium-Density Mixed	0.0	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	38.3	47.1	33.2	73.0
Total	100	100	100	100

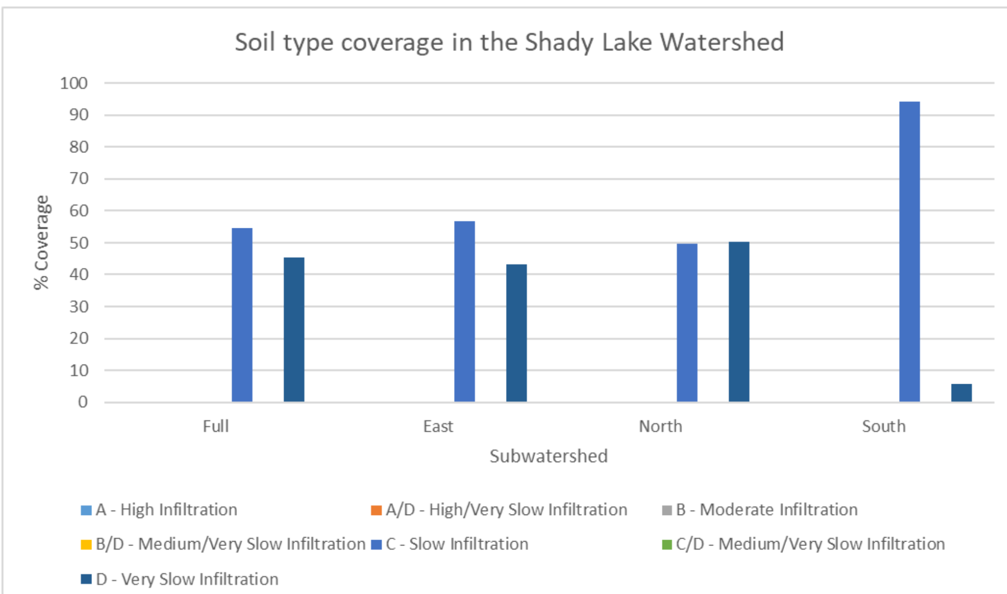


Figure 82. Percent coverage of Shady Lake watershed and subwatersheds by different hydrologic soil groups.

Shady Lake's full watershed features approximately 55% coverage with soil group C and 45% coverage with soil group D, suggesting an overall proneness to runoff. The East and North subwatersheds feature similar coverages to the total watershed, while the South subwatershed is approximately 94% covered with soil group C. The average slope for the full watershed is approximately 13%, with the maximum slope of approximately 33% occurring in the North subwatershed.

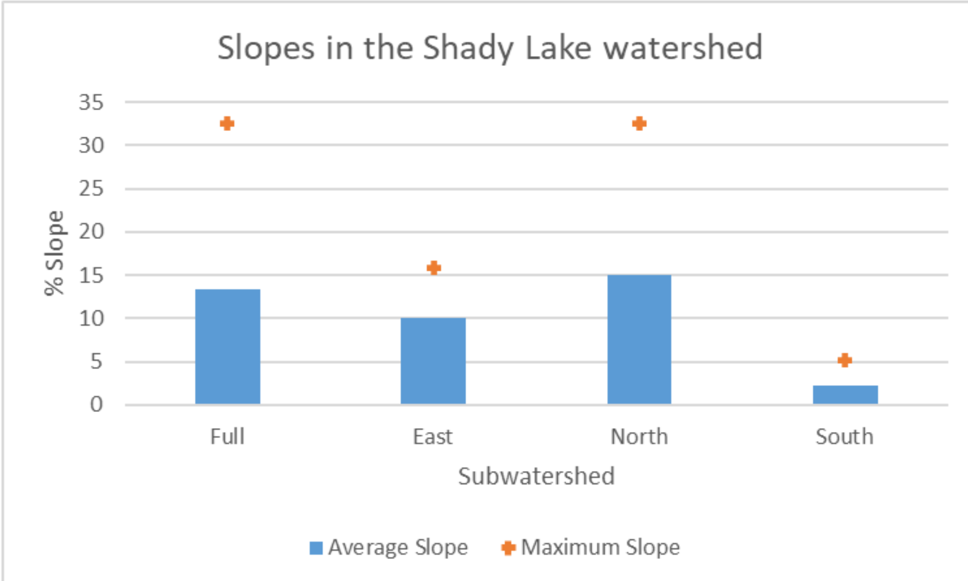


Figure 83. Variation in average and maximum percent slope between subwatersheds in the Shady Lake watershed.

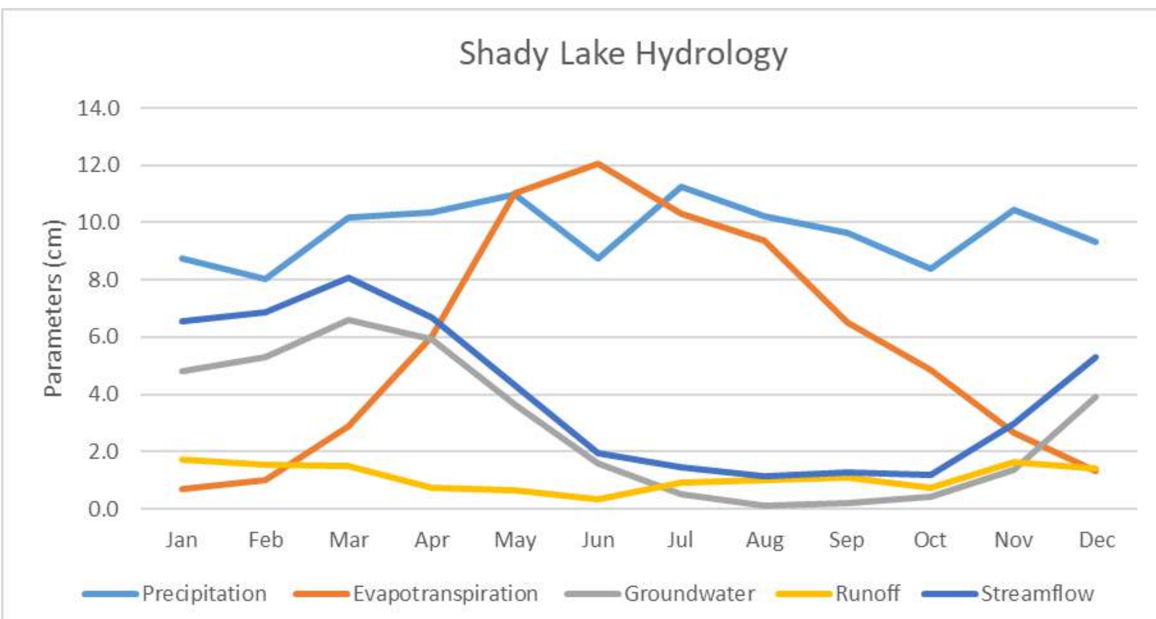


Figure 84. Estimated seasonal changes in hydrology in the Shady Lake watershed

Table 190. Total hydrological parameters in the full Shady Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	4.8	1.7	6.6	0.2
Feb	8.0	1.0	5.3	1.6	6.9	0.2
Mar	10.2	2.9	6.6	1.5	8.1	0.2
Apr	10.4	6.0	5.9	0.8	6.7	0.2
May	11.0	11.0	3.7	0.7	4.3	0.1
Jun	8.8	12.0	1.6	0.3	1.9	0.1
Jul	11.2	10.3	0.5	0.9	1.4	0.0
Aug	10.2	9.4	0.1	1.0	1.2	0.0
Sep	9.7	6.5	0.2	1.1	1.3	0.0
Oct	8.4	4.8	0.4	0.7	1.2	0.0
Nov	10.4	2.7	1.4	1.6	3.0	0.1
Dec	9.3	1.3	3.9	1.4	5.3	0.1
Total	116.4	68.7	34.5	13.3	47.8	0.1

Shady Lake's subwatersheds are modeled to experience an approximately 33% maximum difference in regard to runoff over the course of an average year, with the South subwatershed generally featuring the highest runoff earlier in the season and the North subwatershed yielding the highest runoff during most of the warmer months. When direct precipitation and evapotranspiration to the lake itself are considered, Shady Lake is estimated to receive approximately 108,468 m³ or 28.7 million gallons of water each year.

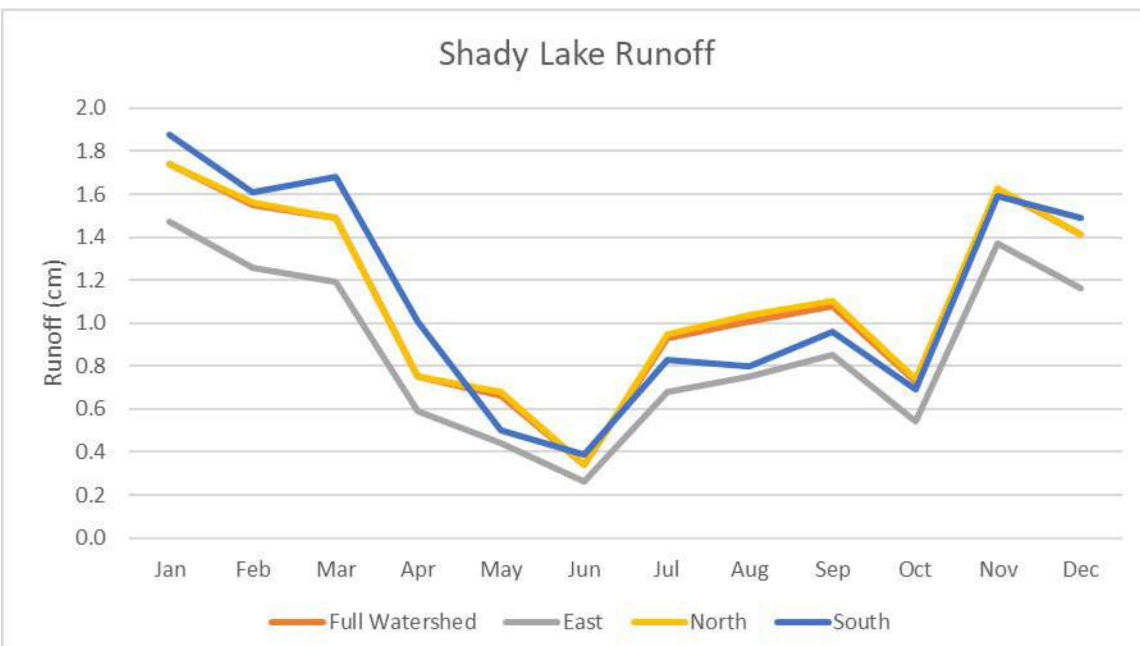


Figure 85. Average monthly runoff occurring in each subwatershed in the Shady Lake watershed

As no bathymetric data for Shady Lake was available, the lake's volume was estimated using depths collected in the field to be approximately 25,465 m³ or 6.7 million gallons of water. Using this and the estimated annual hydraulic load, Shady Lake is estimated to flush completely approximately 4.3 times a year, with a hydraulic retention time of approximately 85.7 days. When examined on a monthly basis, the lake's annualized flushing rate is estimated to be at its lowest during the month of August.

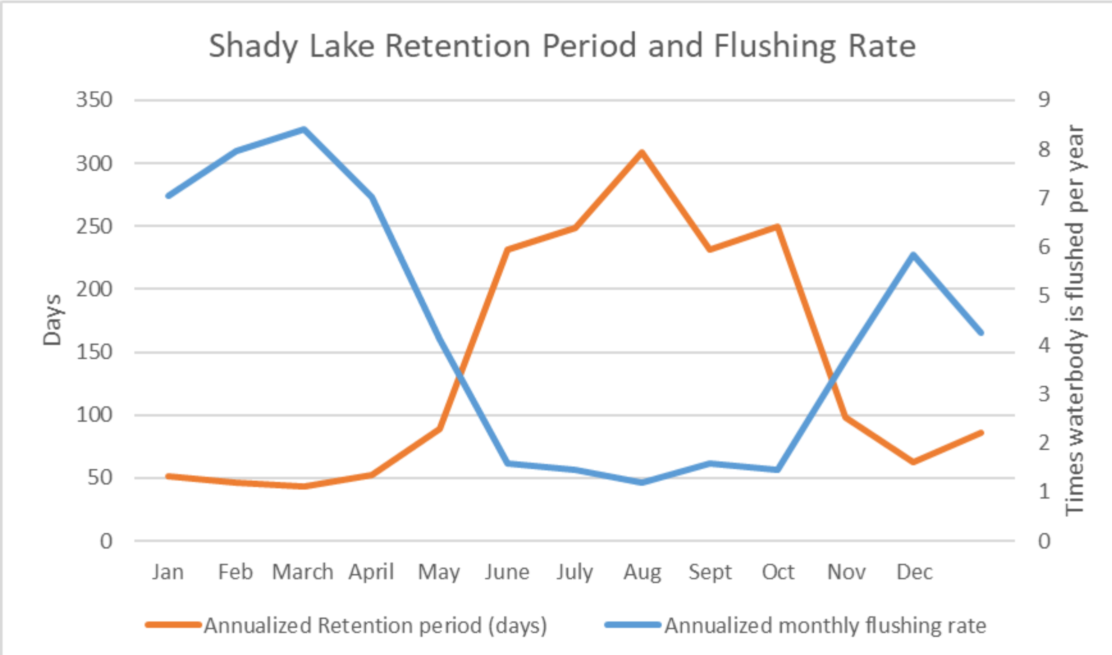


Figure 86. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Shady Lake, based on variations in hydraulic loads.

Table 191. Estimated annual loads of nitrogen in the total Shady Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	3.2	0.80
	Wetland	0.1	0.01
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	0.2	0.06
	Medium-Density Mixed	0.0	0.00
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	2.1	0.52
Other Sources	Farm Animals and Waterfowl	0.1	0.02
	Stream Bank	0.0	0.00
	Groundwater	23.2	5.85
	Dryfall	9.1	2.29
	Septic Systems	358.4	90.44
	Total	396.3	100

The estimated annual nitrogen load for Shady Lake is dominated by nitrogen originating from septic systems within the watershed, as well as from groundwater. Runoff-based nitrogen loads largely originated from forested land and low-density urbanized open space. The largest annual load was estimated to originate from the North subwatershed, while the South subwatershed yielded the highest load per acre.

Table 192. Estimated annual loads of nitrogen by subwatershed in the Shady Lake watershed

Category	Description	Full Watershed kg	East kg	North kg	South kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0
	Forest	3.2	0.3	2.7	0.0
	Wetland	0.1	0.0	0.0	0.0
	Open Land	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0
	Low-Density Mixed	0.2	0.1	0.1	0.2
	Medium-Density Mixed	0.0	0.0	0.0	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0
	Low-Density Open Space	2.1	0.4	1.5	0.5
Other Sources	Farm Animals	0.1	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0
	Groundwater	23.2	4.3	17.3	1.7
	Dryfall	9.1	.	.	.
	Septic Systems	358.4	68.5	228.3	60.5
	Total (kg)	396.3	73.5	250.0	62.9
	kg/acre	7.8	8.6	6.3	17.0

Table 193. Estimated annual loads of phosphorus in the total Shady Lake watershed

Category	Description	Total Phosphorus kg	%
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.18	0.8
	Wetland	0.00	0.0
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.02	0.1
	Medium-Density Mixed	0.00	0.0
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.18	0.8
Other Sources	Farm Animals and Waterfowl	0.03	0.1
	Stream Bank	0.00	0.0
	Groundwater	0.54	2.5
	Dryfall	0.05	0.2
	Septic Systems	20.83	95.5
	Total	21.82	100.0

Table 194. Estimated annual loads of phosphorus by subwatershed in the Shady Lake watershed

Category	Description	Full Watershed kg	East kg	North kg	South kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00
	Forest	0.18	0.02	0.12	0.00
	Wetland	0.00	0.00	0.00	0.00
	Open Land	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.02	0.01	0.01	0.10
	Medium-Density Mixed	0.00	0.00	0.00	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.18	0.04	0.10	0.00
Other Sources	Farm Animals and Waterfowl	0.03	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00
	Groundwater	0.54	0.11	0.31	0.00
	Dryfall	0.05	.	.	.
	Septic Systems	20.83	5.9	6.3	10.1
	Total (kg)	21.82	6.06	6.79	10.18
	kg/acre	0.43	0.71	0.17	2.75

Shady Lake's watershed-based annual phosphorus load is estimated to originate largely from septic systems, which account for approximately 95% of the total watershed-based load. The Southern subwatershed was modeled to yield the highest overall annual phosphorus load, as well as the highest load per acre, likely as a product of the number of septic systems within close distance of the lake.

Over the course of the 2022 growing season, Shady Lake was not measured to feature anoxia at the bottom of the water column. Additionally, samples collected from the bottom of the water column did not yield concentrations of total phosphorus that were notably greater than those collected at the surface. As such, the lake's internal phosphorus load was calculated using a reduced loading rate to be approximately 1.91 kg/yr.

Table 195 below displays the external and internal loads of phosphorus for Shady Lake, as well as the grand total, which is estimated to be approximately 23.73 kg/year. Watershed-based loading was modeled to be the largest driver of phosphorus loading in Shady Lake, contributing to approximately 92% of the total annual load.

Table 195. Total estimated annual phosphorus loads for Shady Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	21.82
Internal	1.91
Total	**23.73**

Table 196. Estimated annual loads of sediment in the total Shady Lake

Description	Sediment	
	kgx1000	%
Hay/Pasture	0.000	0.0
Cropland	0.000	0.0
Forest	0.030	19.4
Wetland	0.000	0.0
Open Land	0.000	0.0
Barren Land	0.000	0.0
Low-Density Mixed	0.010	6.5
Medium-Density Mixed	0.000	0.0
High-Density Mixed	0.000	0.0
Low-Density Open Space	0.050	32.3
Farm Animals and Waterfowl	0.000	0.0
Stream Bank	0.065	41.9
Groundwater	0.000	0.0
Septic Systems	0.000	0.0
Total	0.155	100.0

Shady Lake is estimated to receive a relatively small annual sediment load, at only approximately 155 kg/year. This load was dominated by sediment originating as runoff from low-density urbanized open space and from the erosion of stream banks. The Southern subwatershed was estimated to yield both the highest overall annual sediment load and the largest load per acre.

Table 197. Estimated annual loads of sediment by subwatershed in the Shady Lake watershed

Description	Full Watershed kg x 1000	East kg x 1000	North kg x 1000	South kg x 1000
Hay/Pasture	0.000	0.000	0.000	0.000
Cropland	0.000	0.000	0.000	0.000
Forest	0.030	0.000	0.010	0.000
Wetland	0.000	0.000	0.000	0.000
Open Land	0.000	0.000	0.000	0.000
Barren Land	0.000	0.000	0.000	0.000
Low-Density Mixed	0.010	0.000	0.000	0.009
Medium-Density Mixed	0.000	0.000	0.000	0.000
High-Density Mixed	0.000	0.000	0.000	0.000
Low-Density Open Space	0.050	0.020	0.010	0.023
Farm Animals and Waterfowl	0.000	0.000	0.000	0.000
Stream Bank	0.065	0.002	0.007	0.006
Groundwater	0.000	0.000	0.000	0.000
Septic Systems	0.000	0.000	0.000	0.000
Total (kgx1000)	0.155	0.022	0.027	0.038
kg/acre	3.040	2.588	0.684	10.270

Table 198. Estimated annual loads of bacteria in the total Shady Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	3.60E+07	0.1
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.11E+10	67.6
	Other Wildlife	1.01E+10	32.3
	Total	3.12E+10	100

Shady Lake's total estimated annual load of bacteria is modeled to originate largely from urbanized areas in the watershed and wildlife in forested areas. The North subwatershed yielded the highest bacterial load of the three subwatersheds.

Table 199. Estimated annual bacterial loads by subwatershed in the Shady Lake watershed

Description	Full Watershed	East	North	South
	%	%	%	%
Farm Animals and Waterfowl	0.1	0.0	0.0	0.0
WWTP	0.0	0.0	0.0	0.0
Septic Systems	0.0	0.0	0.0	0.0
Urban Areas	67.6	79.3	56.3	100.0
Other Wildlife	32.3	20.7	43.7	0.0
Total (organisms)	3.12E+10	6.81E+09	2.00E+10	8.95E+09

UPPER GREENWOOD LAKE

Upper Greenwood Lake is one of the largest lakes in the study by surface area at approximately 412 acres, with a watershed of approximately 4,229 acres. Approximately half of the watershed is classified as forested land, with an additional approximately 24% of the area classified as wetlands. Approximately 20% of the watershed is classified as urban land. The watershed contains Mt. Laurel Lake and Lake Lookover and these lakes' full watersheds. Mt. Laurel Lake feeds immediately into Upper Greenwood Lake through a dam, with this being one of the lake's primary inlets, the other being Sawmill Pond Brook, which enters the southeastern side of the lake. The outlet and dam are located at the northern end of the lake. This stream, known as Longhouse Creek, flows northeast into New York, eventually joining Wawayanda Creek. Descriptions of the lake's subwatersheds are as follows:

- **Fairlawn:** This approximately 239-acre subwatershed is situated along the northwestern shoreline of the lake and contains Fairlawn Dr., Hewitt Rd., and several other streets and the adjacent developed areas. The area consists mainly of urbanized land, with forested land also making up a notable percentage of the subwatershed.

- **Landing:** This approximately 168-acre subwatershed is located along the southeastern shoreline, containing the length of North Lake Shore Dr. and several smaller streets. The area is approximately 67% forested, with urbanized land making up a majority of the remaining space.
- **Longhouse:** This approximately 1,336-acre subwatershed is located south of the lake, containing both Mt. Laurel Lake and Lake Lookover, as well as the major inlet Longhouse Creek. The area is approximately 66% forested.

- **Northeast:** This approximately 288-acre subwatershed contains the length of North Lake Shore Drive, as well as the development to the east of the lake's outlet stream. The area is mostly (approximately 70%) forested, with much of the remaining land being classified as urban.
- **North Islands:** As the name suggests, this subwatershed contains the island in the northern half of the lake. The area is approximately 86% urbanized, with the remaining area classified mostly as forested land and wetlands.
- **Northwest:** This approximately 129-acre subwatershed contains the lake community's clubhouse and boat launch, as well as a minor inlet and the developed areas along Paterson, Tansboro, and Verona Roads. Approximately half of the area is classified as urbanized, with a majority of the remaining land being classified as forested land.
- **Sawmill Pond Brook:** This is the largest of Upper Greenwood Lake's subwatersheds at approximately 1,933 acres, containing one of the lake's major inlet streams. Approximately 90% of the area is classified as forested land or wetlands.

South Islands: This is the smallest of Upper Greenwood Lake's subwatersheds at approximately 39 acres. The area is classified as approximately 72% developed area, with the remaining land mostly consisting of forested land and wetlands

Table 200. Land-use by subwatershed in the Upper Greenwood Lake watershed.

Source	Full Watershed	Fairlawn	Landing	Longhouse	Northeast	North Islands	Northwest	Sawmill Pond Brook	South Islands
	Area (acres)								
Open Water	67.3	0.0	0.0	37.1	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	5.2	0.2	0.0	3.7	0.0	0.0	0.0	1.0	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	2316.1	62.8	113.2	880.2	202.6	7.7	49.7	993.1	9.4
Wetland	1006.7	6.7	2.7	235.7	3.5	1.0	8.4	742.8	1.2
Open Land	7.7	0.0	0.0	5.4	0.5	0.2	0.2	1.2	0.2
Barren Land	1.0	0.5	0.0	0.2	0.0	0.2	0.0	0.0	0.0
Low-Density Mixed	186.1	39.5	9.1	39.8	21.5	8.6	15.6	43.2	8.2
Medium-Density Mixed	46.9	9.6	2.0	10.9	4.2	3.2	3.7	12.1	1.5
High-Density Mixed	3.7	1.0	0.0	0.5	0.2	0.2	1.2	1.2	0.2
Low-Density Open Space	588.4	119.1	41.0	122.6	55.8	43.7	50.4	138.1	17.8
Total	4229.1	239.4	168.0	1336.1	288.3	64.8	129.2	1932.7	38.5

Table 200 continued. Land-use by subwatershed in the Upper Greenwood Lake watershed.

Source	Full Watershed	Fairlawn	Landing	Longhouse	Northeast	North Islands	Northwest	Sawmill Pond Brook	South Islands
	Area (%)								
Open Water	1.6	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0
Hay/Pasture	0.1	0.1	0.0	0.3	0.0	0.0	0.0	0.1	0.0
Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	54.8	26.2	67.4	65.9	70.3	11.9	38.5	51.4	24.4
Wetland	23.8	2.8	1.6	17.6	1.2	1.5	6.5	38.4	3.1
Open Land	0.2	0.0	0.0	0.4	0.2	0.3	0.2	0.1	0.5
Barren Land	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Low-Density Mixed	4.4	16.5	5.4	3.0	7.5	13.3	12.1	2.2	21.3
Medium-Density Mixed	1.1	4.0	1.2	0.8	1.5	4.9	2.9	0.6	3.9
High-Density Mixed	0.1	0.4	0.0	0.0	0.1	0.3	0.9	0.1	0.5
Low-Density Open Space	13.9	49.7	24.4	9.2	19.4	67.4	39.0	7.1	46.2
Total	100	100	100	100	100	100	100	100	100

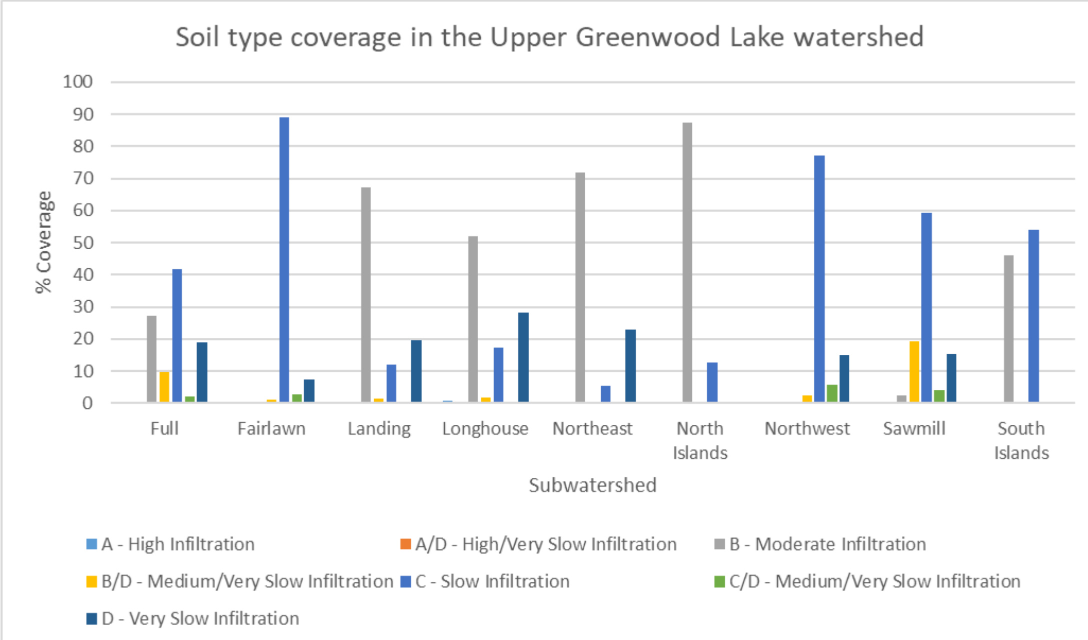


Figure 86. Percent coverage of Upper Greenwood Lake's watershed and subwatersheds by different hydrologic soil groups.

The full Upper Greenwood Lake watershed features a relatively high diversity of soil groups; however the group C soils were modeled to dominate the area and were the dominant group in four of the subwatersheds. The average slope for the full watershed was relatively gradual at approximately 9%, however the maximum slope was relatively high at approximately 58% in the Longhouse Creek subwatershed.

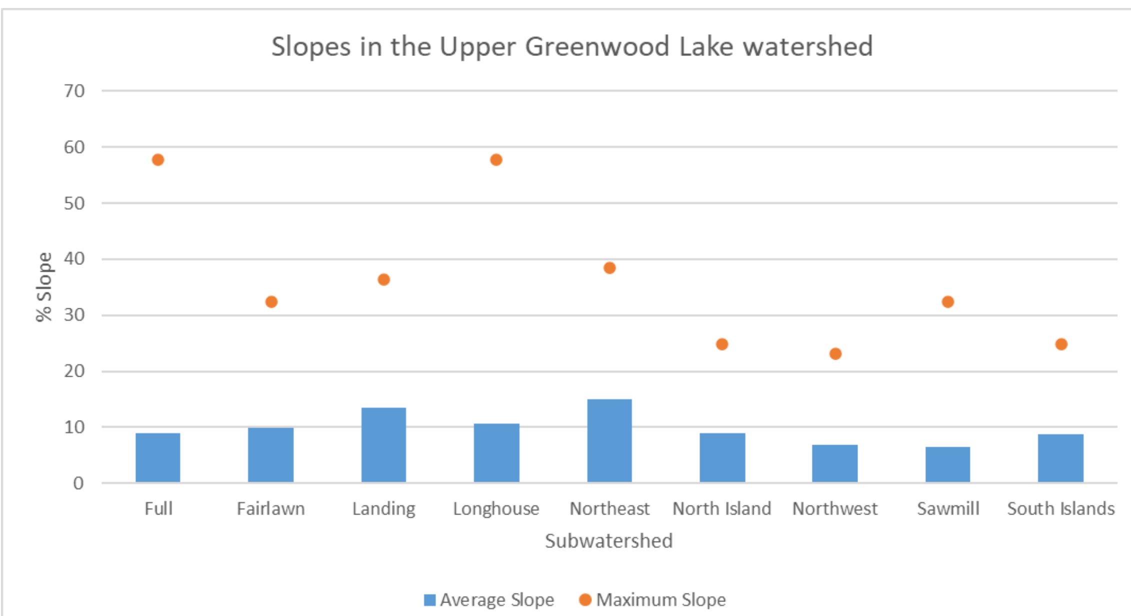


Figure 87. Variation in average and maximum percent slope between subwatersheds in the Upper Greenwood Lake watershed.

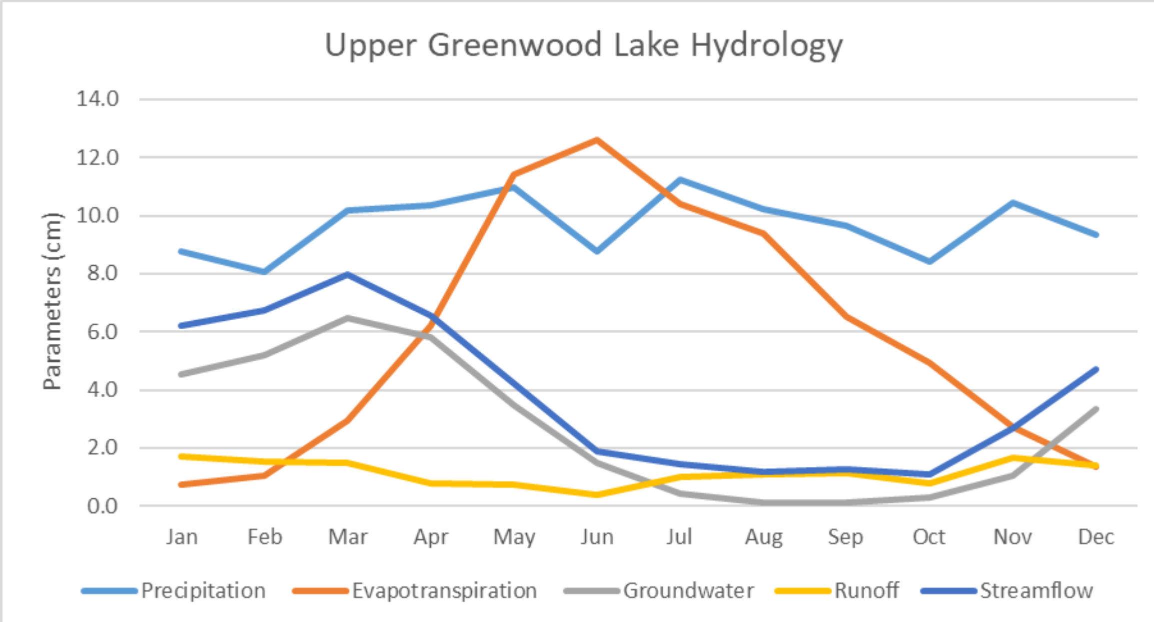


Figure 88. Estimated seasonal changes in hydrology in the Upper Greenwood Lake Watershed

Table 201. Total hydrological parameters in the full Upper Greenwood Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.8	4.5	1.7	6.2	14.0
Feb	8.0	1.0	5.2	1.6	6.7	16.7
Mar	10.2	3.0	6.5	1.5	8.0	18.0
Apr	10.4	6.2	5.8	0.8	6.6	15.3
May	11.0	11.4	3.5	0.7	4.2	9.5
Jun	8.8	12.6	1.5	0.4	1.9	4.4
Jul	11.2	10.4	0.4	1.0	1.4	3.2
Aug	10.2	9.4	0.1	1.1	1.2	2.7
Sep	9.7	6.5	0.1	1.1	1.3	2.9
Oct	8.4	4.9	0.3	0.8	1.1	2.4
Nov	10.4	2.7	1.0	1.7	2.7	6.3
Dec	9.3	1.4	3.3	1.4	4.7	10.7
Total	116.4	70.3	32.3	13.6	45.9	8.8

Upper Greenwood Lake's subwatersheds feature as much as a 50% difference in modeled runoff. The Sawmill Pond Brook subwatershed is estimated to yield the highest runoff over the course of an average year. Although this watershed largely consists of forested land and wetlands, it also features a relatively high acreage of urbanized land, possibly leading to high seasonal runoff. When direct precipitation and evapotranspiration to the lake itself are considered, Upper Greenwood Lake is estimated to receive approximately 8,631,282 m³ or 2,280 million gallons of water each year.

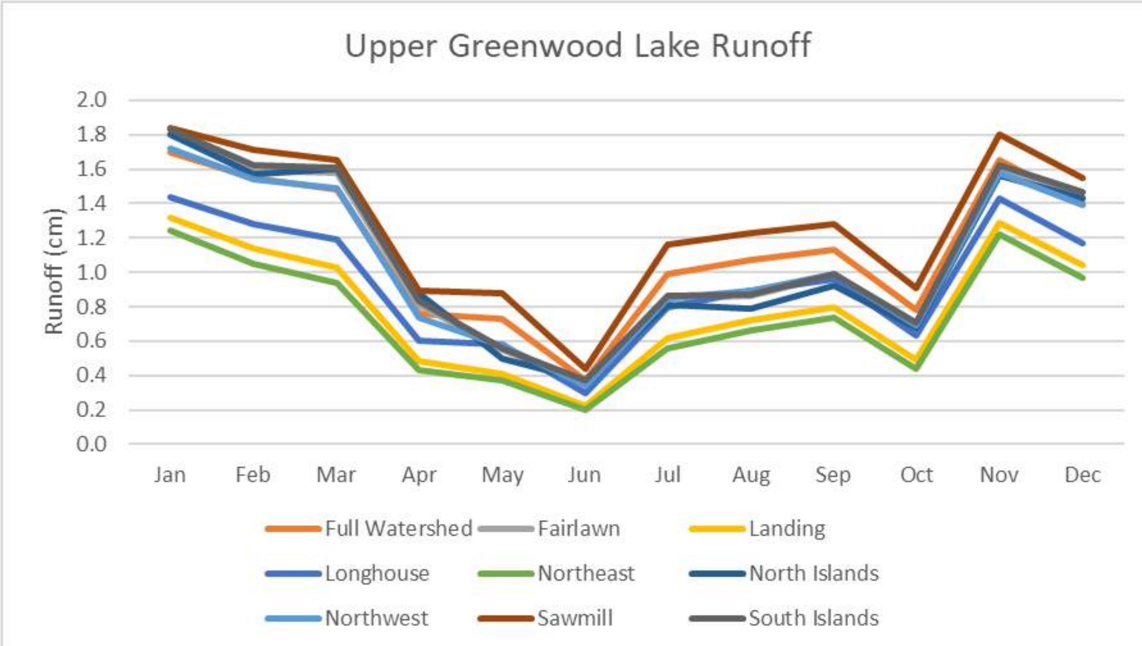


Figure 89. Average monthly runoff occurring in each subwatershed in the Upper Greenwood Lake Watershed

A bathymetric study of Upper Greenwood Lake was performed by Princeton Hydro in 2021 in which the approximate volume of the lake was estimated to be 3,104,954 m³ or 820.2 million gallons of water. Using this volume and the estimated hydraulic load produced by the GWLF-E model, Upper Greenwood Lake was estimated to flush completely approximately 2.8 times a year, with a retention period of approximately 131.4 days. When examined on a monthly basis, the lake's annualized flushing rate is at its lowest during the month of August during an average year, with June and October also being notable periods of decreased flushing.

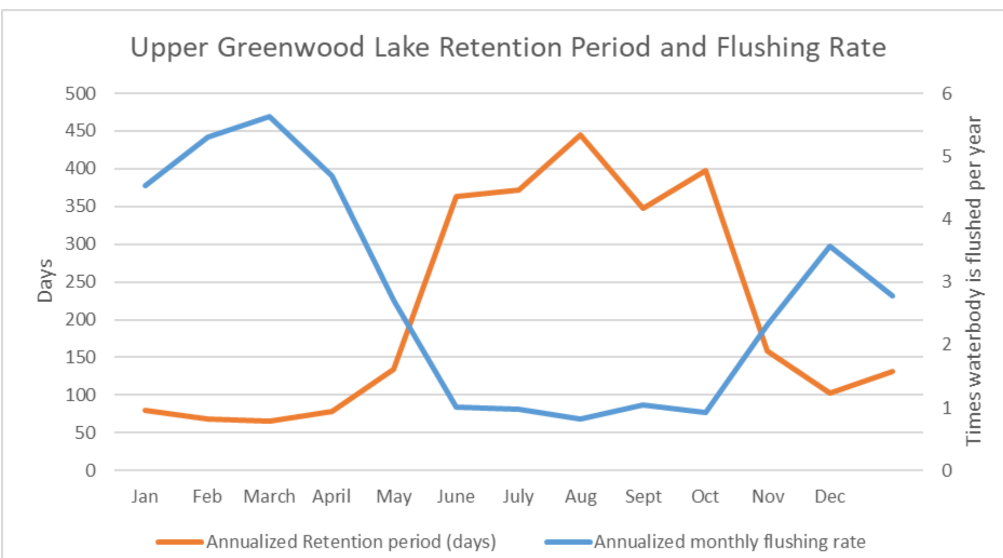


Figure 90. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Upper Greenwood Lake, based on variations in hydraulic loads.

Table 202. Estimated annual loads of nitrogen in the total Upper Greenwood Lake watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	2.4	0.03
	Cropland	0.0	0.00
	Forest	161.4	1.85
	Wetland	183.3	2.10
	Open Land	4.0	0.05
	Barren Land	0.3	0.00
	Low-Density Mixed	23.5	0.27
	Medium-Density Mixed	25.8	0.30
	High-Density Mixed	2.0	0.02
	Low-Density Open Space	74.5	0.85
Other Sources	Farm Animals and Waterfowl	4.4	0.05
	Stream Bank	0.0	0.00
	Groundwater	1795.8	20.59
	Dryfall	751.2	8.62
	Septic Systems	5691.3	65.27
	Total	8719.8	100

The estimated annual nitrogen load for Upper Greenwood Lake is dominated by nitrogen originating from septic systems within the watershed, as well as from groundwater and dryfall. Runoff-based nitrogen loads largely originated from forested areas and wetlands. The overall largest annual load was estimated to originate from the Sawmill Pond Brook subwatershed, while the South Islands subwatershed yielded the highest load per acre. This is likely due to the large number of septic systems present in this subwatershed that are within 15 meters of the lake.

Table 203. Estimated annual loads of phosphorus in the total Upper Greenwood Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.83	0.1
	Cropland	0.00	0.0
	Forest	8.31	1.4
	Wetland	8.05	1.3
	Open Land	0.19	0.0
	Barren Land	0.01	0.0
	Low-Density Mixed	2.04	0.3
	Medium-Density Mixed	2.09	0.3
	High-Density Mixed	0.17	0.0
	Low-Density Open Space	6.46	1.1
Other Sources	Farm Animals and Waterfowl	1.50	0.2
	Stream Bank	34.00	5.7
	Groundwater	42.20	7.0
	Dryfall	3.76	0.6
	Septic Systems	492.09	81.8
	Total	601.69	100.0

Table 204. Estimated annual loads of nitrogen by subwatershed in the Upper Greenwood Lake watershed

Category	Description	Full Watershed kg	Fairlawn kg	Landing kg	Longhouse kg	Northeast kg	North Islands kg	Northwest kg	Sawmill Pond Brook kg	South Islands kg
Runoff	Hay/Pasture	2.4	0.1	0.0	1.6	0.0	0.0	0.0	0.3	0.0
	Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Forest	161.4	4.4	8.3	49.1	13.6	0.3	3.5	67.1	0.7
	Wetland	183.3	1.3	0.4	41.9	0.5	0.1	1.6	131.0	0.2
	Open Land	4.0	0.0	0.0	2.9	0.2	0.1	0.1	0.6	0.1
	Barren Land	0.3	0.2	0.0	0.1	0.0	0.1	0.0	0.0	0.0
	Low-Density Mixed	23.5	5.2	1.1	4.9	2.8	1.0	2.1	5.3	1.2
	Medium-Density Mixed	25.8	6.1	0.9	6.8	2.2	2.6	1.5	6.0	0.6
	High-Density Mixed	2.0	0.6	0.0	0.3	0.1	0.2	0.5	0.6	0.1
	Low-Density Open Space	74.5	15.7	4.9	15.1	7.4	5.1	6.7	16.8	2.6
Other Sources	Farm Animals and Waterfowl	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	11.0	0.0	0.0	1.0	15.0	0.0
	Groundwater	1795.8	112.4	92.5	623.6	161.6	33.0	58.1	654.3	20.4
	Dryfall	751.2	.	.	.	.	.	.	.	.
	Septic Systems	5691.3	1108.5	482.6	1051.6	622.7	570.2	401.3	1082.8	425.2
	Total (kg)	11150.1	1254.4	590.6	1808.9	811.1	612.5	476.5	1979.8	451.1
	kg/acre	2.6	5.2	3.5	1.4	2.8	9.5	3.7	1.0	11.7

Table 205. Estimated annual loads of phosphorus by subwatershed in the Upper Greenwood Lake watershed

Category	Description	Full Watershed kg	Fairlawn kg	Landing kg	Longhouse kg	Northeast kg	North Islands kg	Northwest kg	Sawmill Pond Brook kg	South Islands kg
Runoff	Hay/Pasture	0.83	0.06	0.00	0.42	0.00	0.00	0.00	0.07	0.00
	Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest	8.31	0.23	1.16	2.17	2.29	0.02	0.20	2.55	0.05
	Wetland	8.05	0.08	0.03	1.46	0.03	0.01	0.08	4.24	0.01
	Open Land	0.19	0.00	0.00	0.14	0.01	0.01	0.00	0.01	0.00
	Barren Land	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low-Density Mixed	2.04	0.57	0.12	0.33	0.31	0.11	0.23	0.35	0.13
	Medium-Density Mixed	2.09	0.62	0.09	0.43	0.22	0.26	0.16	0.37	0.06
	High-Density Mixed	0.17	0.06	0.00	0.02	0.01	0.02	0.05	0.04	0.01
	Low-Density Open Space	6.46	1.70	0.53	1.03	0.80	0.55	0.73	1.11	0.28
Other Sources	Farm Animals and Waterfowl	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Stream Bank	34.00	0.00	0.00	4.00	0.00	0.00	0.00	5.00	0.00
	Groundwater	42.20	4.56	2.42	10.27	4.23	0.86	1.71	16.12	0.53
	Dryfall	3.76	.	.	.	.	.	.	.	.
	Septic Systems	492.09	73.91	63.83	82.96	69.71	68.03	16.80	24.52	161.26
	Total (kg)	601.69	81.79	68.18	103.23	77.61	69.87	19.96	54.38	162.33
	kg/acre	0.14	0.34	0.41	0.08	0.27	1.08	0.15	0.03	4.22

Upper Greenwood Lake's watershed-based annual phosphorus load is estimated to originate largely from septic systems, which account for approximately 82% of the total watershed-based load. As noted above with nitrogen, the lake features a large number of septic systems within its watershed, and several are present within 15 m of the waterbody or inflowing streams, resulting in an increased load of phosphorus entering the lake. The South Islands subwatershed was modeled to yield both the highest overall annual phosphorus load, as well as the highest load per acre.

Upper Greenwood Lake's water column was not measured to feature bottom anoxia at any point during the 2022 season. Furthermore, samples collected from the bottom of the water column did not yield notably higher concentrations of total phosphorus than those collected at the surface. Because of this, the lake's internal phosphorus load was modeled only using the reduced oxic loading rate, resulting in an estimated annual internal phosphorus load of 152.95 kg.

Table 206 below displays the external and internal loads of phosphorus for Upper Greenwood Lake, as well as the grand total, which is estimated to be approximately 754.64 kg/year. Watershed-based loading was modeled to be the largest driver of phosphorus loading in Upper Greenwood Lake, contributing to approximately 80% of the total annual load.

Table 206. Total estimated annual phosphorus loads for Upper Greenwood Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	601.69
Internal	152.95
Total	**754.64**

Table 207. Estimated annual loads of sediment in the total Upper Greenwood Lake watershed

Category	Description	Sediment	
		kgx1000	%
Runoff	Hay/Pasture	0.090	0.1
	Cropland	0.000	0.0
	Forest	0.990	1.2
	Wetland	0.220	0.3
	Open Land	0.080	0.1
	Barren Land	0.000	0.0
	Low-Density Mixed	0.550	0.7
	Medium-Density Mixed	0.770	0.9
	High-Density Mixed	0.060	0.1
	Low-Density Open Space	1.750	2.1
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	79.380	94.6
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	83.890	100.0

Table 208. Estimated annual loads of sediment by subwatershed in the Upper Greenwood Lake watershed

Category	Description	Full Watershed kg x 1000	Fairlawn kg x 1000	Landing kg x 1000	Longhouse kg x 1000	Northeast kg x 1000	North Islands kg x 1000	Northwest kg x 1000	Sawmill kg x 1000	South Islands kg x 1000
Runoff	Hay/Pasture	0.090	0.010	0.000	0.010	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	0.990	0.000	0.690	0.130	1.500	0.010	0.010	0.070	0.010
	Wetland	0.220	0.010	0.010	0.020	0.010	0.000	0.000	0.010	0.000
	Open Land	0.080	0.000	0.000	0.020	0.010	0.010	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	0.550	0.230	0.050	0.030	0.120	0.050	0.090	0.020	0.050
	Medium-Density Mixed	0.770	0.330	0.050	0.060	0.120	0.140	0.070	0.030	0.030
	High-Density Mixed	0.060	0.030	0.000	0.000	0.010	0.010	0.020	0.000	0.010
	Low-Density Open Space	1.750	0.680	0.220	0.100	0.310	0.230	0.290	0.080	0.110
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	79.380	0.623	0.022	3.029	0.254	0.416	1.237	2.688	0.021
	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)	83.890	1.913	1.042	3.399	2.334	0.866	1.717	2.898	0.231
	kg/acre	19.837	7.991	6.202	2.544	8.096	13.364	13.289	1.499	6.000

Table 209. Estimated annual bacterial loads by subwatershed in the Upper Greenwood Lake watershed

Category	Description	Full Watershed %	Fairlawn %	Landing %	Longhouse %	Northeast %	North Islands %	Northwest %	Sawmill %	South Islands %
Fecal Coliform	Farm Animals and Waterfowl	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WWTP	0.0	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	0.0
	Urban Areas	31.9	91.3	43.0	7.4	38.3	82.5	85.6	6.7	28.9
	Other Wildlife	63.6	8.7	57.0	92.6	61.7	17.5	14.4	93.3	71.1
	Total (organisms)	1.30E+12	2.82E+11	7.19E+10	3.40E+11	1.17E+11	4.74E+10	1.23E+11	3.82E+11	1.35E+10

A large majority (over 94.6%) of Upper Greenwood Lake's estimated total annual sediment load is modeled to originate as streambank runoff, with runoff from urban land also yielding a notable yearly load. The Longhouse subwatershed is estimated to yield the highest overall annual sediment load, while the North Islands and Northwest subwatersheds are estimated to yield the highest annual load per acre.

Table 210. Estimated annual loads of bacteria in the total Upper Greenwood Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	5.83E+10	4.5
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	4.14E+11	31.9
	Other Wildlife	8.26E+11	63.6
	Total	1.30E+12	100.0

Upper Greenwood Lake's total estimated annual load of bacteria is modeled to originate largely from wildlife in forested areas of the watershed, with urban areas being another notable source. The Sawmill Pond Brook subwatershed yielded the highest bacterial load of the eight subwatersheds.

VAN NOSTRAND LAKE

Van Nostrand Lake's watershed covers an area of approximately 46.2 acres, while the lake itself features a surface area of approximately 10.5 acres. The lake's watershed is almost entirely covered with forested land and wetlands, with forested lands dominating. The lake features no true inlet and is likely fed by groundwater and runoff. The outlet and dam are located in the southwestern corner of the lake. The outlet stream flows west and under Macopin Rd., entering a wetland near the Apshawa Preserve and eventually entering Butler Reservoir. Descriptions of the lake's subwatersheds are as follows:

- **Northeast:** As is the case with the other two subwatersheds, this approximately 18.8-acre subwatershed entirely consists of undeveloped land, with forested land being the dominant land use.
- **Northwest:** This approximately 15.5-acre subwatershed is almost entirely classified as forested land, with less than an acre of low-density urbanized open space containing the only house in the watershed.
- **South:** This is the smallest of Van Nostrand Lake's subwatersheds at approximately 12.1 acres. As with the other subwatersheds, the area is almost entirely forested with a small area of wetlands also present.

Table 211. Land-use by subwatershed in the Van Nostrand Lake watershed.

Source	Full Watershed	Northeast	Northwest	South
	Area (acres)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	39.8	15.1	14.8	9.9
Wetland	5.7	3.7	0.0	2.2
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	0.0	0.0	0.0	0.0
Medium-Density Mixed	0.0	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	0.7	0.0	0.7	0.0
Total	46.2	18.8	15.5	12.1

Table 211 continued. Land-use by subwatershed in the Van Nostrand Lake watershed.

Source	Full Watershed	Northeast	Northwest	South
	Area (%)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.0	0.0	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	86.1	80.3	95.5	81.8
Wetland	12.3	19.7	0.0	18.2
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	0.0	0.0	0.0	0.0
Medium-Density Mixed	0.0	0.0	0.0	0.0
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	1.5	0.0	4.5	0.0
Total	100	100	100	100

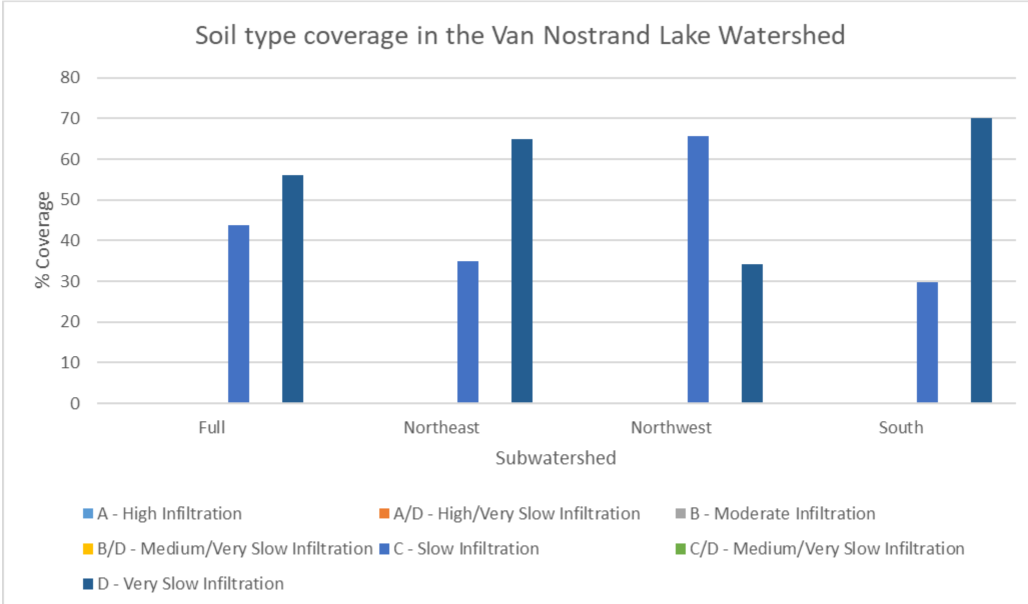


Figure 91. Percent coverage of Van Nostrand Lake watershed and subwatersheds by different hydrologic soil groups.

Van Nostrand Lake's full watershed features full coverage with slower infiltration soil-groups, particularly the group D soils. Most of the lake's subwatersheds feature a similar soil composition to the full watershed, with the exception of the Northwest subwatershed, which is dominated by soil group C. Slopes in the Van Nostrand Lake watershed are relatively gradual, with no subwatershed featuring an average slope of 10% or over, and a maximum slope (occurring in the Northeast subwatershed) of approximately 25%.

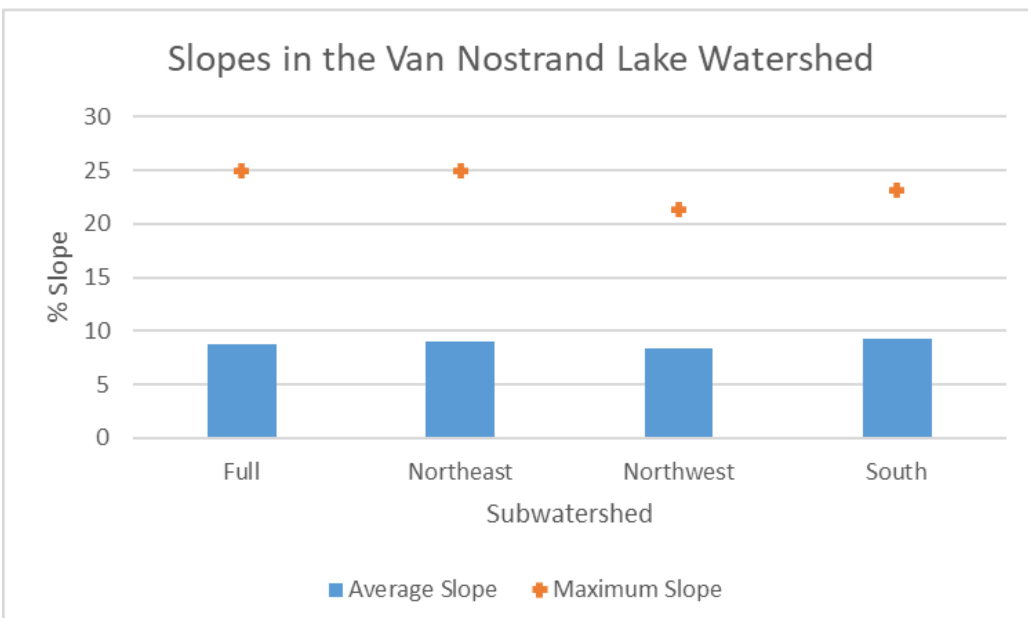


Figure 92. Variation in average and maximum percent slope between subwatersheds in the Van Nostrand Lake watershed.

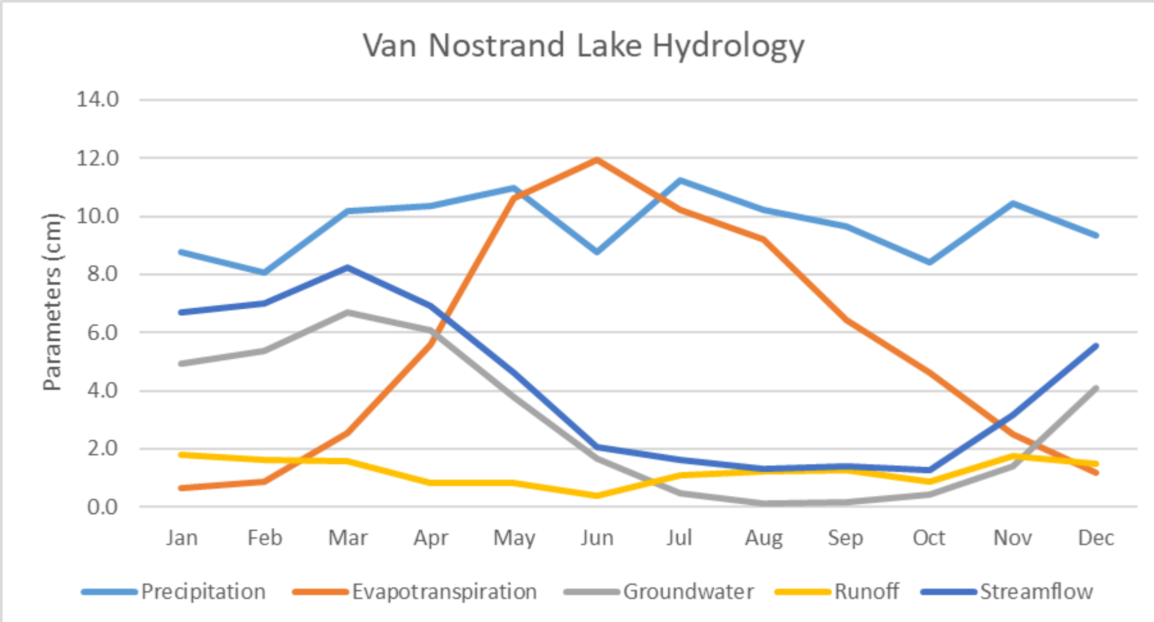


Figure 93. Estimated seasonal changes in hydrology in the Van Nostrand Lake watershed

Table 212. Total hydrological parameters in the full Van Nostrand Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.6	4.9	1.8	6.7	0.2
Feb	8.0	0.9	5.4	1.6	7.0	0.2
Mar	10.2	2.5	6.7	1.6	8.2	0.2
Apr	10.4	5.6	6.1	0.8	6.9	0.2
May	11.0	10.6	3.8	0.8	4.6	0.1
Jun	8.8	11.9	1.7	0.4	2.1	0.1
Jul	11.2	10.2	0.5	1.1	1.6	0.0
Aug	10.2	9.2	0.1	1.2	1.3	0.0
Sep	9.7	6.4	0.1	1.3	1.4	0.0
Oct	8.4	4.6	0.4	0.9	1.3	0.0
Nov	10.4	2.5	1.4	1.7	3.1	0.1
Dec	9.3	1.2	4.1	1.5	5.6	0.1
Total	116.4	66.4	35.1	14.7	49.8	0.1

The South and Northeastern subwatersheds are estimated to yield the highest runoff during an average year. This may be in part due to these two subwatersheds' higher percentages of very slow infiltration soil groups. When direct precipitation and evapotranspiration to the lake itself are considered, Van Nostrand Lake is estimated to receive approximately 114,309 m³ or 30.2 million gallons of water each year.

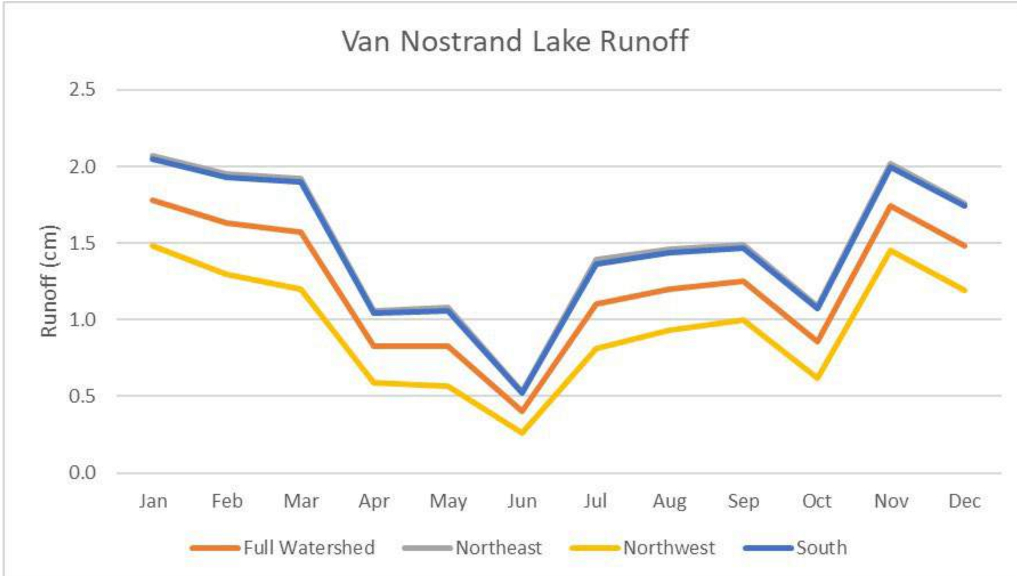


Figure94. Average monthly runoff occurring in each subwatershed in the Van Nostrand Lake watershed

As no bathymetric data for Van Nostrand Lake was available, the lake's volume was estimated using depths collected in the field to be approximately 47,149 m³ or 12.5 million gallons of water. Using this and the estimated annual hydraulic load, Van Nostrand Lake is estimated to flush completely approximately 2.4 times a year, with a hydraulic retention time of approximately 150.6 days. When examined on a monthly basis, the lake's annualized flushing rate is estimated to be at its lowest during the month of June.

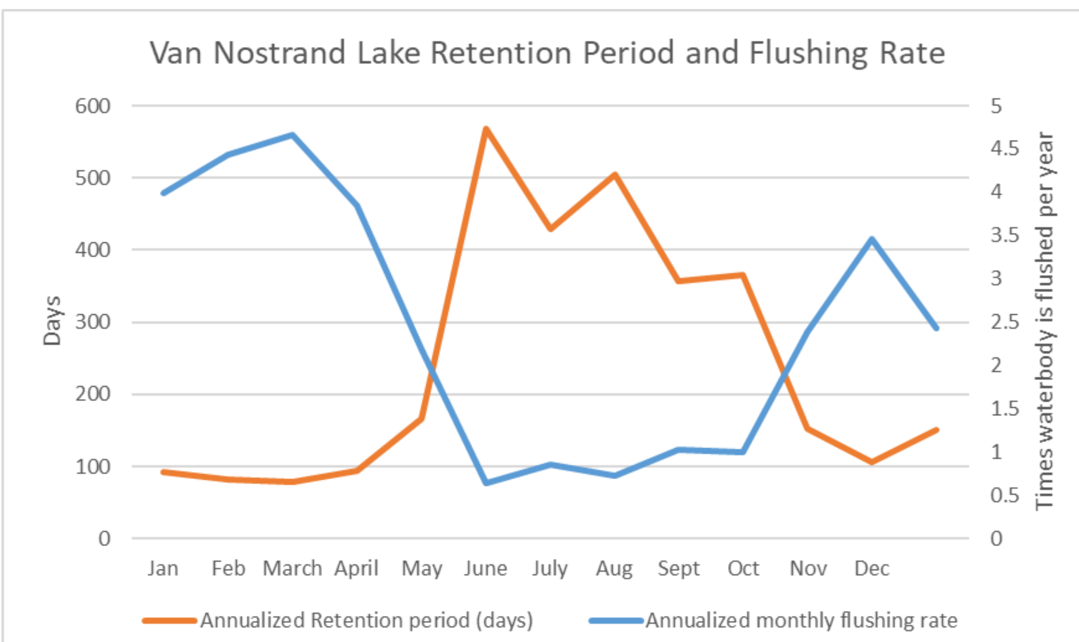


Figure 95. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Van Nostrand Lake, based on variations in hydraulic loads.

Table 213. Estimated annual loads of nitrogen in the total Van Nostrand Lake watershed

Category	Description	Total Nitrogen	
		kg	%
Runoff	Hay/Pasture	0.0	0.00
	Cropland	0.0	0.00
	Forest	3.9	9.76
	Wetland	1.38	3.45
	Open Land	0.0	0.00
	Barren Land	0.0	0.00
	Low-Density Mixed	0.0	0.00
	Medium-Density Mixed	0.0	0.00
	High-Density Mixed	0.0	0.00
	Low-Density Open Space	0.1	0.18
Other Sources	Farm Animals and Waterfowl	0.1	0.19
	Stream Bank	0.0	0.00
	Groundwater	22.3	55.87
	Dryfall	9.0	22.57
	Septic Systems	3.2	7.97
	Total	39.9	100

Table 214. Estimated annual loads of nitrogen by subwatershed in the Van Nostrand Lake watershed

Category	Description	Full Watershed	Northeast	Northwest	South
		kg	kg	kg	kg
Runoff	Hay/Pasture	0.0	0.0	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0
	Forest	3.9	1.7	1.4	1.1
	Wetland	1.4	0.9	0.0	0.5
	Open Land	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0
	Low-Density Mixed	0.0	0.0	0.0	0.0
	Medium-Density Mixed	0.0	0.0	0.0	0.0
	High-Density Mixed	0.0	0.0	0.0	0.0
	Low-Density Open Space	0.1	0.0	0.1	0.0
Other Sources	Farm Animals and Waterfowl	0.1	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0
	Groundwater	22.3	8.1	8.6	5.3
	Dryfall	9.0	.	.	.
	Septic Systems	3.2	0.0	3.2	0.0
	Total (kg)	39.9	10.7	13.2	7.0
	kg/acre	0.9	0.6	0.8	0.6

The estimated annual nitrogen load for Van Nostrand Lake is dominated by nitrogen originating from dryfall and groundwater. Runoff-based nitrogen loads largely originated from forested land. Unlike many of the other waterbodies in this study, septic-based nitrogen, while notable, was not as large of a contributor to the overall load, as only one septic system exists within the watershed. The largest annual load and the largest load per acre were estimated to originate from the Northwest subwatershed

Table 215. Estimated annual loads of phosphorus in the total Van Nostrand Lake watershed

Category	Description	Total Phosphorus kg	Total Phosphorus %
Runoff	Hay/Pasture	0.00	0.0
	Cropland	0.00	0.0
	Forest	0.26	26.0
	Wetland	0.08	8.0
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.00	0.0
	Medium-Density Mixed	0.00	0.0
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.01	1.0
Other Sources	Farm Animals and Waterfowl	0.03	2.7
	Stream Bank	0.00	0.0
	Groundwater	0.58	57.9
	Dryfall	0.05	4.5
	Septic Systems	0.00	0.0
	Total	1.00	100.0

Table 216. Estimated annual loads of phosphorus by subwatershed in the Van Nostrand Lake watershed

Category	Description	Full Watershed kg	Northeast kg	Northwest kg	South kg
Runoff	Hay/Pasture	0.00	0.00	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00
	Forest	0.26	0.12	0.09	0.07
	Wetland	0.08	0.05	0.00	0.03
	Open Land	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.00	0.00	0.00	0.00
	Medium-Density Mixed	0.00	0.00	0.00	0.00
	High-Density Mixed	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.01	0.00	0.01	0.00
Other Sources	Farm Animals and Waterfowl	0.03	0.00	0.00	0.00
	Stream Bank	0.00	0.21	0.00	0.00
	Groundwater	0.58	0.00	0.22	0.14
	Dryfall	0.05	.	.	.
	Septic Systems	0.00	0.00	0.00	0.00
	Total (kg)	1.00	0.38	0.32	0.24
	kg/acre	0.02	0.02	0.02	0.02

Van Nostrand's watershed-based annual phosphorus load is estimated to be relatively low at only 1.00 kg/yr, or 0.02 kg/acre. A majority of phosphorus is estimated to originate from groundwater, although the runoff-based phosphorus load from forested areas is also notable. The Northeast subwatershed is estimated to yield the highest overall phosphorus load of the three subwatersheds, and no one subwatershed produced a higher load per acre than the other two, with all yielding only 0.02 kg/acre.

The water column in Van Nostrand Lake was measured to be anoxic below 1 meter during the July event. Discrete water quality samples, however, did not indicate a difference in total phosphorus concentrations between the top and the bottom of the water column. The internal phosphorus load was therefore modeled only using the oxic loading coefficient, yielding an estimated internal phosphorus load of 3.90 kg/yr.

Table 217 displays the external and internal loads of phosphorus for Van Nostrand Lake, as well as the grand total, which is estimated to be approximately 4.90 kg/year. The lake's internal load was modeled to be the largest driver of phosphorus loading, contributing to approximately 80% of the total annual load.

Table 217. Total estimated annual phosphorus loads for Van Nostrand Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	1.00
Internal	3.90
Total	**4.90**

Table 218. Estimated annual loads of sediment in the total Van Nostrand Lake watershed

Category	Description	Sediment kgx1000	Sediment %
Runoff	Hay/Pasture	0.000	0.0
	Cropland	0.000	0.0
	Forest	0.060	85.7
	Wetland	0.010	14.3
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.000	0.0
	Medium-Density Mixed	0.000	0.0
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.000	0.0
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.000	0.0
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	0.070	100.0

Van Nostrand Lake is estimated to receive a relatively small annual sediment load, at only approximately 70 kg/year. This load was dominated by sediment originating as runoff from forested land. The Northeast and Northwest subwatersheds were estimated to yield the highest overall annual sediment loads, while the Northwest subwatershed yielded the largest load per acre.

Table 219. Estimated annual loads of sediment by subwatershed in the Van Nostrand Lake watershed

Category	Description	Full Watershed kg x 1000	Northeast kg x 1000	Northwest kg x 1000	South kg x 1000
Runoff	Hay/Pasture	0.000	0.000	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000
	Forest	0.060	0.020	0.020	0.010
	Wetland	0.010	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.000	0.000	0.000	0.000
	Medium-Density Mixed	0.000	0.000	0.000	0.000
	High-Density Mixed	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.000	0.000	0.000	0.000
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000
	Stream Bank	0.000	0.000	0.000	0.000
	Groundwater	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000
	Total (kgx1000)	0.070	0.020	0.020	0.010
	kg/acre	1.515	1.064	1.290	0.826

Table 220. Estimated annual loads of bacteria in the total Van Nostrand Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	3.60E+07	0.3
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.42E+07	0.2
	Other Wildlife	1.42E+10	99.6
	Total	1.43E+10	100

Van Nostrand Lake's total estimated annual load of bacteria is modeled to originate largely from wildlife in forested areas. The Northeastern subwatershed yielded the highest bacterial load of the three subwatersheds.

Table 221. Estimated annual bacterial loads by subwatershed in the Van Nostrand Lake watershed

Category	Description	Full Watershed %	Northeast %	Northwest %	South %
Fecal Coliform	Farm Animals	0.3	0.0	0.0	0.0
	WWTP	0.0	0.0	0.0	0.0
	Septic Systems	0.0	0.0	0.0	0.0
	Urban Areas	0.2	0.0	1.3	0.0
	Wildlife	99.6	1.0	98.7	1.0
	Total (organisms)	1.43E+10	5.38E+09	5.36E+09	3.53E+09

WONDER LAKE

Wonder Lake's watershed covers an area of approximately 133.8 acres, while the lake itself features a surface area of approximately 13.7 acres. The watershed is mostly forested with 37.7 acres of urbanized land also present. The lake's inlet, Matthews Brook, enters Wonder Lake at its northern end. The lake features an earthen dam along its eastern shoreline and features two outlet streams; these shortly join each other, flowing east into Butler Reservoir. Descriptions of the lake's subwatersheds are as follows:

- **Matthews Brook:** This is the largest of Wonder Lake's subwatersheds at approximately 94 acres. The area contains the lake's inlet stream, as well as a length of Germantown Rd. and a portion of the development to the immediate west of the lake. The area is mostly forested, with some urbanized areas also making up a notable portion of the subwatershed.
- **Northeast:** This is the smallest of Wonder Lake's subwatersheds at approximately 19.3 acres. The area is entirely forested.
- **South:** This approximately 20.5-acre subwatershed contains most of the lake's earthen dam, as well as the southern portion of the development to the west of the lake. This subwatershed is classified as over 75% urbanized.

Table 222. Land-use by subwatershed in the Wonder Lake watershed.

Source	Full Watershed	Matthews Brook	Northeast	South
	Area (acres)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.5	0.5	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	91.4	69.7	19.3	2.7
Wetland	4.2	2.2	0.0	2.0
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	9.1	3.7	0.0	5.2
Medium-Density Mixed	2.7	0.5	0.0	2.2
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	25.9	17.5	0.0	8.4
Total	133.8	94.1	19.3	20.5

Table 222 continued. Land-use by subwatershed in the Wonder Lake watershed.

Source	Full Watershed	Matthews Brook	Northeast	South
	Area (%)			
Open Water	0.0	0.0	0.0	0.0
Hay/Pasture	0.4	0.5	0.0	0.0
Cropland	0.0	0.0	0.0	0.0
Forest	68.3	74.1	100.0	13.2
Wetland	3.1	2.3	0.0	9.8
Open Land	0.0	0.0	0.0	0.0
Barren Land	0.0	0.0	0.0	0.0
Low-Density Mixed	6.8	3.9	0.0	25.4
Medium-Density Mixed	2.0	0.5	0.0	10.7
High-Density Mixed	0.0	0.0	0.0	0.0
Low-Density Open Space	19.4	18.6	0.0	41.0
Total	100	100	100	100

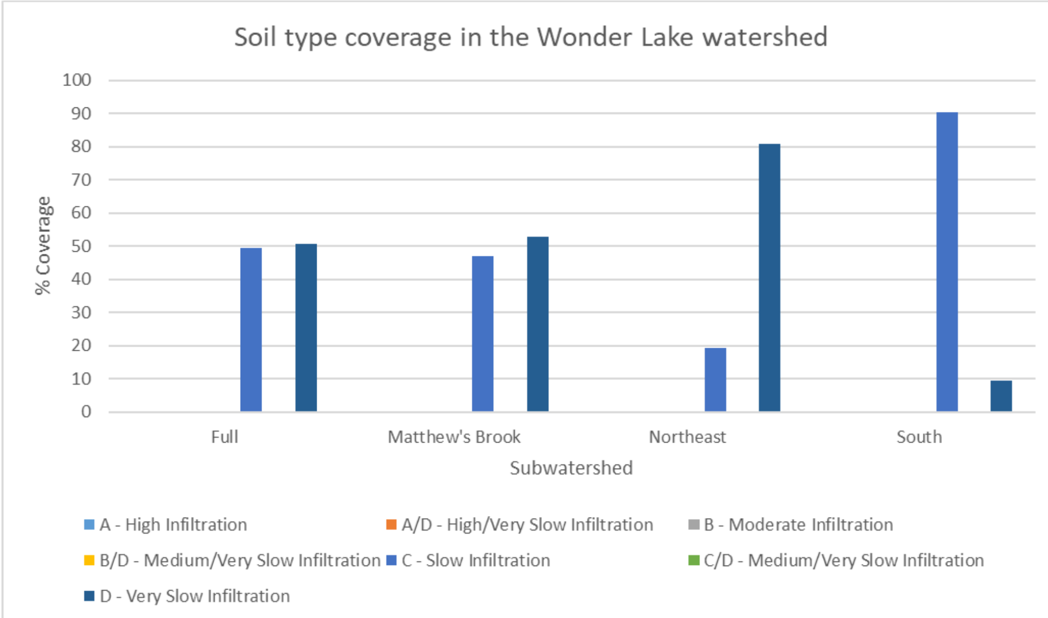


Figure 96. Percent coverage of Wonder Lake watershed and subwatersheds by different hydrologic soil groups.

Wonder Lake's full watershed features almost equal coverage of soil groups C and D. The Northeast subwatershed in particular is dominated with soil group D, suggesting that this subwatershed may yield increased amounts of runoff, based on soils alone. The full watershed features an average slope of approximately 14%, with a maximum slope of approximately 44% located in the Matthew's Brook Watershed. The Northeast subwatershed features a notably higher average slope than the other subwatersheds at approximately 21%.

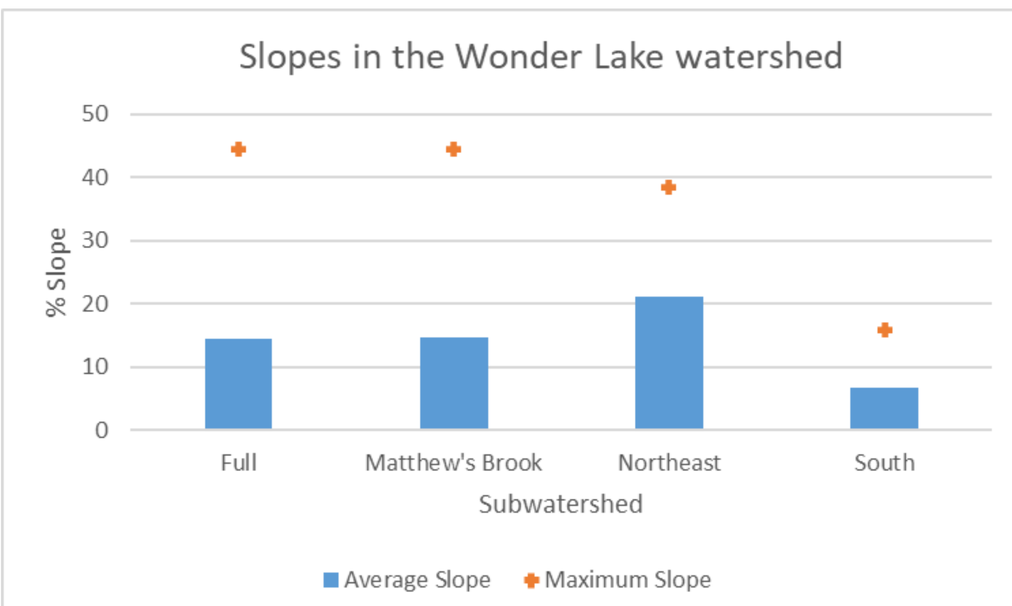


Figure 97. Variation in average and maximum percent slope between subwatersheds in the Wonder Lake watershed.

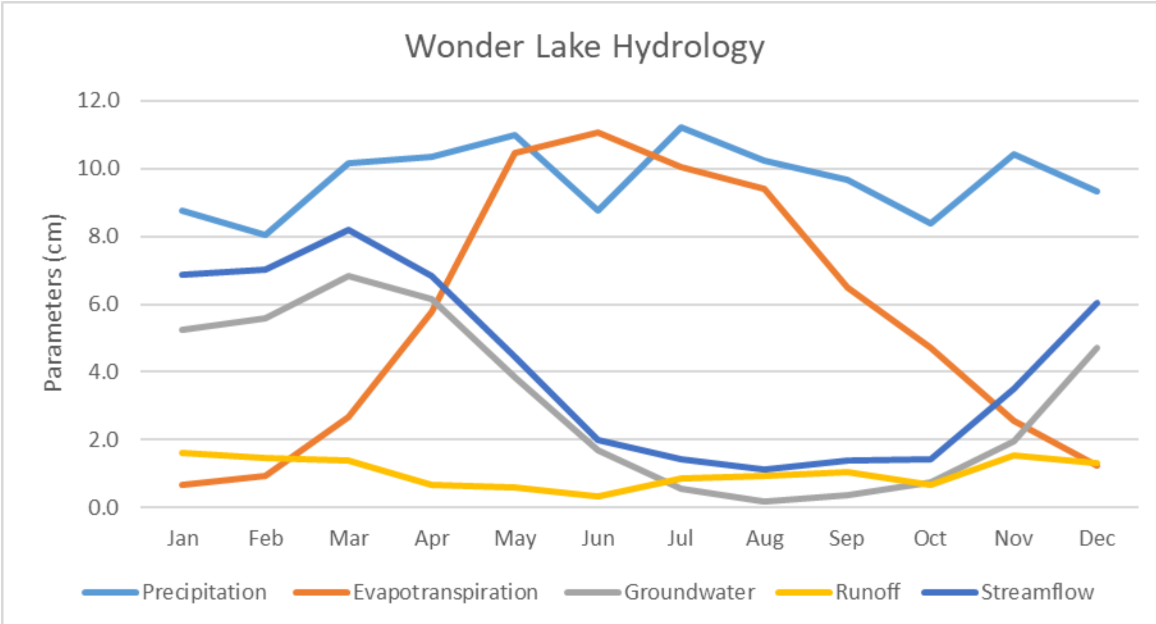


Figure 98. Estimated seasonal changes in hydrology in the Wonder Lake watershed

Table 223. Total hydrological parameters in the full Wonder Lake watershed

Month	Precipitation	Evapotranspiration	Groundwater	Runoff	Streamflow	
	cm	cm	cm	cm	cm	cfs
Jan	8.8	0.7	5.3	1.6	6.9	0.5
Feb	8.0	0.9	5.6	1.5	7.0	0.6
Mar	10.2	2.7	6.8	1.4	8.2	0.6
Apr	10.4	5.8	6.2	0.7	6.8	0.5
May	11.0	10.5	3.8	0.6	4.4	0.3
Jun	8.8	11.1	1.7	0.3	2.0	0.1
Jul	11.2	10.1	0.6	0.9	1.4	0.1
Aug	10.2	9.4	0.2	1.0	1.1	0.1
Sep	9.7	6.5	0.4	1.0	1.4	0.1
Oct	8.4	4.7	0.8	0.7	1.4	0.1
Nov	10.4	2.6	2.0	1.6	3.5	0.3
Dec	9.3	1.2	4.7	1.3	6.1	0.4
Total	116.4	66.0	37.9	12.4	50.4	0.3

Wonder Lake's subwatersheds display an approximately 37% maximum difference in regard to runoff over the course of an average year. The South subwatershed typically yields the highest runoff, although it should be noted that the Northeast subwatershed sometimes surpasses it, particularly during the late summer. When direct precipitation and evapotranspiration to the lake itself are considered, Wonder Lake is estimated to receive approximately 300,541 m³ or 79.4 million gallons of water each year.

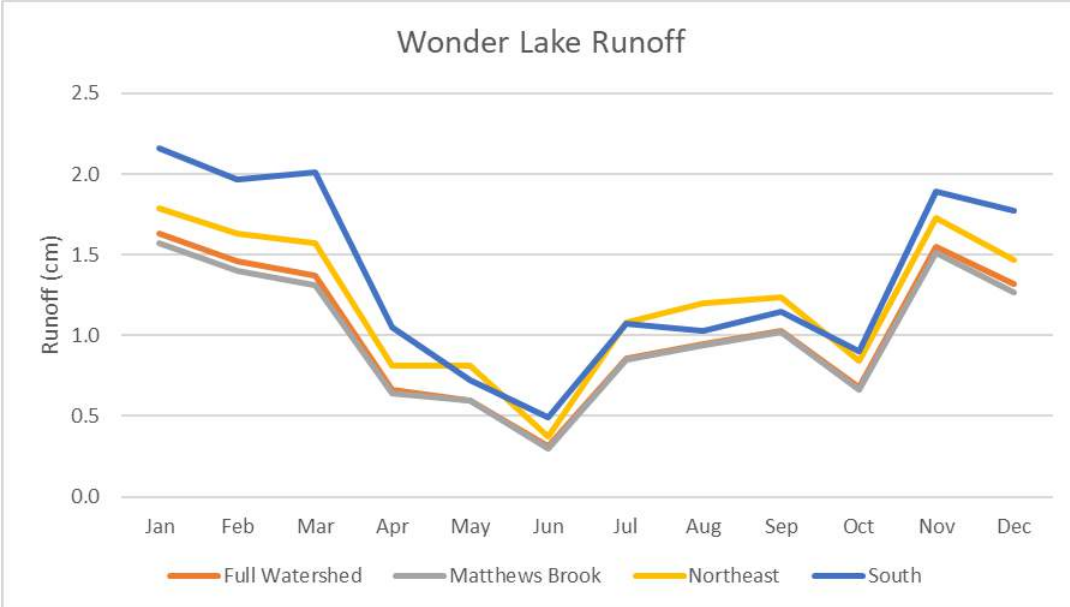


Figure 991. Average monthly runoff occurring in each subwatershed in the Wonder Lake watershed

As no bathymetric data for Wonder Lake was available, the lake's volume was estimated using depths collected in the field to be approximately 48,514 m³ or 12.8 million gallons of water. Using this and the estimated annual hydraulic load, Wonder Lake is estimated to flush completely approximately 6.2 times a year, with a hydraulic retention time of approximately 59 days. When examined on a monthly basis, the lake's annualized flushing rate is estimated to be at its lowest during the month of August.

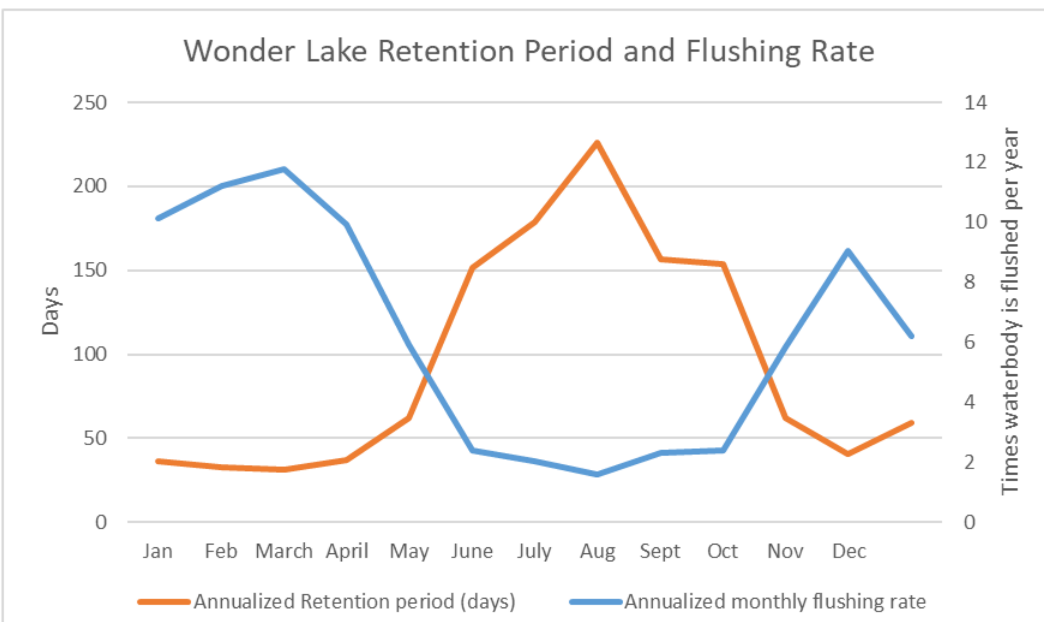


Figure 100. Variations in annualized flushing rates and retention periods over the course of a hypothetical year for Wonder Lake, based on variations in hydraulic loads.

Table 224. Estimated annual loads of nitrogen in the total Wonder Lake watershed

Category	Description	Total Nitrogen kg	Total Nitrogen %
Runoff	Hay/Pasture	0.2	0.1
	Cropland	0.0	0.0
	Forest	8.5	2.5
	Wetland	0.8	0.2
	Open Land	0.0	0.0
	Barren Land	0.0	0.0
	Low-Density Mixed	1.2	0.3
	Medium-Density Mixed	1.7	0.5
	High-Density Mixed	0.0	0.0
	Low-Density Open Space	3.3	1.0
Other Sources	Farm Animals and Waterfowl	0.7	0.2
	Stream Bank	0.0	0.0
	Groundwater	69.9	20.6
	Dryfall	23.9	.
	Septic Systems	229.3	67.6
	Total	339.3	100

Table 225. Estimated annual loads of nitrogen by subwatershed in the Wonder Lake watershed

Category	Description	Full Watershed kg	Matthews Brook kg	Northeast kg	South kg
Runoff	Hay/Pasture	0.2	0.2	0.0	0.0
	Cropland	0.0	0.0	0.0	0.0
	Forest	8.5	6.4	2.3	0.2
	Wetland	0.8	0.5	0.0	0.4
	Open Land	0.0	0.0	0.0	0.0
	Barren Land	0.0	0.0	0.0	0.0
	Low-Density Mixed	1.2	0.4	0.0	0.9
	Medium-Density Mixed	1.7	0.3	0.0	1.1
	High-Density Mixed	0.0	0.0	0.0	0.0
	Low-Density Open Space	3.3	2.0	0.0	1.4
Other Sources	Farm Animals and Waterfowl	0.7	0.0	0.0	0.0
	Stream Bank	0.0	0.0	0.0	0.0
	Groundwater	69.9	49.4	9.9	9.9
	Dryfall	23.9	.	.	.
	Septic Systems	229.3	116.3	0.0	119.4
	Total (kg)	339.3	175.6	12.2	133.3
	kg/acre	2.5	1.9	0.6	6.5

The estimated annual nitrogen load for Wonder Lake is dominated by nitrogen originating from septic systems, groundwater, and dryfall. Runoff-based nitrogen loads largely were estimated to originate from forested land, although urbanized landcover was also estimated to yield a notable annual load. The largest annual load was estimated to originate from the Matthews Brook subwatershed, while the South subwatershed yielded the highest load per acre.

Table 226. Estimated annual loads of phosphorus in the total Wonder Lake watershed

Category	Description	Total Phosphorus	
		kg	%
Runoff	Hay/Pasture	0.09	0.9
	Cropland	0.00	0.0
	Forest	0.65	6.8
	Wetland	0.05	0.5
	Open Land	0.00	0.0
	Barren Land	0.00	0.0
	Low-Density Mixed	0.12	1.3
	Medium-Density Mixed	0.17	1.8
	High-Density Mixed	0.00	0.0
	Low-Density Open Space	0.35	3.7
Other Sources	Farm Animals and Waterfowl	0.24	2.5
	Stream Bank	0.00	0.0
	Groundwater	1.83	19.3
	Dryfall	0.12	1.3
	Septic Systems	5.88	61.9
	Total	9.50	100.0

Table 227. Estimated annual loads of phosphorus by subwatershed in the Wonder Lake watershed

Category	Description	Full Watershed	Matthews Brook	Northeast	South
		kg	kg	kg	kg
Runoff	Hay/Pasture	0.09	0.09	0.00	0.00
	Cropland	0.00	0.00	0.00	0.00
	Forest	0.65	0.49	0.21	0.01
	Wetland	0.05	0.03	0.00	0.02
	Open Land	0.00	0.00	0.00	0.00
	Barren Land	0.00	0.00	0.00	0.00
	Low-Density Mixed	0.12	0.05	0.00	0.09
	Medium-Density Mixed	0.17	0.03	0.00	0.11
	High-Density Mixed	0.00	0.00	0.00	0.00
	Low-Density Open Space	0.35	0.22	0.00	0.15
Other Sources	Farm Animals and Waterfowl	0.24	0.00	0.00	0.00
	Stream Bank	0.00	0.00	0.00	0.00
	Groundwater	1.83	1.29	0.26	0.29
	Dryfall	0.12	.	.	.
	Septic Systems	5.88	3.36	0.00	5.04
	Total (kg)	9.50	5.56	0.47	5.71
	kg/acre	0.07	0.06	0.02	0.28

Wonder Lake's watershed-based annual phosphorus load is estimated to largely originate from septic systems and groundwater. Runoff-based phosphorus loading is modeled to originate mostly from forested land and low-density open space. The Southern subwatershed is estimated to yield the highest overall phosphorus load of the three subwatersheds and the highest load per acre.

Wonder Lake was observed to feature anoxia during the summer of 2022, with the mid-lake station featuring oxygen concentrations less than 1 mg/L throughout the entire water column. This may be in part due to the lake's high coverage with water lilies (*Nymphaea odorata*) and other plants, which may result in reduced atmospheric mixing of oxygen into the water column. A higher concentration of total phosphorus was detected in the bottom sample than in the surface sample during this event, however this difference was not as great as might be expected for anoxia in the full water column. When modeling the lake's internal load, it was assumed that most of the increased anoxic loading typically occurred at and below 1 meter in depth for one month out of the year. Taking into account the areas of reduced loading outside of this depth and during the rest of the growing season, Wonder Lake's annual internal load was estimated to be approximately 8.82 kg. During a hypothetical season where the water column did not feature any anoxic loading, the lake's estimated internal load would be 5.10 kg.

Table 228 below displays the external and internal loads of phosphorus for Wonder Lake, as well as the grand total, which is estimated to be approximately 18.32 kg/year. The lake's external load was modeled to be the larger driver of phosphorus loading, contributing to approximately 52% of the total annual load.

Table 228. Total estimated annual phosphorus loads for Wonder Lake from external and internal sources

Source	Phosphorus (kg/yr)
External (Runoff, Groundwater, Septic Systems)	9.50
Internal	8.82
Total	**18.32**

Table 229. Estimated annual loads of sediment in the total Wonder Lake watershed

Category	Description	Sediment	
		kgx1000	%
Runoff	Hay/Pasture	0.010	0.8
	Cropland	0.000	0.0
	Forest	0.200	15.1
	Wetland	0.010	0.8
	Open Land	0.000	0.0
	Barren Land	0.000	0.0
	Low-Density Mixed	0.050	3.8
	Medium-Density Mixed	0.100	7.5
	High-Density Mixed	0.000	0.0
	Low-Density Open Space	0.140	10.5
Other Sources	Farm Animals and Waterfowl	0.000	0.0
	Stream Bank	0.818	61.6
	Groundwater	0.000	0.0
	Septic Systems	0.000	0.0
	Total	1.328	100.0

Wonder Lake is estimated to receive a majority of its estimated annual sediment load as streambank erosion, with runoff from forested land and low-density urban open space also being a notable contributor. The Matthews Brook subwatershed was estimated to yield the highest overall annual sediment load, while the South subwatershed was estimated to yield the largest load per acre.

Table 230. Estimated annual loads of sediment by subwatershed in the Wonder Lake watershed

Category	Description	Full Watershed kg x 1000	Matthews Brook kg x 1000	Northeast kg x 1000	South kg x 1000
Runoff	Hay/Pasture	0.010	0.010	0.000	0.000
	Cropland	0.000	0.000	0.000	0.000
	Forest	0.200	0.150	0.080	0.000
	Wetland	0.010	0.000	0.000	0.000
	Open Land	0.000	0.000	0.000	0.000
	Barren Land	0.000	0.000	0.000	0.000
	Low-Density Mixed	0.050	0.020	0.000	0.030
	Medium-Density Mixed	0.100	0.020	0.000	0.070
	High-Density Mixed	0.000	0.000	0.000	0.000
	Low-Density Open Space	0.140	0.090	0.000	0.060
Other Sources	Farm Animals and Waterfowl	0.000	0.000	0.000	0.000
	Stream Bank	0.818	0.500	0.000	0.060
	Groundwater	0.000	0.000	0.000	0.000
	Septic Systems	0.000	0.000	0.000	0.000
	Total (kgx1000)	1.328	0.790	0.080	0.220
	kg/acre	9.925	8.395	4.145	10.732

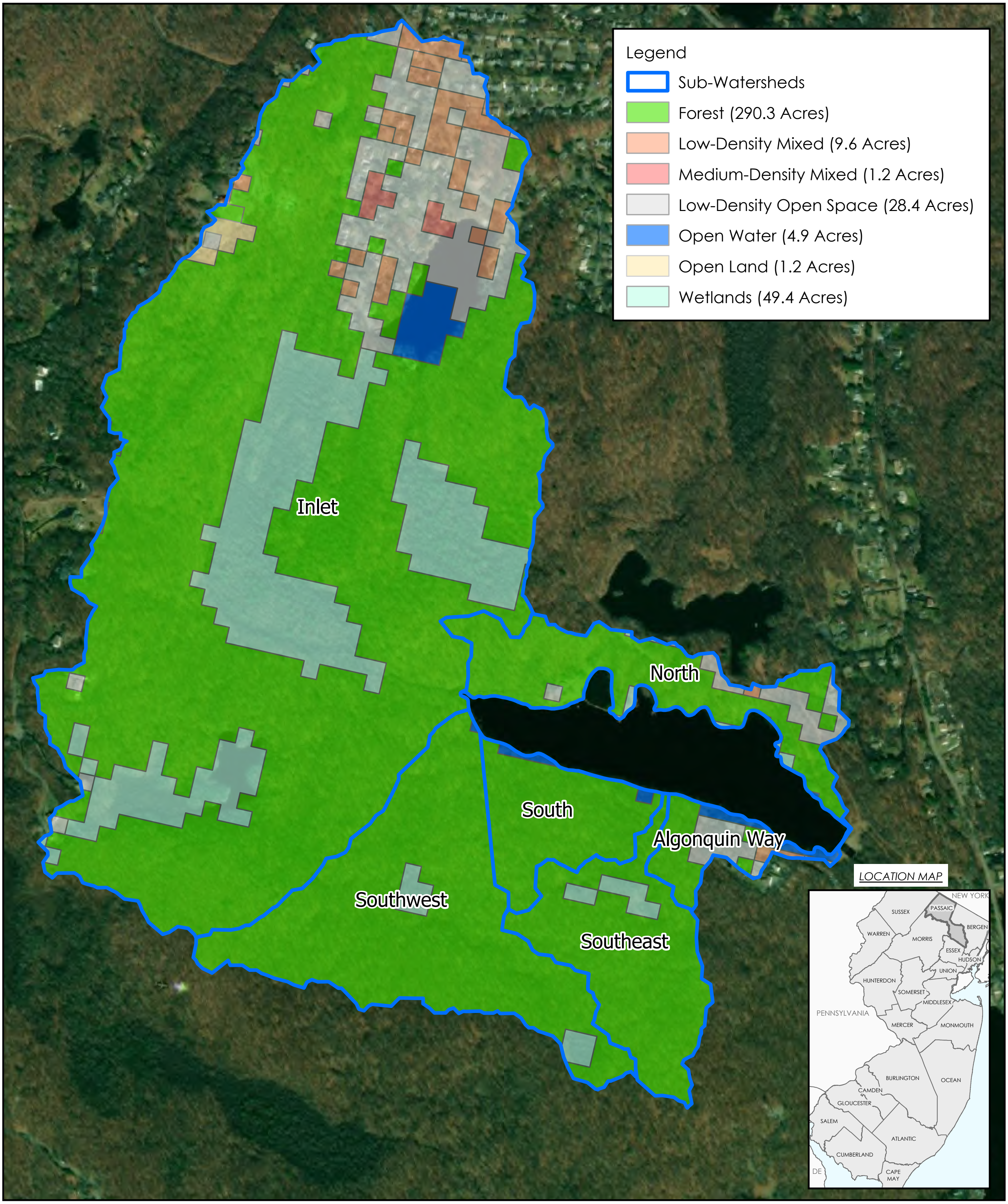
Table 231. Estimated annual loads of bacteria in the total Wonder Lake watershed

Category	Description	Fecal Coliform Organisms	%
Fecal Coliform	Farm Animals and Waterfowl	3.24E+08	0.5
	WWTP	0.00E+00	0.0
	Septic Systems	0.00E+00	0.0
	Urban Areas	2.79E+10	45.9
	Other Wildlife	3.26E+10	53.6
	Total	6.08E+10	100

Wonder Lake's total estimated annual load of bacteria is modeled to originate largely from wildlife in forested areas and from urban areas. The South subwatershed yielded the highest bacterial load of the three subwatersheds.

Table 232. Estimated annual bacterial loads by subwatershed in the Wonder Lake watershed

Category	Description	Full Watershed	Matthews Brook	Northeast	South
		%	%	%	%
Fecal Coliform	Farm Animals and Waterfowl	0.5	0.0	0.0	0.0
	WWTP	0.0	0.0	0.0	0.0
	Septic Systems	0.0	0.0	0.0	0.0
	Urban Areas	45.9	32.1	0.0	97.6
	Other Wildlife	53.6	67.9	100	2.4
	Total (organisms)	6.08E+10	3.66E+10	6.87E+09	3.99E+10



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NOTES:

Sub-watersheds and 2019 NLCD data mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro. NLCD acres totals listed here.

Acres listed are totals for the entire watershed, not sub-watersheds

0 800 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

ALGONQUIN WATERS
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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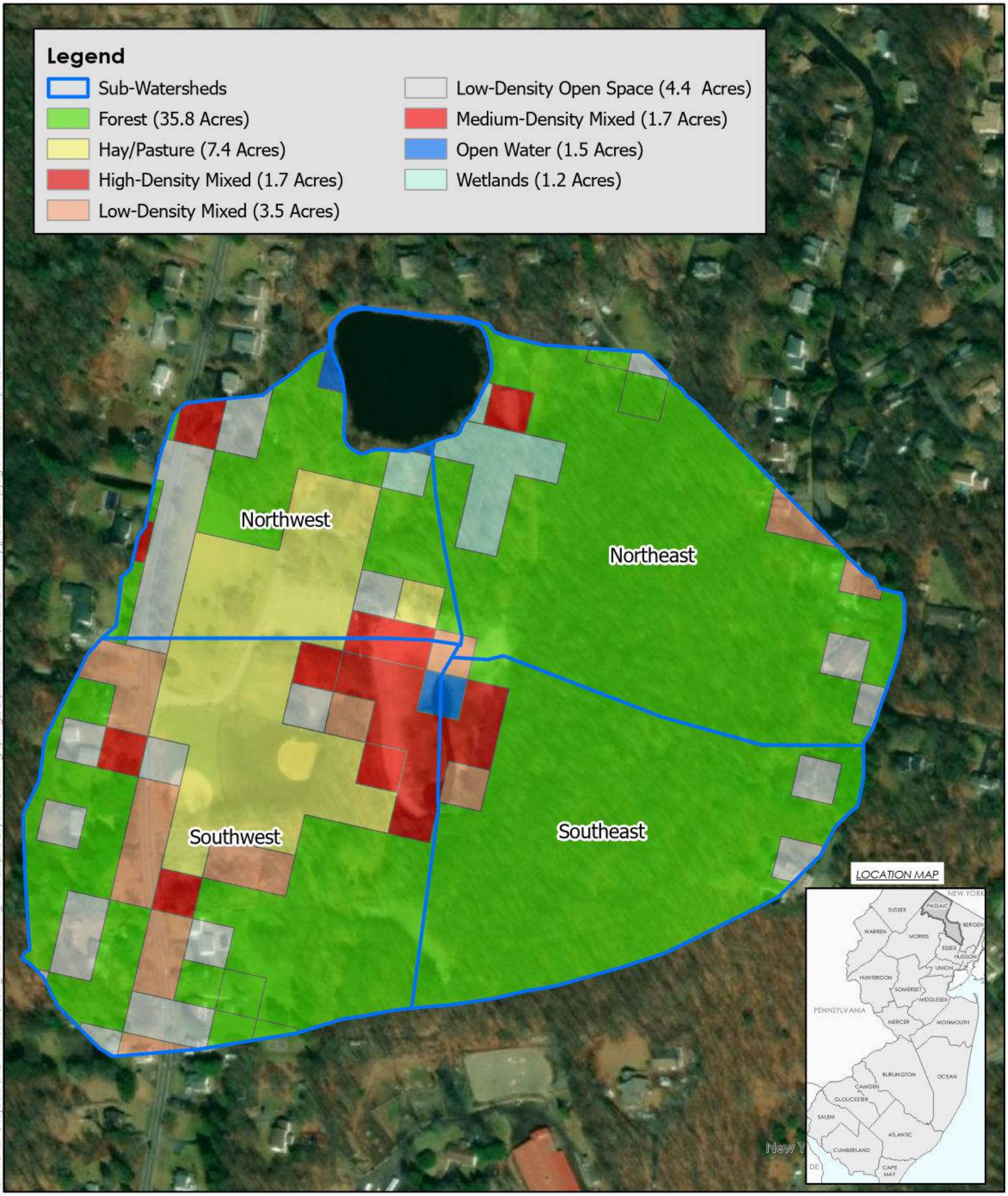

NOTES:

Sub-watersheds and 2019 NLCD data mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro. NLCD acre totals listed here.

Acres listed are totals for the entire watershed, not sub-watersheds

0 300 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

BUBBLING SPRINGS POND

WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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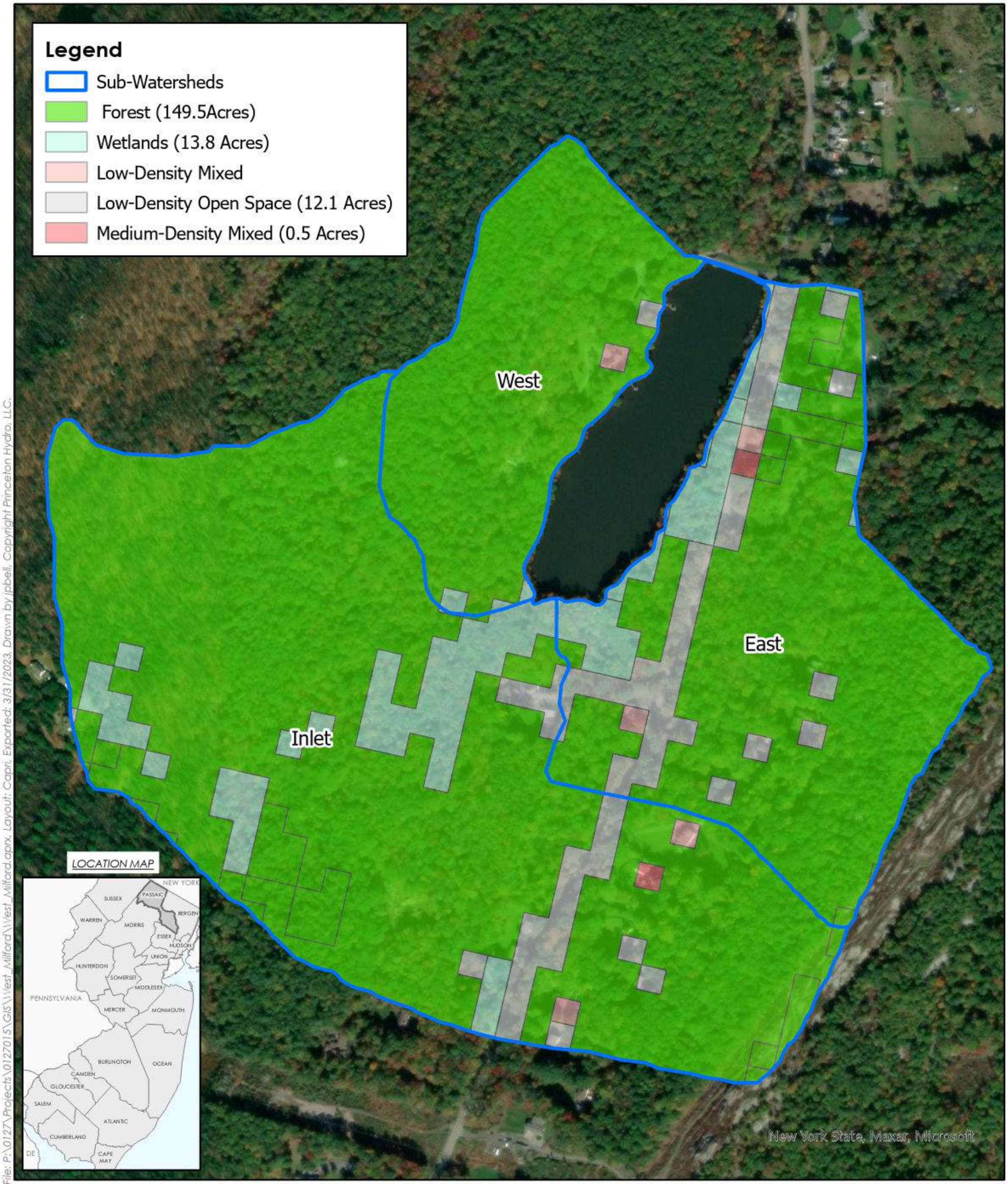

NOTES:

Sub-watersheds and 2019 NLCD data mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro. NLCD acre totals listed here.

Acres listed are totals for the entire watershed, not sub-watersheds

0 250 500 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

CAPRI LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

PRINCETON HYDRO
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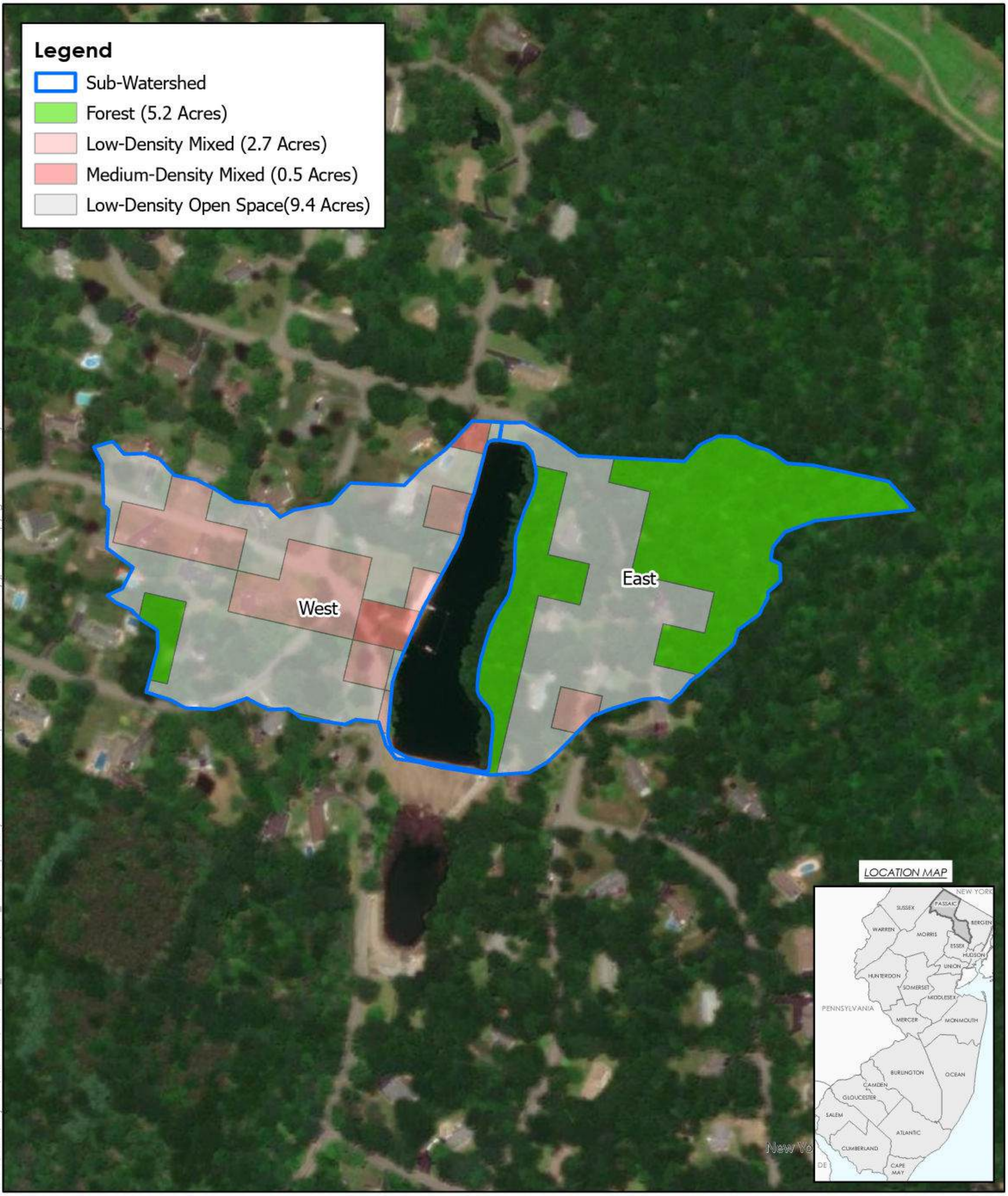

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NOTES:

Sub-watersheds and 2019 NLCD data mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro. NLCD acre totals listed here.

Acres listed are totals for the entire watershed, not sub-watersheds

0 150 300 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

FARMCREST ACRES POND
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

PRINCETON HYDRO
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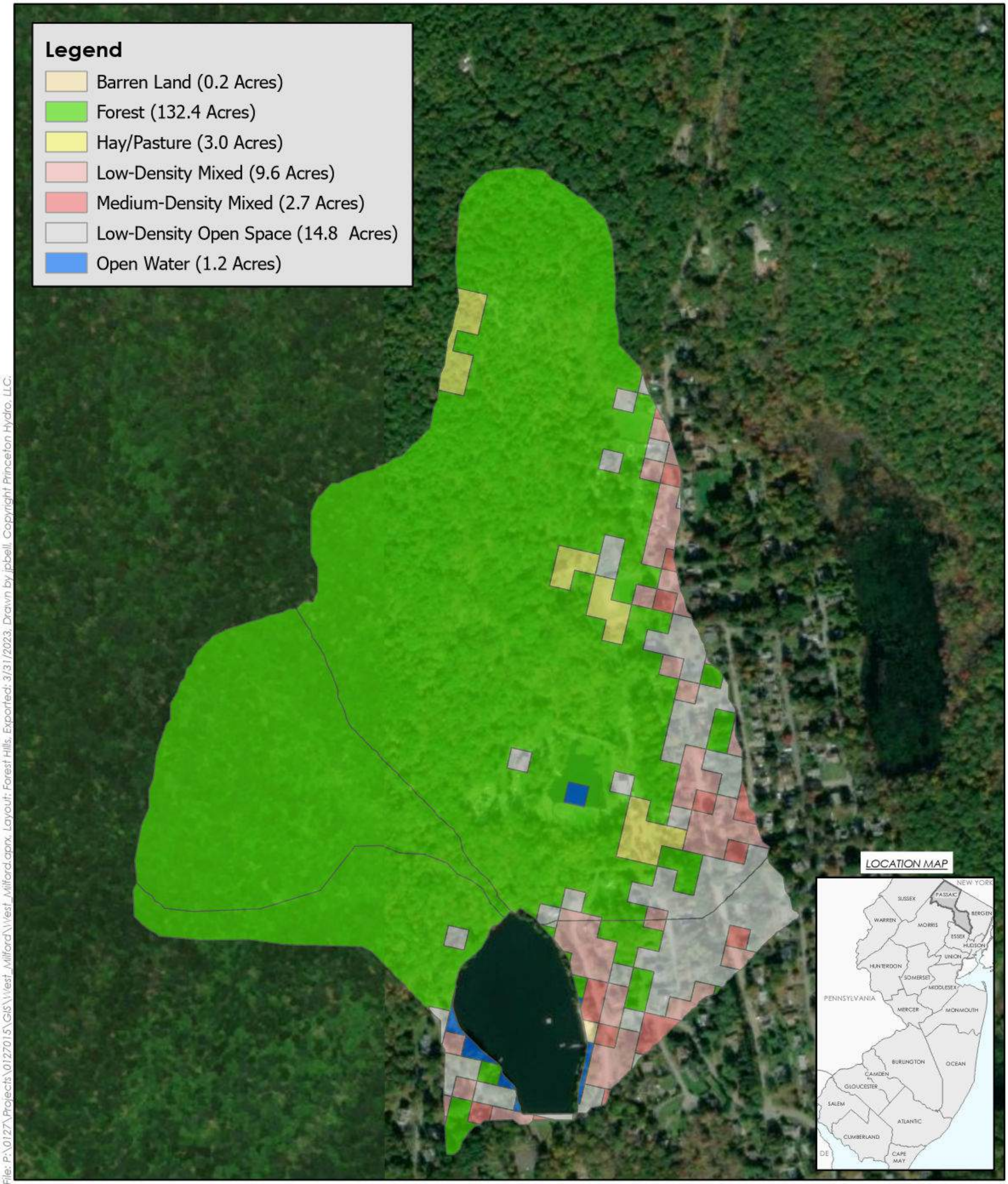

NOTES:

Sub-watersheds and 2019 NLCD data mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro. NLCD acre totals listed here.

Acres listed are totals for the entire watershed, not sub-watersheds

0 300 600 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

FOREST HILL LAKE

WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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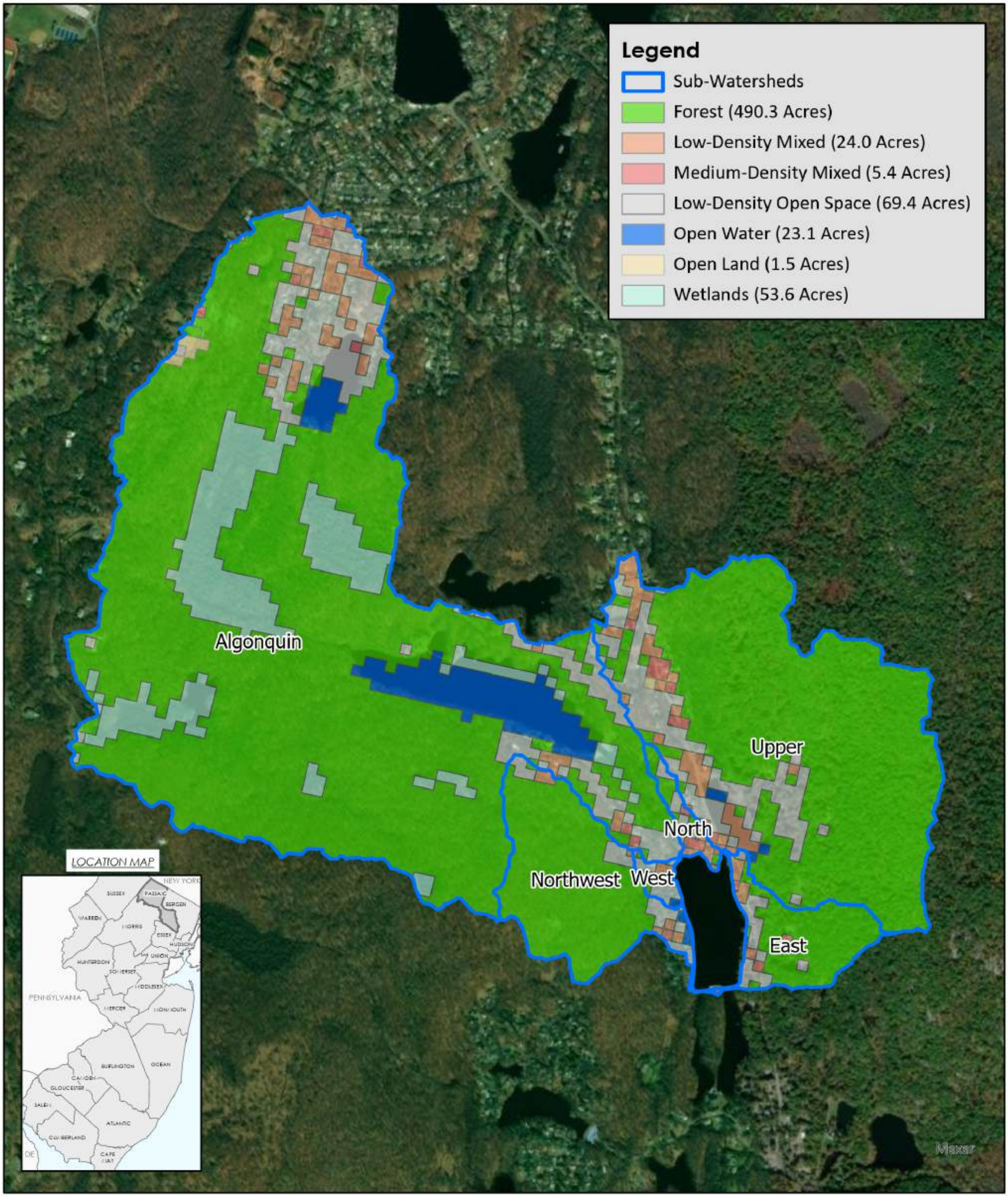

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 600 1,200 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

GORDON LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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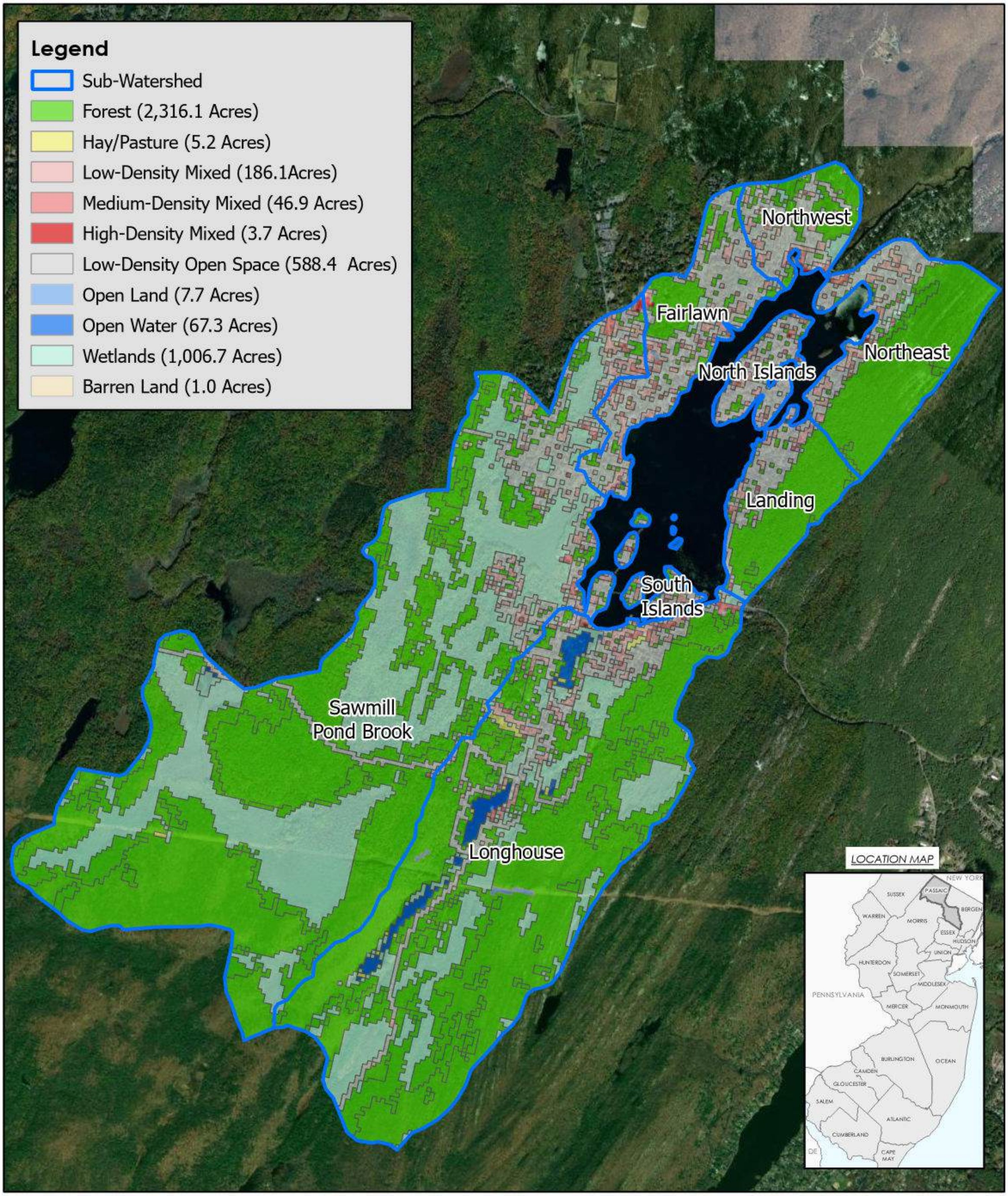

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 1,500 3,000 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

UPPER GREENWOOD LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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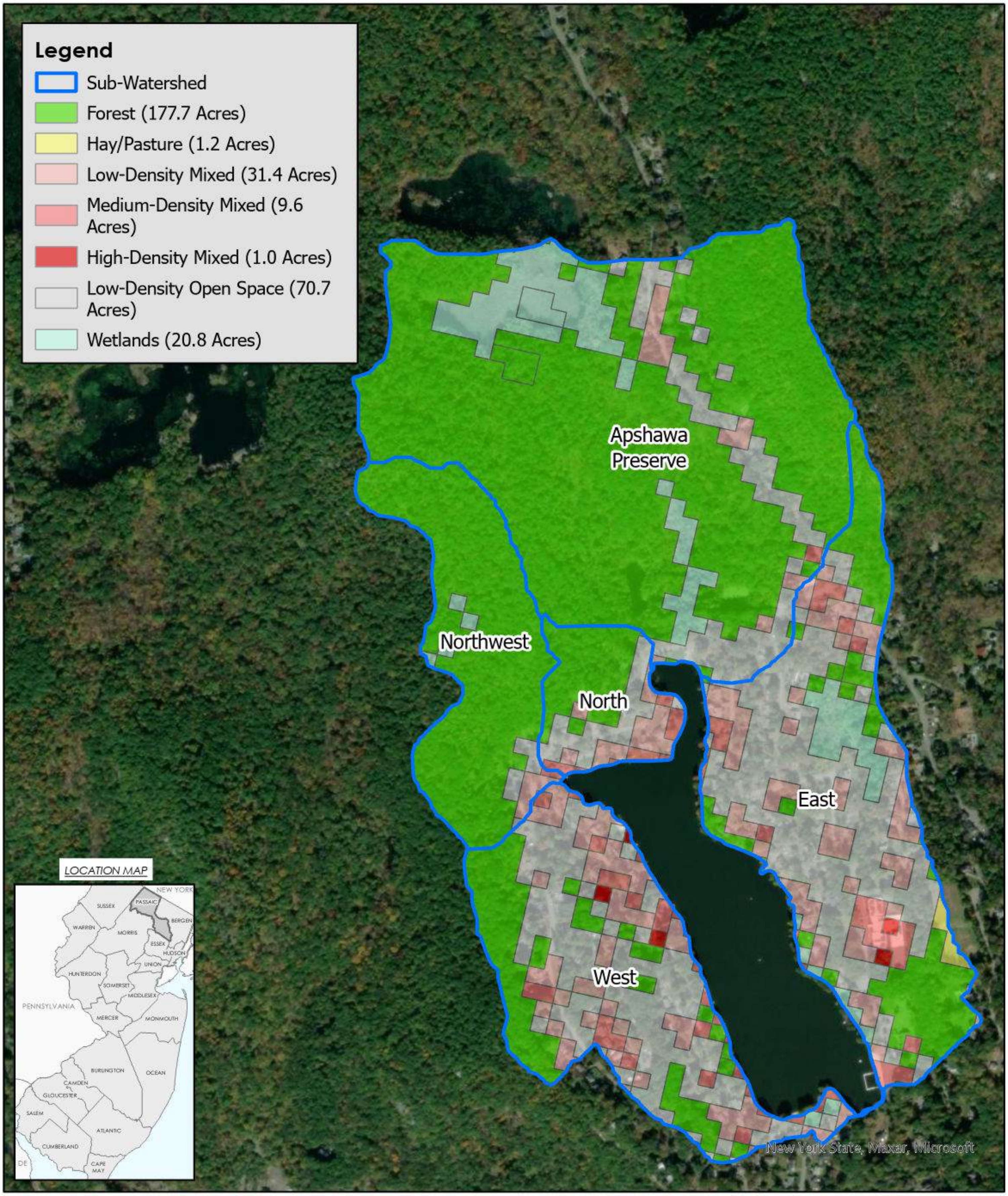

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 400 800 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

HIGHCREST LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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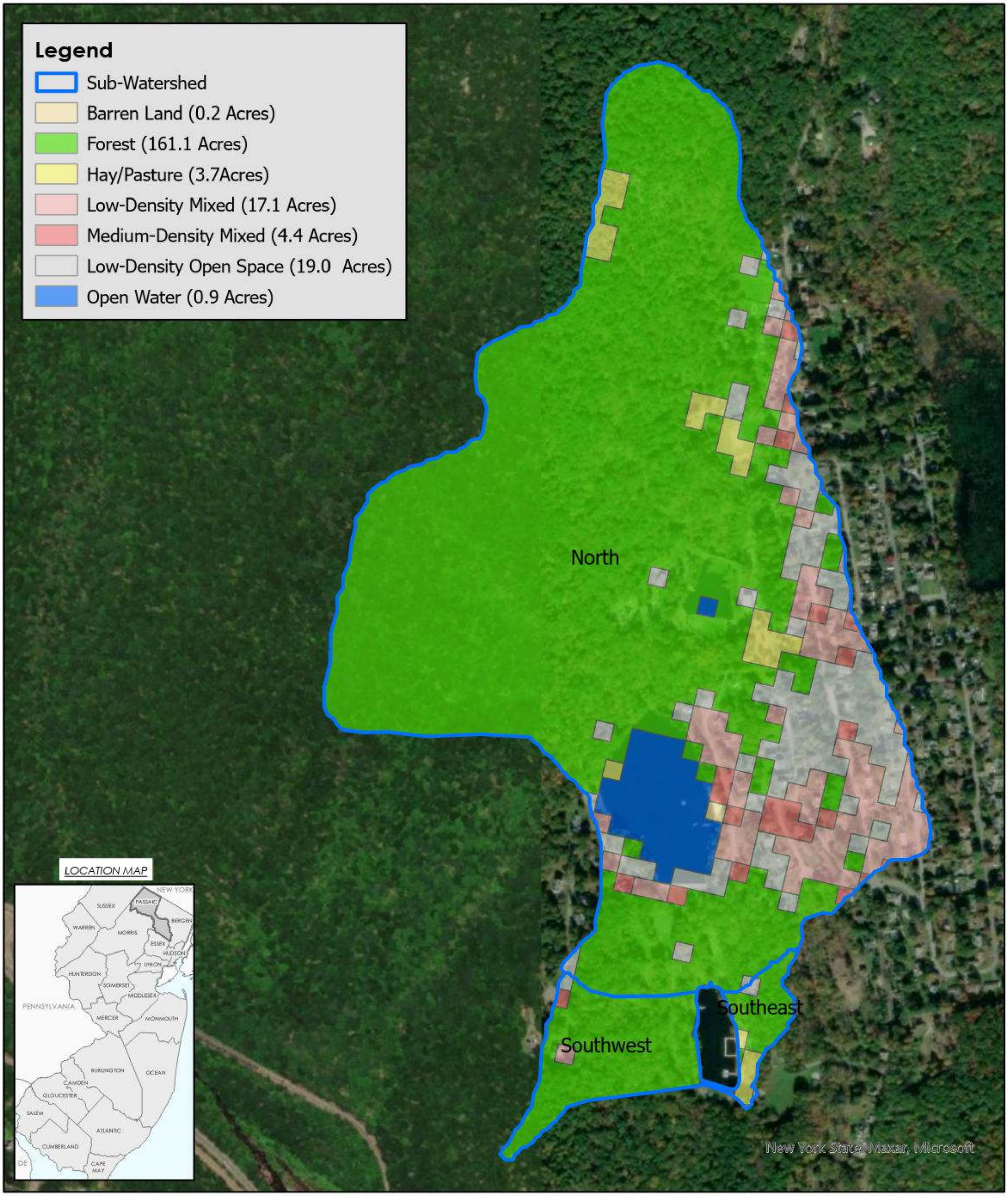

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 350 700 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

JOHNS LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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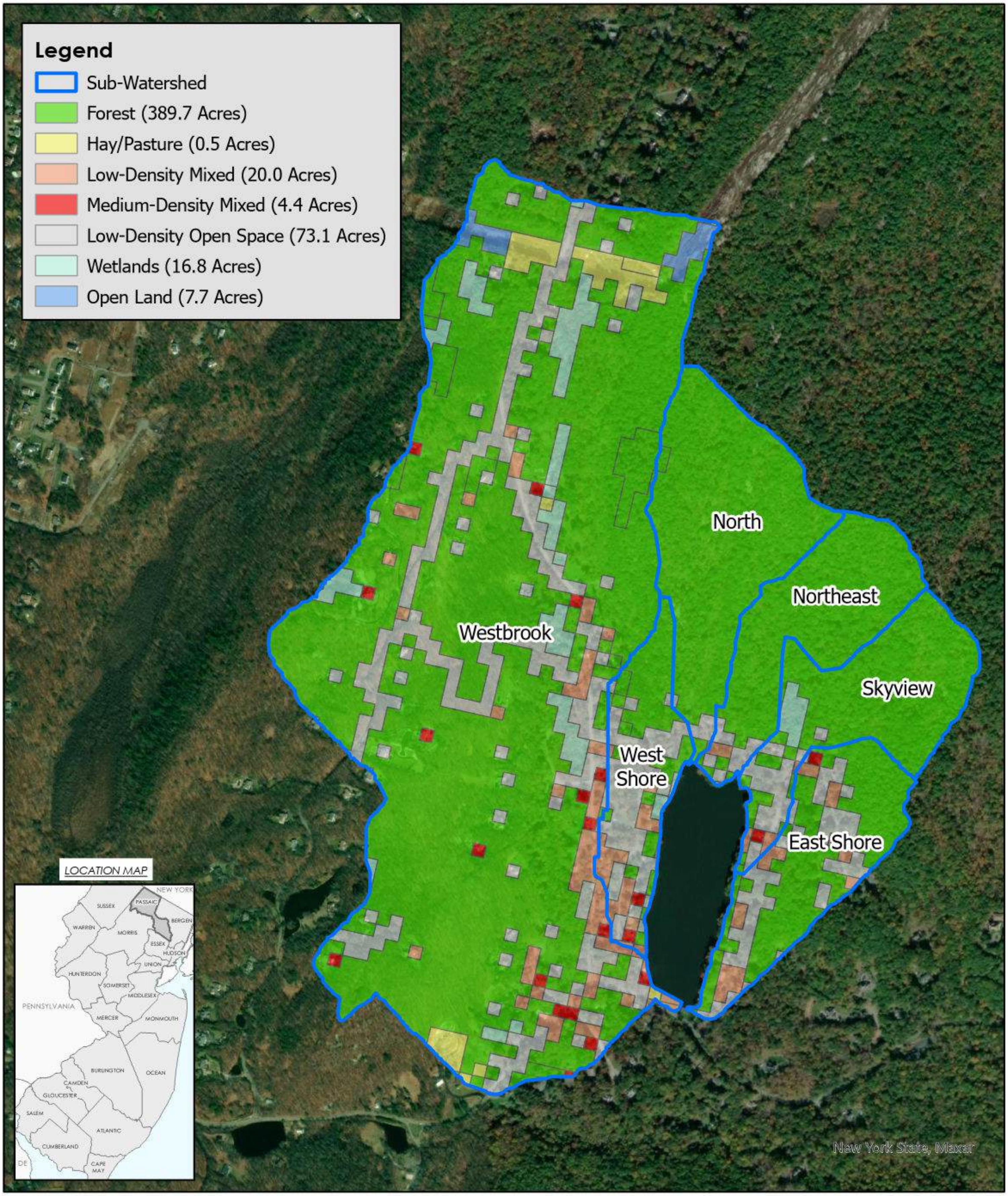

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 500 1,000 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

KITCHELL LAKE

WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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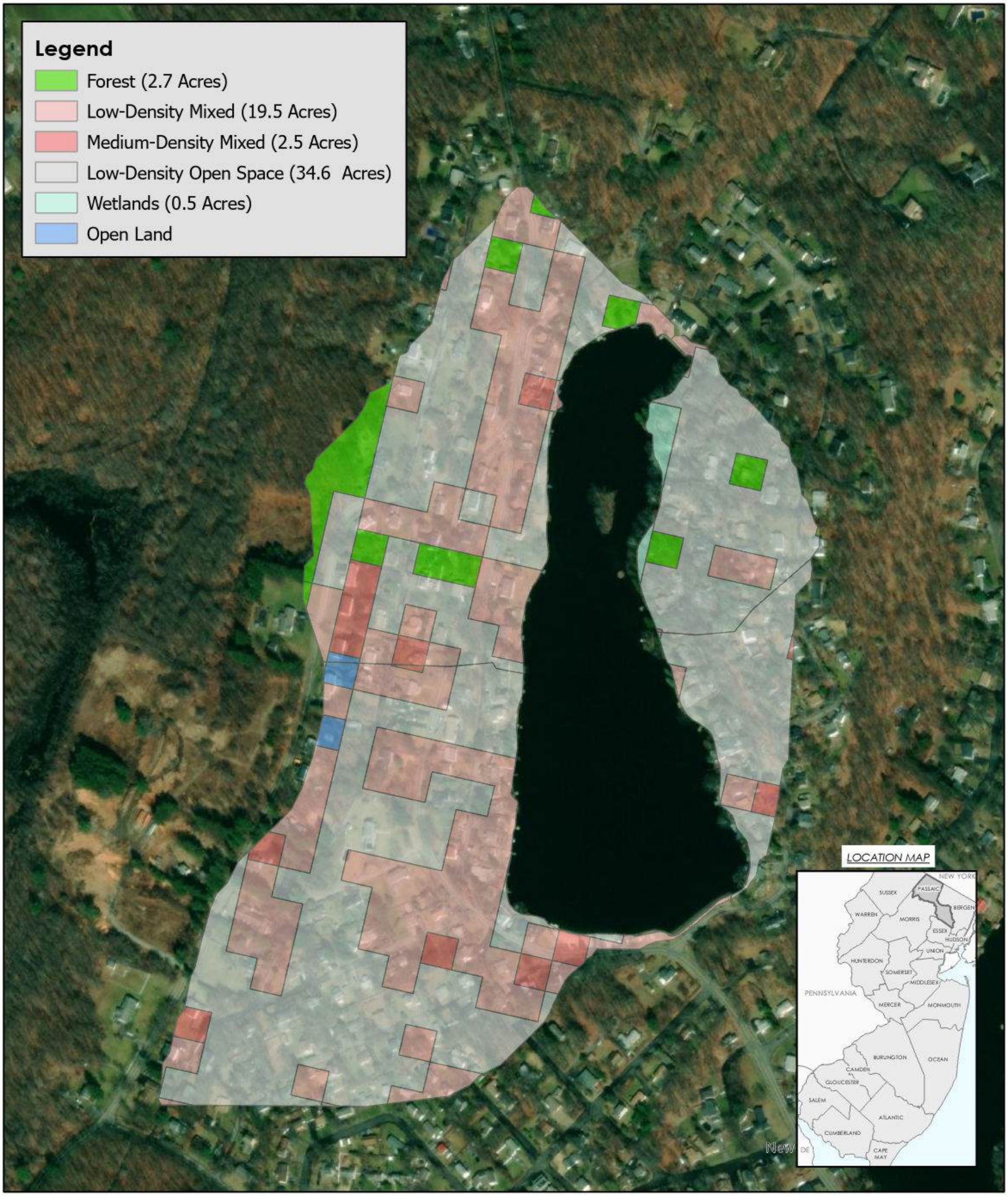

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 200 400 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

LINDYS LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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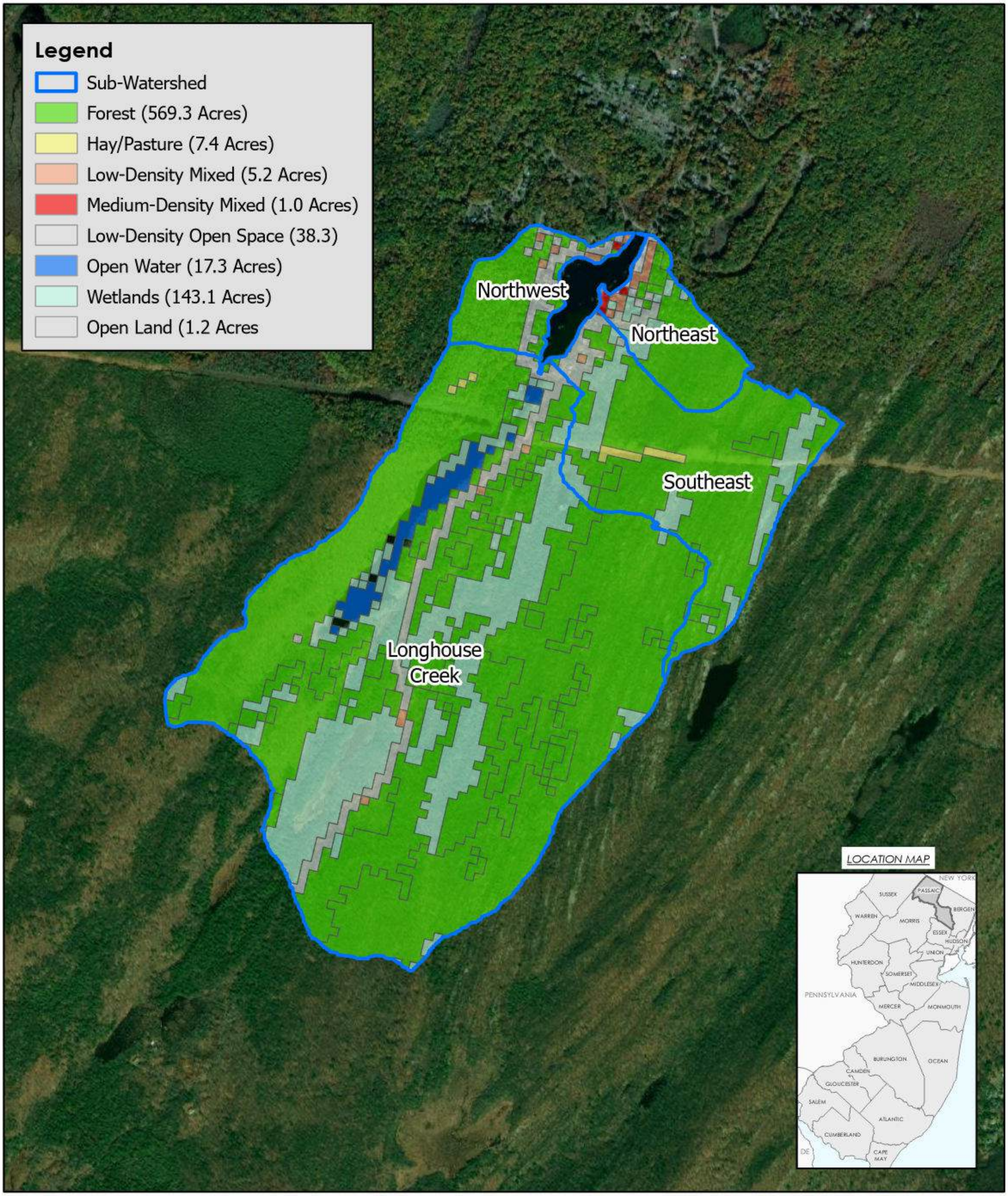

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 750 1,500 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

LAKE LOOKOVER
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

PRINCETON HYDRO
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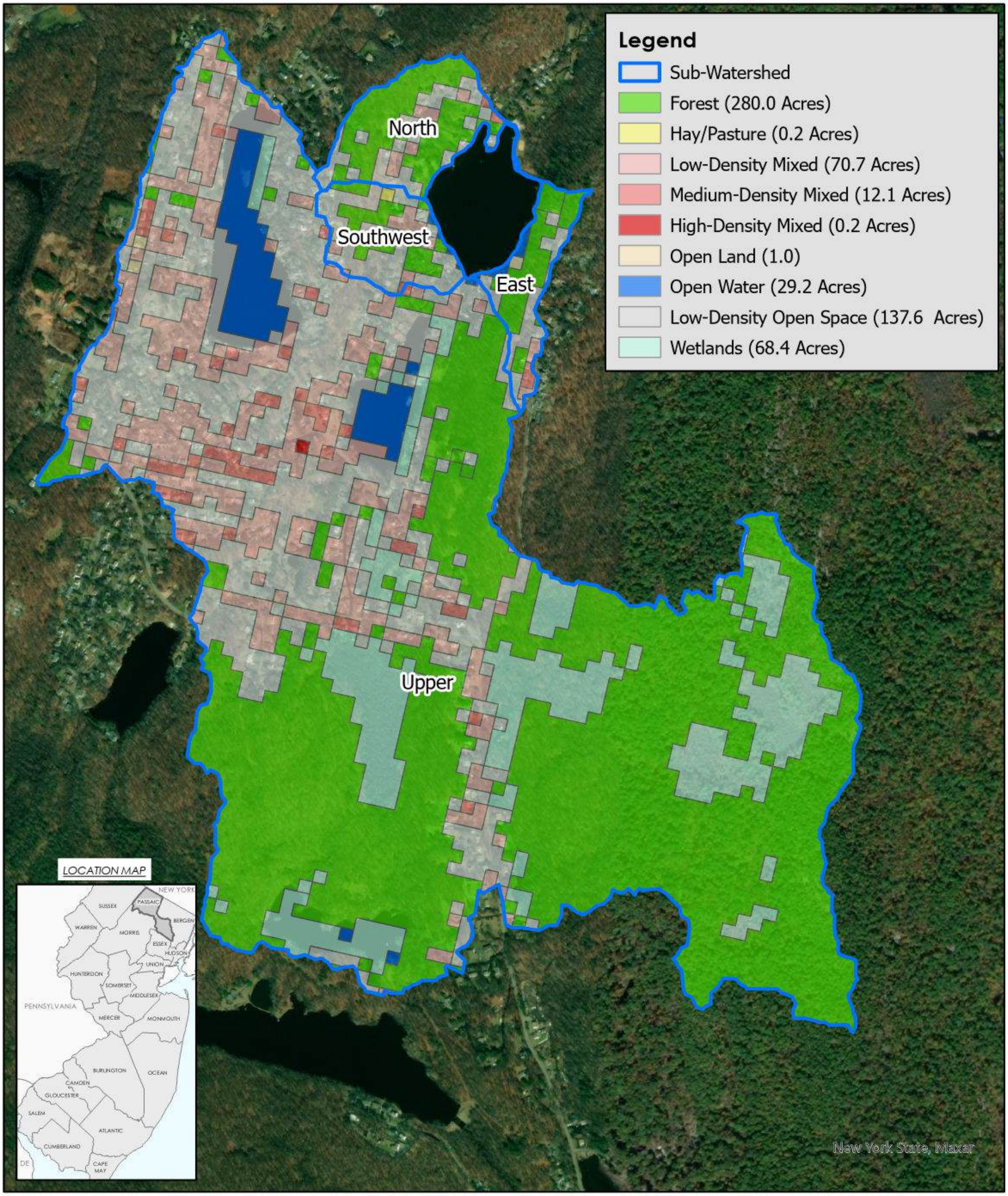

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 500 1,000 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

LOWER MT. GLEN LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
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PASSAIC COUNTY, NEW JERSEY

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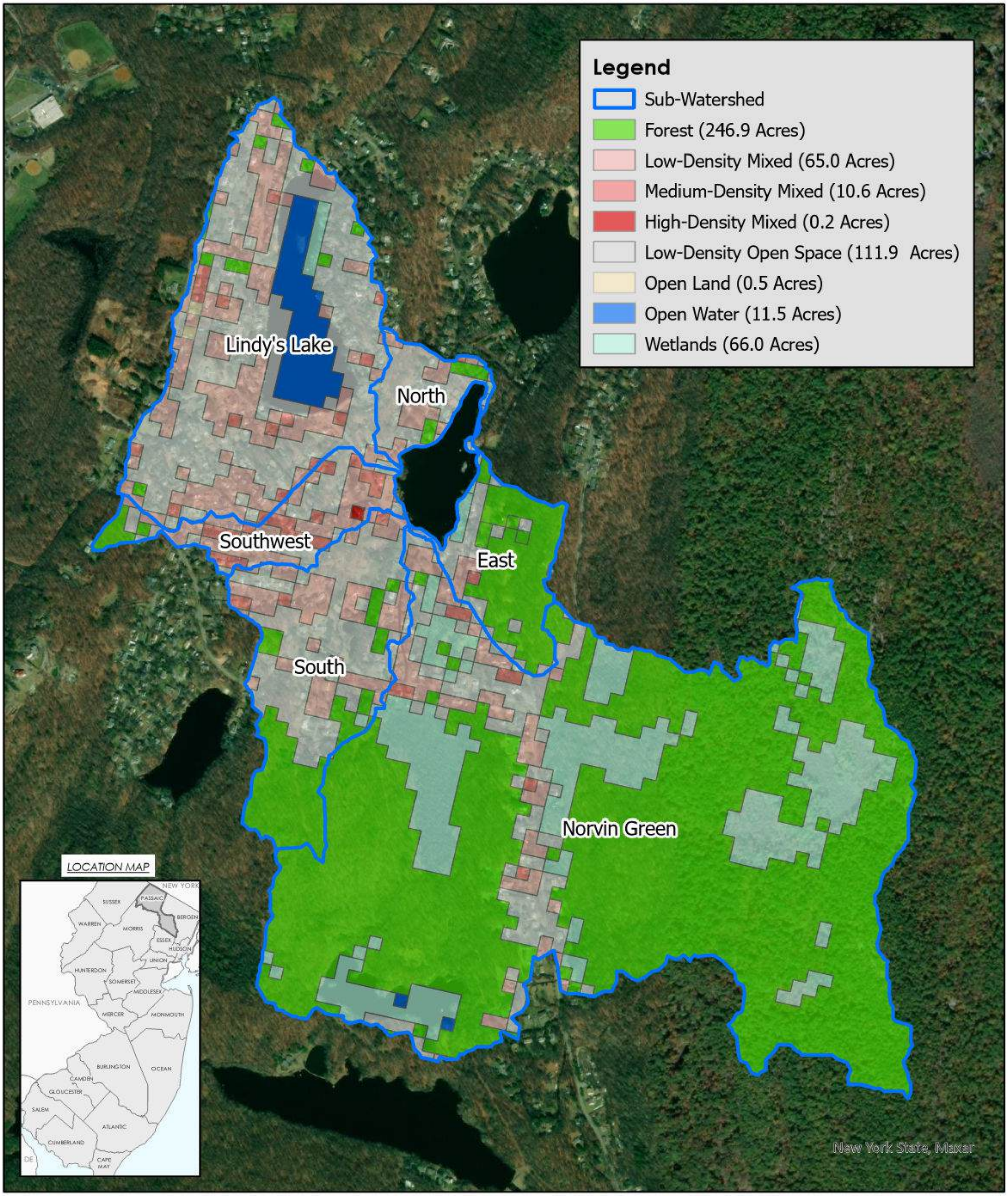

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 500 1,000 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

UPPER MT. GLEN LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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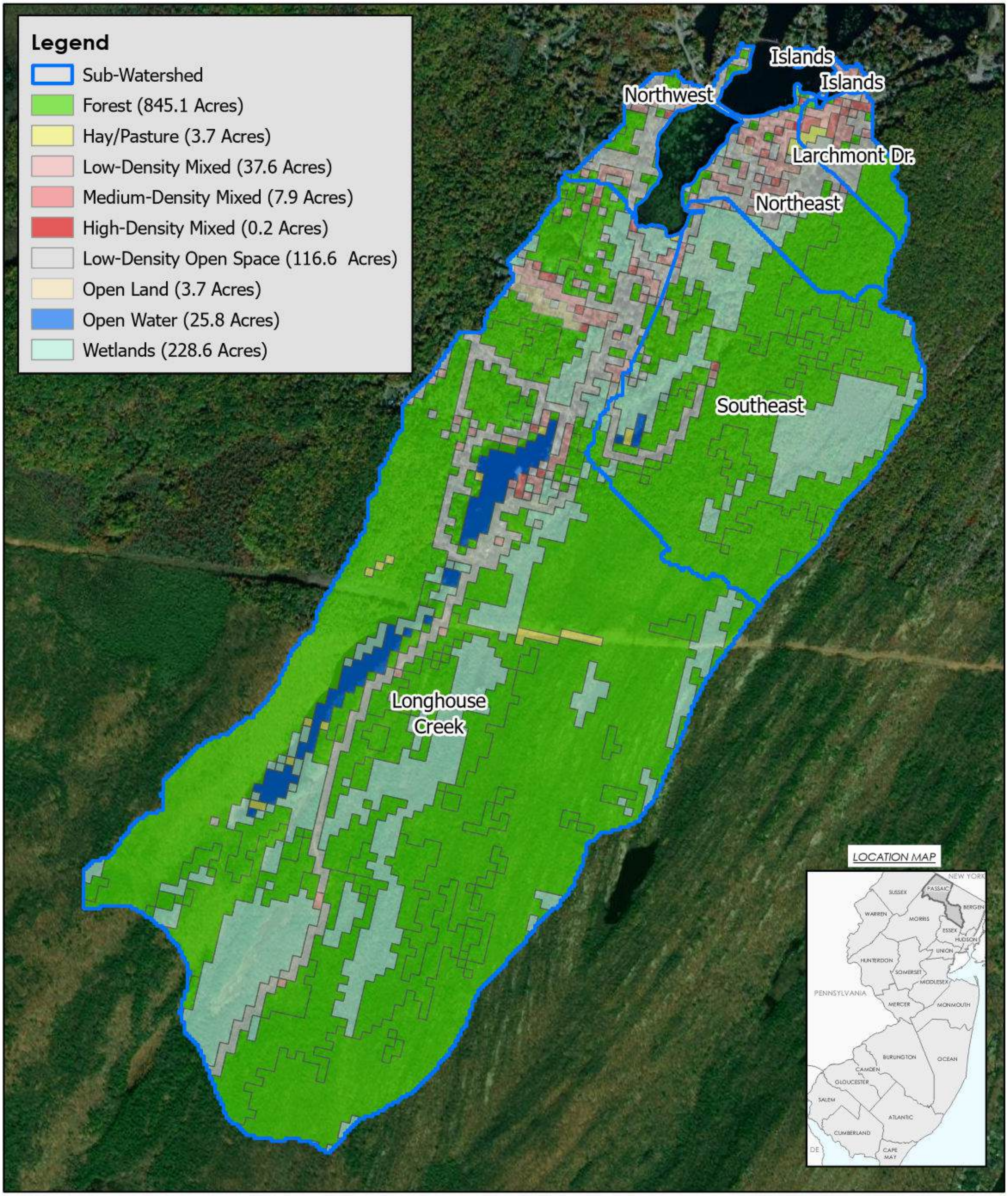

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 750 1,500 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

MT. LAUREL LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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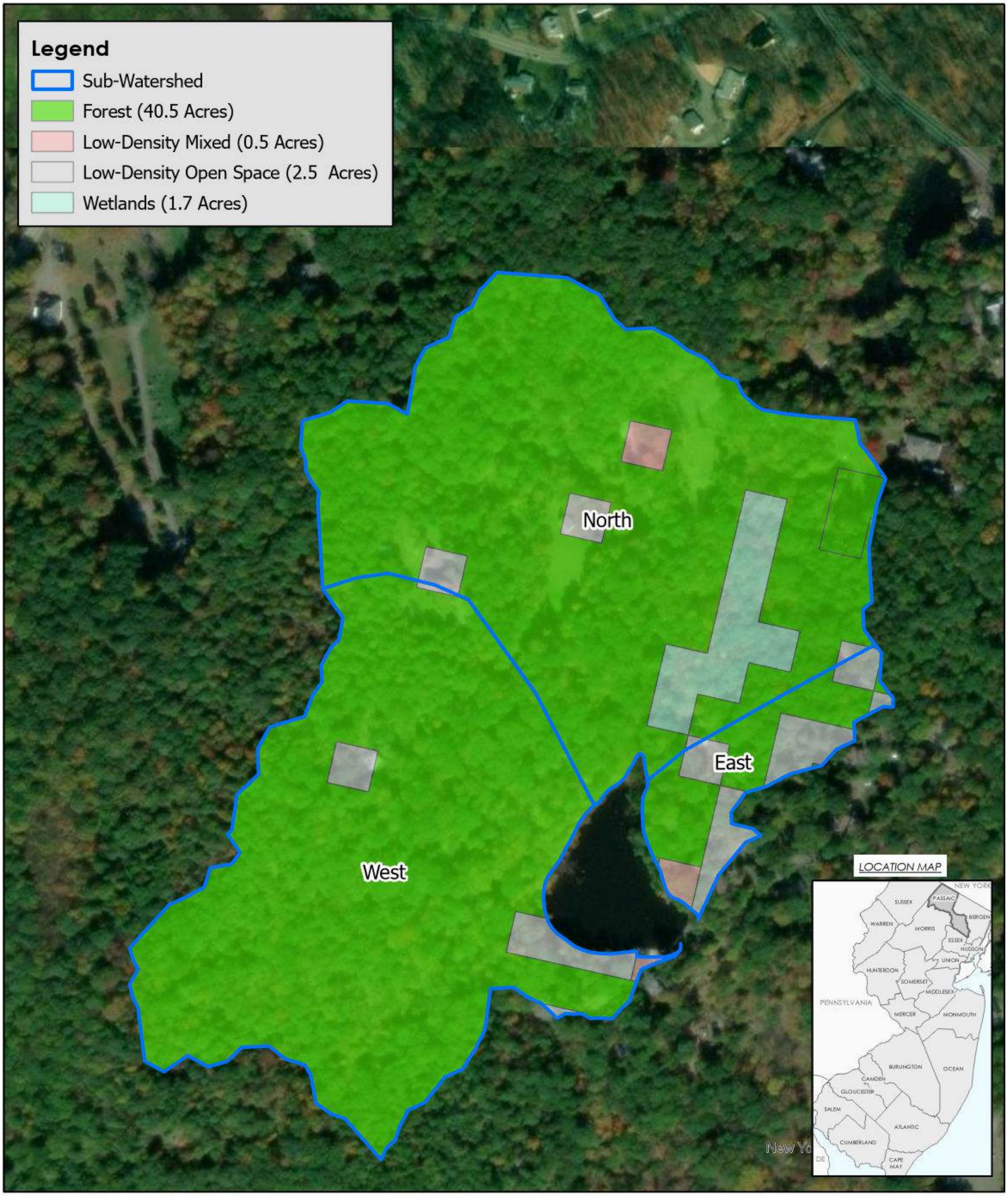

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 150 300 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

MOUNTAIN. SPRINGS LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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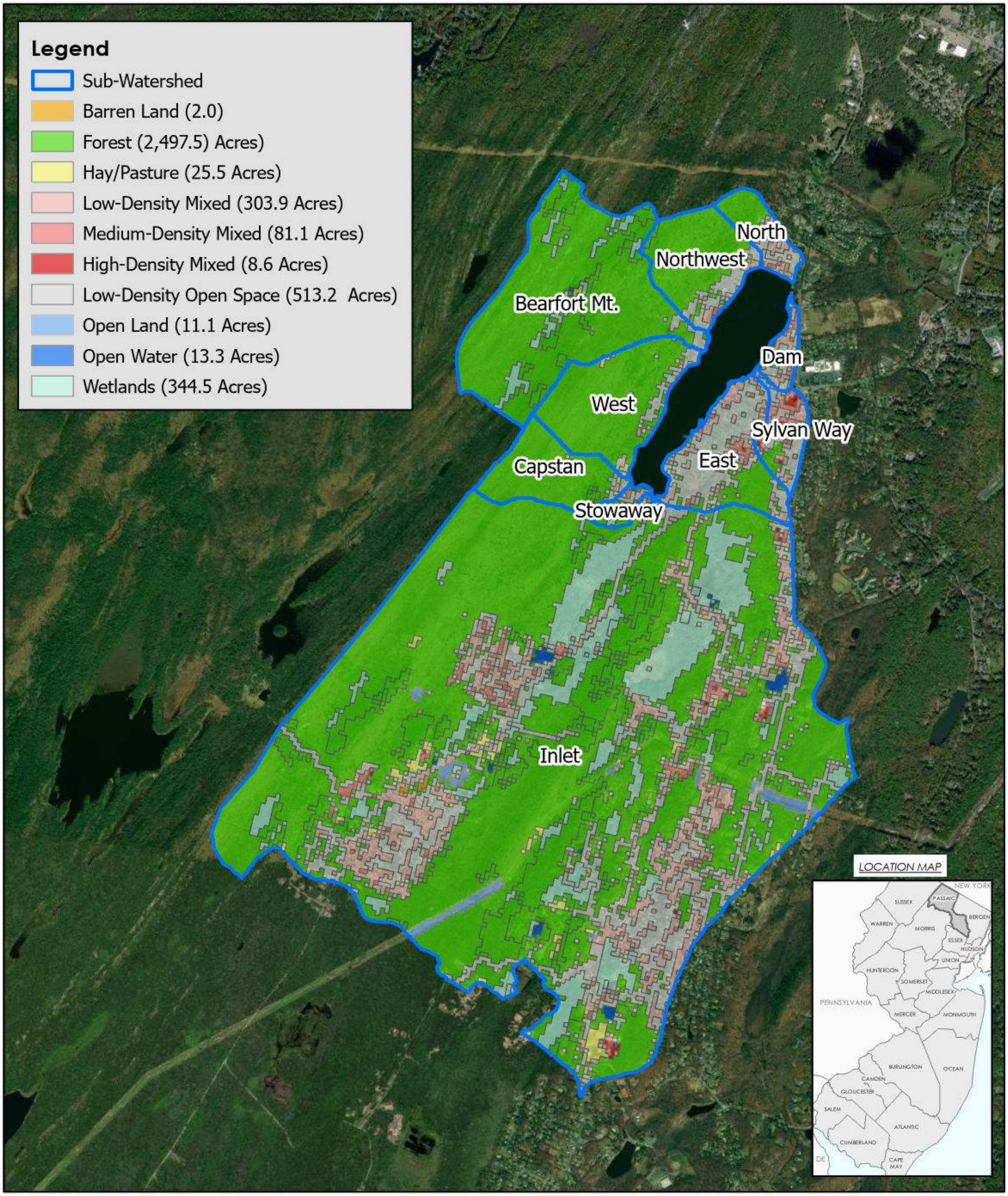

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 1,500 3,000 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

PINECLIFF LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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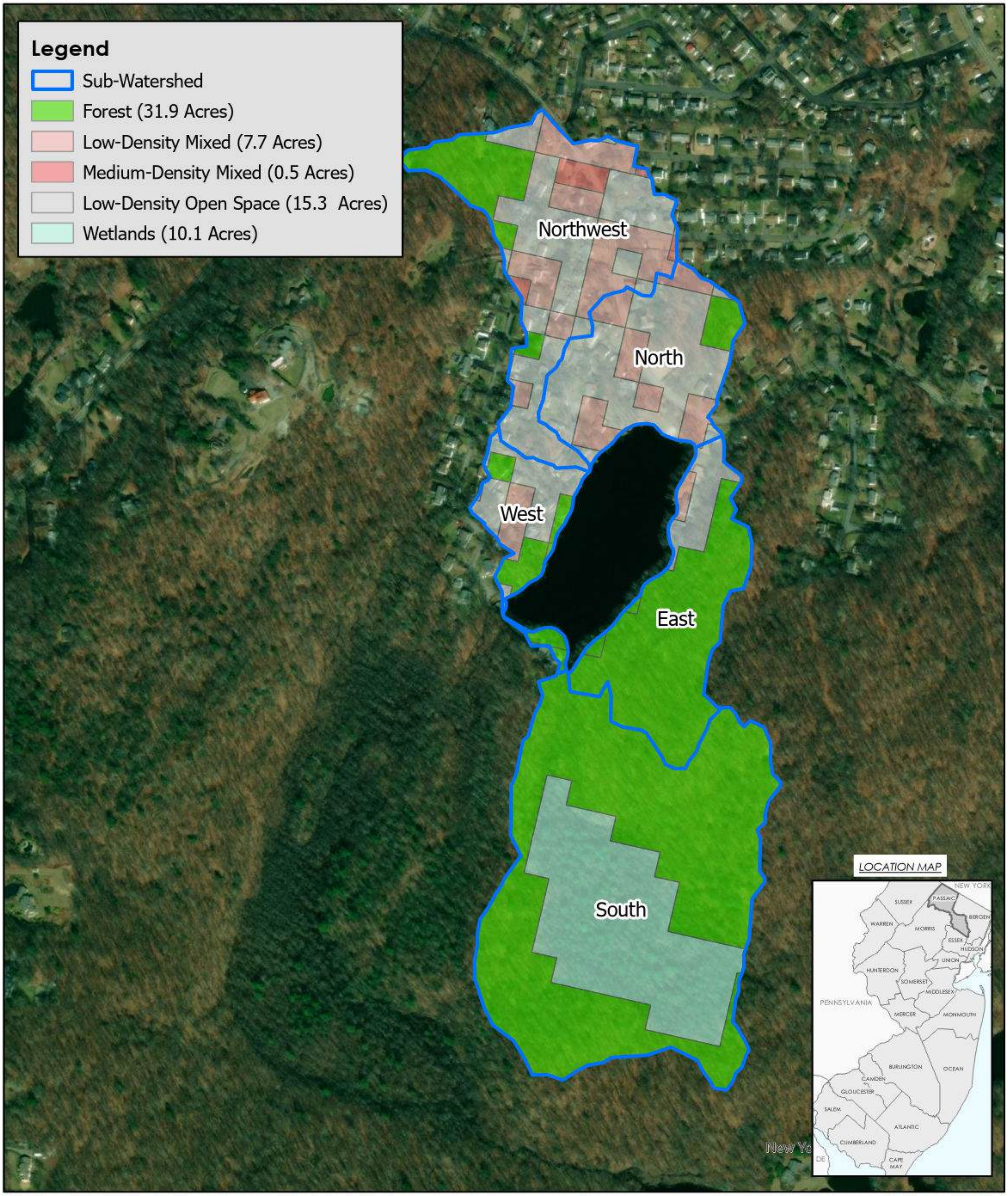

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 250 500 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

POST BROOK FARMS LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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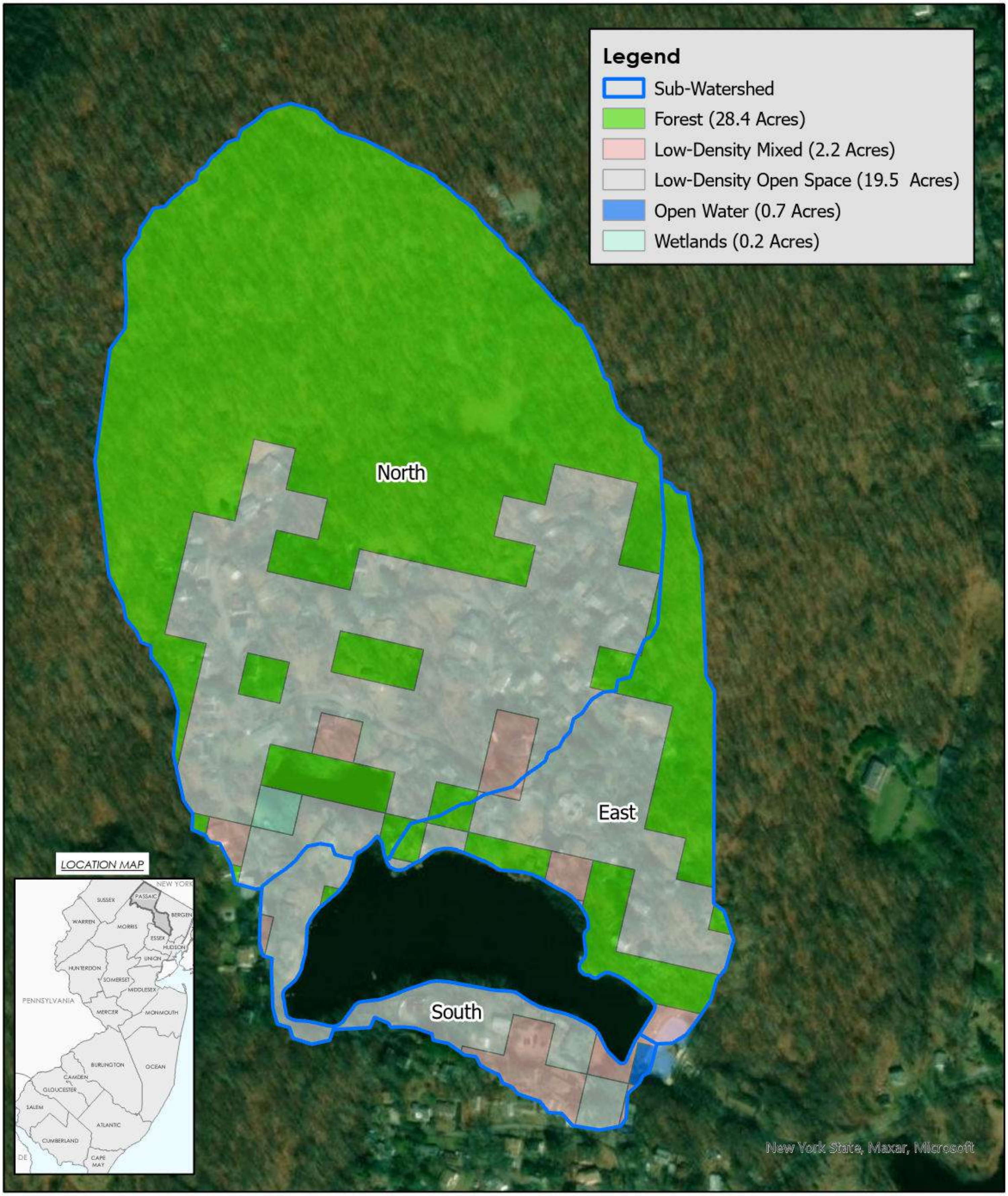

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 150 300 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

SHADY LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED
MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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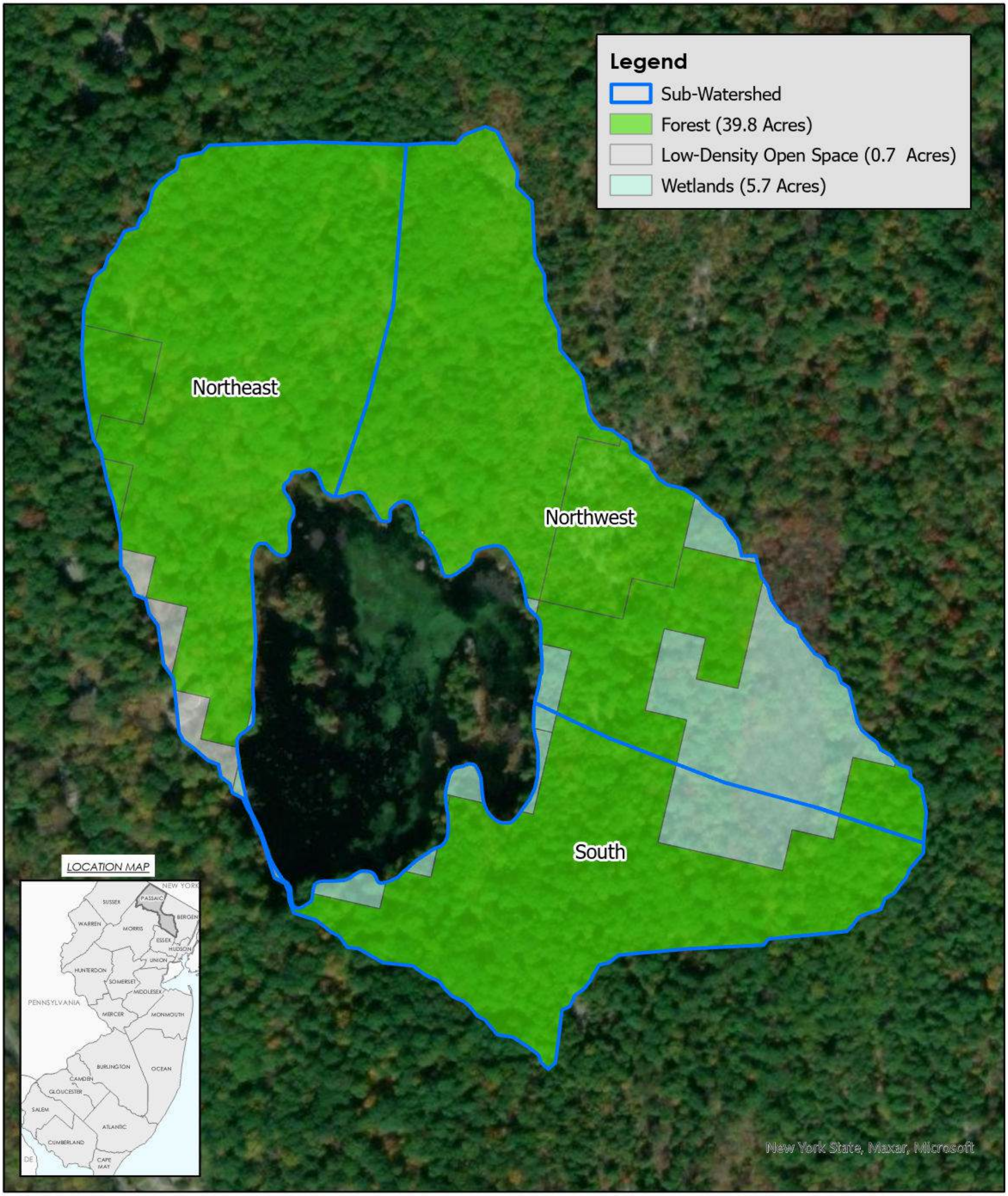

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 150 300 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

VAN NOSTRAND LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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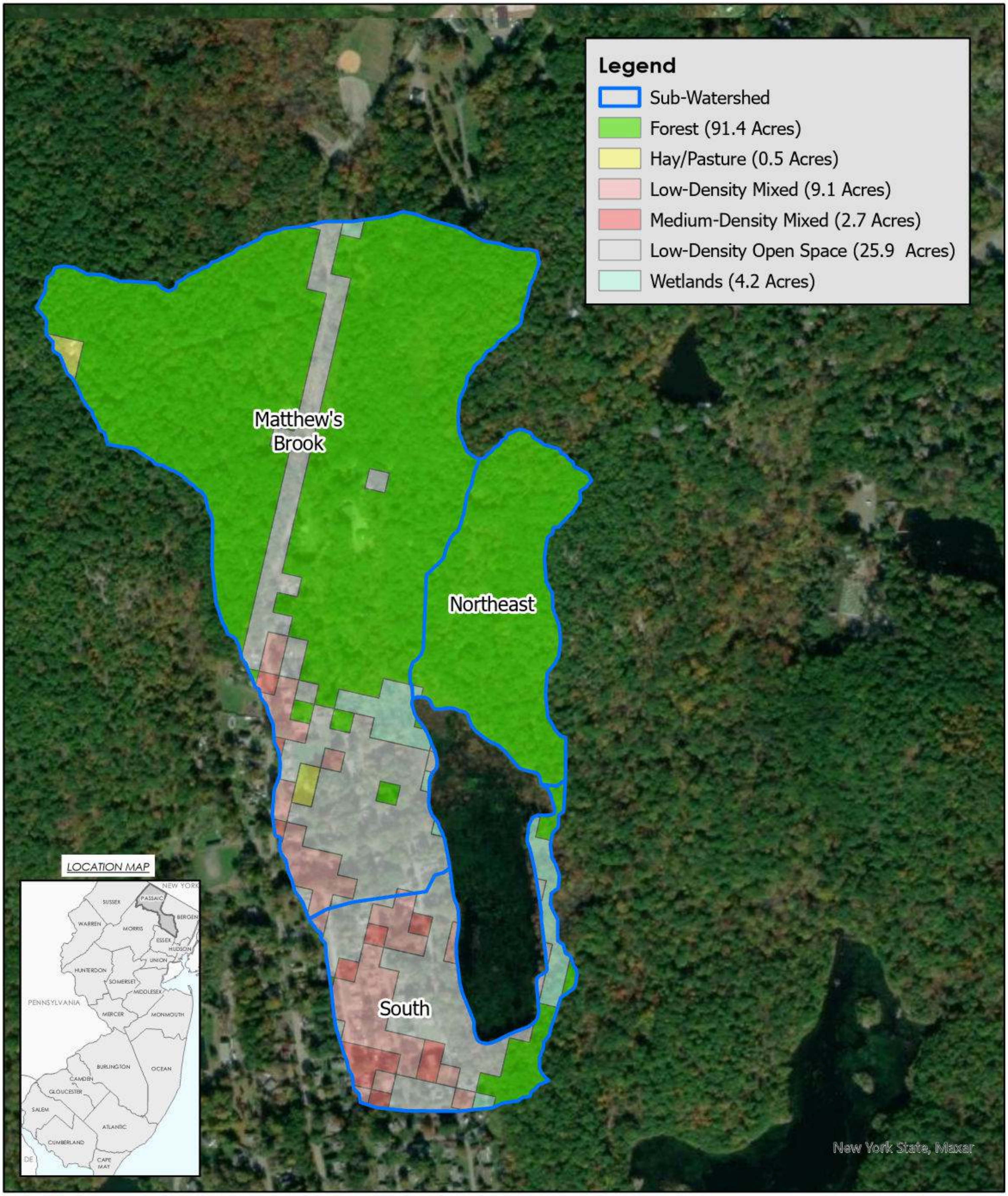

NOTES:

Sub-watersheds mapped with modelmywatershed.org and checked for accuracy by Princeton Hydro.

Acres listed are totals for the entire watershed, not sub-watersheds

0 300 600 Feet

Spatial Reference: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

WONDER LAKE
WATERSHEDS AND LAND USE

WEST MILFORD WATERSHED MANAGEMENT PLAN
TOWNSHIP OF WEST MILFORD
PASSAIC COUNTY, NEW JERSEY

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4. LAKE-BASED WATER QUALITY DATA

4.0 METHODS

Sampling events were conducted at each lake three different times over the course of 2022 in order to collect data during spring, summer, and autumn conditions. At each lake, *In-situ* water quality data was collected at two locations using a calibrated multi-probe water quality meter. Princeton Hydro is certified by the State of New Jersey for the analysis of *In-situ* water quality data (Certification #10006). This data was collected throughout the water column in half-meter to one-meter increments in order to generate full profiles of the entirety of the water column. The parameters sampled as part of *In-situ* water quality sampling are water temperature (°C), dissolved oxygen (mg/L), specific conductivity (µS/cm), and pH (standard units). Additionally, water clarity was measured using a Secchi disk.

At a sampling point located at the deepest area of each lake, discrete water quality samples were collected at the surface of the water column by hand and half a meter above the bottom sediments using a Van Dorn sampler. At the end of each sampling event, these samples were delivered to the laboratory Environmental Compliance Monitoring (#18630) in Hillsborough, NJ for analysis. Samples were analyzed for the following parameters:

- Total Phosphorus (TP)
- Soluble Reactive Phosphorus (SRP)
- Chlorophyll *a* (Chl. *a*)
- Nitrate Nitrogen (NO_3-N)
- Ammonia Nitrogen (NH_3-N)
- Total Suspended Solids (TSS)

In addition, plankton samples were collected at the discrete water quality sampling location. These were sampled using a tow-net pulled vertically from a depth within the lake's thermocline (the sharpest change in temperature along the water column). If a lake was not stratified and featured no thermocline, the net was pulled from a depth equal to twice the Secchi depth. Samples were taken to Princeton Hydro's in-house laboratory, preserved with Lugol's solution, and assessed for community composition.

Additionally, notes were taken regarding pertinent observations, such as weather, SAV or algae growth, and water color. Maps displaying the sampling locations on each lake are provided in Appendix II.

4.1 RESULTS

In-situ water quality

Thermal stratification is a common phenomenon that occurs in lakes with sufficient depth. Thermal stratification typically begins to form sometime between mid-spring to early summer, depending on a number of factors. As surface water temperatures rise, this water becomes less dense and rises above a layer of colder water situated in the bottom of the water column. As the difference in temperature between these two layers increases, they become less able to mix. The sharpest change in water temperature between two adjacent depths under these conditions is typically referred to as the thermocline. *In-situ* water quality data for all lakes studied is provided in Appendix II.

The reduction of dissolved oxygen at the bottom of the lake is a common occurrence associated with thermal stratification. As the warm, upper layer of the water column separates from the cooler, deeper layer, atmospheric oxygen that normally mixes into the water column at the surface is less able to mix to the lower reaches of the water column. As a result, dissolved oxygen concentrations at the bottom of a stratified lake will typically become reduced through respiration of bacteria and other organisms. This both reduces available habitat for fish and other organisms and can potentially lead to the loading of phosphorus into the water column from the bottom sediments, which will be described in greater detail below.

Discrete water quality

The parameters analyzed in a typical suite of discrete water quality samples in a recreational lake in New Jersey consist largely of nutrients that are used by plants, algae, and cyanobacteria. Of these nutrients, one of the most important for many lakes in the region is phosphorus. Phosphorus is often a limiting nutrient in a lake, meaning that even a relatively small increase in the nutrient will result in a large increase in algae productivity. Very high spikes of phosphorus are usually associated with large algae and/or cyanobacteria blooms. In this study, two variations of phosphorus were assessed: total phosphorus (TP) and soluble reactive phosphorus (SRP). Total phosphorus is all phosphorus present in the water sample, including that which is locked in organic matter or algae cells and not present available for assimilation by other algae or cyanobacteria. Soluble reactive phosphorus is the portion of phosphorus in the sample that is freely available for assimilation by photosynthetic organisms. SRP is typically detected at very low concentrations, and any significant increases usually result in an excess of algae and/or cyanobacteria.

While phosphorus can enter a waterbody through the watershed, it can also enter the water column through a process known as internal loading. In instances where bottom dissolved oxygen levels go completely anoxic (DO <1 mg/L), redox reactions at the sediment-water interface allow phosphorus normally bound to solid substances in the sediment to precipitate back into the water column. During a mixing event (such as fall turnover) where the surface and deep waters mix, this released phosphorus is mixed to the top of the water column, where it is available for assimilation by algae and cyanobacteria. The NJ Surface Water Quality Standards list 0.05 mg/L of total phosphorus as the maximum concentration that should be measured in any standing body of water with the FW2 classification.

In addition to phosphorus, water samples were analyzed for nitrate-N and ammonia. While nitrogen is not typically the limiting nutrient in most northeastern lakes, it can be assimilated by plants and algae once it has been reduced to ammonia. Nitrogen often enters the waterbody during storm events as organic debris and fertilizers are washed into the waterbody, as well as through the atmosphere. Additionally, groundwater inputs usually naturally contain relatively high nitrogen concentrations compared to surface water. Ammonia enters the water column through a variety of processes, such as the fixation of nitrogen by bacteria, or by the decomposition of organic matter.

Water samples were also analyzed for total suspended solids (TSS), a measure of organic debris and suspended sediments in the water column. A high TSS results in water that appears muddy and features poor water clarity and may explain these conditions in the absence of high chlorophyll *a* concentrations or plankton counts. Often, TSS will increase following a rain event as sediment washes into the waterbody.

Lastly, water samples were also analyzed for chlorophyll *a,* a compound utilized during photosynthesis by most plants, algae, and cyanobacteria. Chlorophyll *a* is typically used as a proxy for overall algae and cyanobacteria growth and is usually positively correlated with phosphorus concentrations and negatively correlated with Secchi depths.

ALGONQUIN WATERS

In-situ Water Quality

Algonquin Waters had very good Secchi depths during all three of the 2022 monitoring events. Secchi depths varied from 1.8 m to 2.5 m, remaining well above the recommended threshold. The temperature of the lake ranged from 14.28 °C to 23.70 °C in June, with the onset of thermal stratification present at the dam station. Temperatures were highest in August, ranging between 26.18 °C and 26.53 °C at the West station. A thermal gradient had formed within the bottom 1.0 m of the water column at the Dam station, with a difference in temperature of 26.28 °C at 2.0 m to 24.85 °C at 3.0 m. In October, the lake had cooled, with temperatures at both stations between 12.82 °C and 14.41 °C.

DO concentrations in Algonquin Waters at both stations in June showed a well oxygenated water column, with values between 8.25 mg/L and 10.55 mg/L. By August, DO concentrations had decreased, with the Dam station becoming anoxic at 3.0 m; DO concentrations fell from 7.46 mg/L at the surface to 0.86 mg/L at 3.0 m. By October, DO concentrations had increased throughout the entire water column at both stations, ranging between 9.47 mg/L and 9.99 mg/L. The pH profile values ranged from 6.42 to 7.84 over the course of the monitoring and were within the normal range. Specific conductivity values were also normal and fluctuated between 100.49 µS/cm and 144.33 µS/cm.

Table 233. 2022 In-Situ Monitoring for Algonquin Waters Lake

***In-Situ* Monitoring for Algonquin Waters Lake 2022**

Date	Station	Depth (m) Total	Secchi	Sample	Temperature °C	Specific Conductance µS/cm	Dissolved Oxygen mg/L	% Sat.	pH S.U.
6/1/2022	Algonquin Waters - Dam	3.7	1.9	0.0	23.07	108.27	8.42	101.17	7.71
				1.0	23.01	112.19	8.81	106.01	7.65
				2.0	20.16	105.97	9.18	104.70	7.60
				3.0	15.32	102.60	10.01	103.22	7.64
				3.5	14.28	103.24	9.36	93.16	7.57
6/1/2022	Algonquin Waters - West	3.0	2.0	0.0	22.48	108.68	8.64	102.86	7.53
				1.0	23.70	100.49	8.25	100.49	7.51
				2.0	19.76	106.63	9.47	106.63	7.56
				2.5	18.01	114.63	10.55	114.63	7.57
8/1/2022	Algonquin Waters - Dam	3.5	2.0	0.0	26.47	113.92	7.46	95.94	6.74
				1.0	26.53	113.78	7.41	95.15	6.82
				2.0	26.28	114.23	5.99	75.48	6.79
				3.0	24.85	144.33	0.86	9.35	6.42
8/1/2022	Algonquin Waters - West	2.9	1.8	0.0	26.16	108.42	7.65	97.98	7.29
				1.0	26.41	113.55	7.60	97.44	7.34
				2.0	26.37	113.39	7.38	94.45	7.27
				2.5	26.18	113.68	6.84	86.68	7.11
10/6/2022	Algonquin Waters - Dam	3.6	2.4	0.0	13.91	110.77	9.57	95.53	7.58
				1.0	13.41	110.91	9.62	94.93	7.56
				2.0	13.17	110.99	9.75	95.49	7.47
				3.0	13.04	111.99	9.54	93.47	7.39
10/6/2022	Algonquin Waters - West	2.8	2.5	0.0	14.41	111.11	9.47	95.51	7.84
				1.0	13.27	111.50	9.64	94.91	7.70
				2.0	13.04	110.85	9.79	96.37	7.50
				2.5	12.82	112.19	9.99	97.40	7.36

Discrete Water Quality

TP concentrations never exceeded 0.02 mg/L during the 2022 monitoring events. This is within the recommended range and indicates that phosphorus is not present in excess quantities within Algonquin Waters. SRP concentrations were likewise low and were consistently below the lab detection limit of 0.002 mg/L for all samples collected in 2022.

Chlorophyll *a* concentrations ranged between 3.9 mg/L and 21.0 mg/L. Concentrations were highest at the deep sample in August at 21.0 mg/L.

Nitrate-N concentrations ranged from 0.03 mg/L to 0.17 mg/L. These concentrations are within the normal range for a surface waterbody. Ammonia-N concentrations varied from below the lab detection limit of 0.01 mg/L to 0.35 mg/L. All samples except for the deep sample in August were at or below the recommended levels. This increase in ammonia-N concentration coincides with the anoxic conditions measured at a depth of 3.0 m in August. This is common in deep anoxic water during the summer because there is no oxygen present to aid in the conversion of ammonia to nitrite and nitrate; this process is known as nitrification.

TSS concentrations ranged between 1 mg/L and 9 mg/L during 2022, indicating minimal suspended solids, supporting good water clarity as observed.

Plankton and Macrophytes

Overall plant abundance was low during the 2022 site visits at Algonquin Waters. In June, there was a small amount of the plant-like algae *Chara* along the bottom of the lake near the western sampling station. In August, observations were of ribbon leaf pondweed (*Potamogeton epihydrus*), white water lily (*Nymphaea odorata*), spatterdock (*Nuphar advena*) and watershield *(Brasenia schreberi*) around the edges of the lake. By October, the only SAV species that were noted were predominately in the northern cove and consisted of spatterdock, leafy pondweed (*Potamogeton foliosus*) and Eurasian watermilfoil (*Myriophyllum spicatum*). No nuisance filamentous algae or cyanobacteria particulates were noted during the three monitoring events.

The plankton community in June consisted of 7 identified phytoplankton genera and 9 identified zooplankton genera. Some of the most common genera from the June sample include the diatom genus *Synedra* and the cyanobacteria genus *Microcystis*. In August, the number of phytoplankton genera increased to 17, with common genera including the cyanobacteria genus *Aphanocapsa* and once again *Synedra*. Zooplankton community composition consisted of a variety of rotifers, including *Conochilus*. By October, the community richness had decreased to 11 phytoplankton genera and 13 zooplankton genera. Zooplankton identified were primarily rotifers and cladocerans. Cyanobacteria were still prevalent in the phytoplankton community, with *Aphanizomenon* identified as common in the October sample.

BUBBLING SPRINGS POND

In-situ Water Quality

The results of the water quality monitoring events in 2022 at Bubbling Springs Lake indicate that overall, water quality values were within normal ranges during all three monitoring events. The Secchi depths measured in Bubbling Springs Lake varied between 1.1 m and 1.9+ m, indicating that the Secchi was still visible at the bottom of the lake. The highest Secchi depths were recorded at the Dam station during the monitoring events in 2022. July Secchi depths were the lowest of the season at both stations, and it was the only monitoring event where the Secchi disk did not reach the bottom at both stations, indicating increased particulates in the water column and reduced water clarity.

The pH profile values ranged from 7.55 to 8.48 over the course of the season. pH values showed normal fluctuations from surface to bottom and were within the normal range. The temperature of the lake ranged from 21.91 °C to 23.44 °C in June. Temperatures were highest in July, ranging between 26.46 °C and 27.69 °C. By October, the lake had cooled, with temperatures at both stations between 13.19 °C and 14.48 °C.

DO concentrations in Bubbling Spring Lake were elevated in June, with concentrations ranging from 11.16 mg/L to 15.71 mg/L. These elevated concentrations were likely the result of increased biological productivity; specifically, the photosynthetic processes of plants and plankton. During July, DO concentrations were lower than those in June, but still sufficiently elevated with concentrations between 6.75 mg/L to 11.02 mg/L. These elevated concentrations, paired with the lower Secchi depths, suggest that the density of particulates was elevated in the water column during July. DO concentrations never fell to a concentration that would be detrimental to the aquatic organisms in the lake. In summary, Bubbling Springs Lake had moderate water clarity in 2022, and elevated DO concentrations, with pH, temperature, and specific conductance levels all within acceptable ranges for aquatic life.

Table 234. 2022 In-Situ Monitoring for Bubbling Springs Lake

***In-Situ* Monitoring for Bubbling Springs Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
6/1/2022	Bubbling Springs - Dam	1.9	1.9+	0.0	23.38	532.95	11.49	139.70	7.76
				0.5	23.44	533.37	11.40	138.25	7.81
				1.0	23.08	526.85	15.30	184.50	8.29
				1.5	22.05	507.70	15.71	186.27	8.48
6/1/2022	Bubbling Springs - South	1.6	1.6+	0.0	23.13	535.55	11.84	143.03	8.15
				0.5	23.36	534.72	11.87	143.88	8.14
				1.0	23.05	528.73	14.24	172.30	8.41
				1.5	21.91	527.55	11.16	134.65	8.00
7/26/2022	Bubbling Springs - Dam	1.8	1.2	0.0	27.62	684.67	9.17	119.13	7.75
				0.5	27.10	682.88	9.19	119.24	7.82
				1.0	26.85	677.59	11.02	146.73	8.11
				1.5	26.46	682.02	6.75	91.03	7.55
7/26/2022	Bubbling Springs - South	1.5	1.1	0.0	27.69	686.96	9.30	120.91	7.88
				0.5	27.52	681.71	9.98	142.55	8.05
				1.0	27.01	684.96	10.19	131.89	8.05
10/10/2022	Bubbling Springs - Dam	1.8	1.8+	0.0	14.48	599.17	10.33	108.95	7.91
				0.5	14.07	600.09	10.88	109.20	7.87
				1.0	13.34	598.07	11.16	109.53	7.91
				1.5	13.19	598.39	11.39	111.50	7.90
10/10/2022	Bubbling Springs - South	1.4	1.4+	0.0	14.03	597.80	10.92	108.99	7.96
				0.5	13.61	598.18	11.07	109.06	7.93
				1.0	13.46	597.68	11.06	108.76	7.90

Discrete Water Quality

TP concentrations never exceeded 0.04 mg/L, which is below the New Jersey Surface Water Quality Standards limit of 0.05 mg/L. This indicates that TP in the lake is not present in elevated quantities.

SRP concentrations were consistently below the lab detection limit of 0.002 mg/L for all samples collected in 2022. This is a positive sign, and well below the recommended threshold of 0.005 mg/L. SRP is the primary form of phosphorus used by plants and algae within an aquatic system.

TSS concentrations ranged between 1 mg/L and 8 mg/L. This is below the recommendation threshold of 25 mg/L.

Chlorophyll *a* fluctuated between 0.6 µg/L and 17.0 µg/L, which is below Princeton Hydro's recommended threshold of 20 µg/L. The only sample that exceeded 3.0 µg/L was collected at the in the deep water in July, at a concentration of 17.0 µg/L. This increase suggests increased plant and algae concentrations near the bottom of the lake in July.

Nitrate-N concentrations ranged from 0.07 mg/L to 0.76 mg/L. Typically, lakes with concentrations above 0.30 mg/L indicates nitrogen loading. The elevated surface and deep concentrations in May and September indicate that nitrogen loading may be occurring within Bubbling Springs Lake.

Ammonia-N concentrations varied from below the lab detection limit of 0.01 mg/L, up to 0.60 mg/L. All samples except for the deep sample in October were at or below the recommended levels. Similar to nitrate, this elevated ammonia is a likely contributing factor to the filamentous algae observed and further suggests nitrogen loading in the water body.

Based on the results of the water quality analysis, the majority of the discrete sample water quality parameters were within acceptable limits, including TP, SRP, TSS, and chlorophyll *a*. However, the two nitrogen parameters were elevated at times. Limiting nitrogen loading will be beneficial for the ecological health and visual aesthetic of Bubbling Springs going forward.

Plankton and Macrophytes

The submerged aquatic vegetation in Bubbling Springs Lake consisted of slender naiad (*Najas flexilis*), brittle naiad (*Najas minor*) and water chestnut (*Trapa natans*). The abundance of slender naiad was low and was observed primarily in July. Brittle naiad was more common and observed later in the season during the October monitoring event. The abundance of water chestnut was low, with only a single plant being observed in June.

Algae were also present in Bubbling Springs Lake, with filamentous algae being the most abundant. This filamentous algae was seen at the surface and as benthic algae along the bottom. An algaecide treatment occurred in September to reduce the density of the filamentous algae. Densities were most noticeable near shore and in shallow areas.

The phytoplankton community showed a mix of diatoms, green algae and cyanobacteria. The dominant genera of phytoplankton identified were *Pediastrum, Chlamydomonas, Fragilaria* and *Lyngbya*. The zooplankton community was also well represented with copepods, cladoceran and rotifers; the most common genera were *Asplancha, Daphnia,* and copepod nauplii.

CARPI LAKE

Access was not granted to Carpi Lake during the 2022 season.

FARM CREST ACRES POND

In-situ Water Quality

Farm Crest Acres was sampled on 24 May, 2 August and 10 October during the 2022 growing season. Water clarity was very good during the monitoring events, with the lowest Secchi depth of the season recorded at 1.6 m at the North station in August. The South station in October had the highest Secchi depth at 3.4 m, which is excellent.

Temperatures in May ranged from 14.82 °C to 20.90 °C, and there was a pronounced thermocline at the South station. The profile showed a warmed upper 1.0 m of the water column, known as the epilimnion, followed by a change of several degrees in the bottom 2.0 m of the water column, known as the thermocline. Temperatures throughout the lake had risen to between 20.58 °C to 26.45 °C by August. A thermocline was still present at the South station, with a drop in temperature from 24.98 °C at 2.0 m to 20.58 °C at 3.5 m. The rapid change in temperature with depth reduces the ability for surface water to mix with the deeper water and can lead to DO depletion in the hypolimnion. Temperatures in October were the coolest of the monitoring events, with temperatures ranging between 12.99 °C and 14.54 °C.

The water column was well oxygenated at the North station during each of the monitoring events. DO concentrations at the North station fluctuated from 6.78 mg/L in August to 12.77 mg/L in October. The South station, however, had anoxia during the May and August sampling events as a result of the thermal stratification. The DO profile in May went from 8.69 mg/L at the surface to 0.67 mg/L at 3.0 m. Similarly, in August, the upper 2.0 m of the water column had sufficient levels of DO, followed by anoxic conditions at 3.0 m. The August profile showed a decrease in DO from 6.16 mg/L at 2.0 m to 0.01 mg/L at 3.5 m.

Conductivity levels were between 491.09 µS/cm to 818.58 µS/cm during the 2022 monitoring events. The South station had a spike in the conductivity profile near the bottom in August, which may have been the result of disturbed sediment and increased particulates. pH values were mostly within normal ranges during all monitoring events, with surface values varying between 6.56 to 8.80.

Table 235. 2022 In-Situ Monitoring for Farm Crest Acres Lake

***In-Situ* Monitoring for Farm Crest Acres Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/24/2022	Farm Crest Acres - South	3.5	2.1	0.0	20.90	537.43	8.69	99.99	7.33
				1.0	20.70	536.03	8.70	99.67	7.26
				2.0	17.53	556.48	6.75	72.18	7.05
				3.0	14.82	572.51	0.67	6.11	6.67
5/24/2022	Farm Crest Acres - North	1.7	1.7+	0.0	20.88	537.50	8.78	100.83	7.26
				0.5	20.86	536.63	8.78	100.40	7.25
				1.0	20.84	536.65	8.79	100.88	7.25
				1.5	20.47	521.70	8.58	97.45	7.17
8/2/2022	Farm Crest Acres - South	3.9	1.8	0.0	26.45	536.99	6.69	86.26	7.63
				1.0	25.31	534.70	6.11	77.40	7.55
				2.0	24.98	535.00	6.16	77.40	7.41
				3.0	23.96	546.53	0.34	2.69	6.65
				3.5	20.58	818.58	0.01	0.13	6.56
8/2/2022	Farm Crest Acres - North	1.8	1.6	0.0	26.01	537.93	7.25	92.92	7.59
				0.5	25.54	535.33	6.88	87.44	7.59
				1.0	25.31	534.38	6.78	86.09	7.56
				1.5	24.99	533.66	6.93	87.07	7.52
10/10/2022	Farm Crest Acres - South	3.5	3.4	0.0	13.75	493.03	10.29	101.88	8.14
				1.0	13.26	493.22	10.15	99.29	7.98
				2.0	13.07	493.98	10.16	99.10	7.79
				3.0	12.99	494.40	10.08	98.08	7.71
10/10/2022	Farm Crest Acres -North	1.8	1.8+	0.0	14.54	494.41	10.41	105.15	7.76
				0.5	14.50	493.92	10.38	104.53	7.78
				1.0	13.88	492.83	10.53	104.93	7.89
				1.5	13.59	491.09	12.77	127.65	8.80

Discrete Water Quality

Surface TP concentrations were low during each event throughout the 2022 season in Farm Crest Acres. Concentrations were 0.01 mg/L in June, August and October. Deep TP concentrations were higher than the surface in June and August, with concentrations of 0.02 mg/L and 0.13 mg/L, respectively. The increase in deep TP was the only example of excessive phosphorus in 2022 at Farm Crest Acres. SRP concentrations showed minimal changes during the three monitoring events and varied between 0.001 mg/L and 0.002 mg/L (June surface sample). There was not a spike in SRP in the deep sample in August as there was with TP.

Surface chlorophyll *a* concentrations also remained low through the growing season, with measures ranging from 1.3 µg/L to 4.0 µg/L. The deep sample in August had a chlorophyll *a* concentration of 390.0 µg/L. This is very high and suggests sample contamination resulting in an erroneously high concentration. Causes for this contamination may have been plant debris, sediment or filamentous algae within the sample. TSS was likewise low for the majority of the monitoring events but was also extremely high in the deep sample in August. Outside of this sample, TSS concentrations varied between 1 mg/L and 2 mg/L; however, the deep sample had a concentration 150 mg/L in August. This spike further supports that there was sample contamination, and similarly suggests the influence may have been a combination of sediment and organic material.

Nitrate-N concentrations in the surface samples varied from 0.01 mg/L in August to 0.25 mg/L in June. Deep concentrations where highest in August at 0.37 mg/L and lowest at 0.04 mg/L in October. The elevated concentration in the August deep sample further indicates sample contamination, likely resulting from disturbed sediment at the bottom of the lake. Ammonia-N concentrations at the surface were 0.05 mg/L in June and August and 0.16 mg/L in October. The deep concentrations were 0.13 mg/L in June, 0.05 mg/L in August and 0.22 mg/L in October. The nitrogen parameter concentrations were within normal ranges for a healthy lake.

Plankton and Macrophytes

Generally, SAV abundance was low throughout Farm Crest Acres during the site visits. Plant density appeared to be well managed and there were no visual issues. The only noted plant species were water starwort (*Callitriche sp.*) along the northern edge of the lake and some northern snail seed pondweed (*Potamogeton spirillus)*. Overall, there was no nuisance or problematic SAV growth noted. Similarly, no nuisance algal growth was observed during any of the monitoring events.

Farm Crest Acres had a high plankton community richness in August which consisted of 22 identified phytoplankton genera and 11 identified zooplankton genera. Some of the most common genera from the August sample include the dinoflagellate *Ceratium* and the euglenoid *Trachelomonas*. The zooplankton community in August commonly featured copepod *nauplii* and the rotifer genus *Asplancha,* and also had good representation by the other families. In October, the community richness had decreased to 11 phytoplankton genera and 10 zooplankton genera. Zooplankton identified were once again well distributed amongst the three main groups, with one of the most common genera being the copepod *Skistodiaptomus*. Phytoplankton genera in October were largely diatoms, including *Stephanodiscus*.

FOREST HILL LAKE

In-situ Water Quality

Forest Hills Lake was sampled on 20 May, 25 July and 3 October during the 2022 growing season. Water clarity was fair during the monitoring events, with Secchi depths varying from 1.0 m at both stations in July to 1.5 m at both stations in May. A decline in water clarity during the peak growing season months of June, July and August can be expected, as phytoplankton and filamentous algae densities are generally at their highest. Temperatures in May ranged from 16.35 °C to 19.81 °C, and by July temperatures had risen to between 25.43 °C and 29.31 °C. This is reflective of the very hot and dry July in 2022, which lead to lower flushing rates and increased heat accumulation in the epilimnion. A pronounced thermocline is present at the South station in July, indicated by the rapid temperature drop in the bottom portion of the waterbody.

Specific conductance values were within normal ranges at both stations during all three events. The water column throughout the lake was often well oxygenated, and DO concentrations were as high as 10.58 mg/L in May at the South station. The bottom meter of the water column at the South station in July was the only instance where anoxia was measured; concentrations were as low as 0.04 mg/L. Low DO concentrations were also observed in May at the South station when the DO was 2.93 mg/L at 3.5 m. DO concentrations at these concentrations are often detrimental to the aquatic organisms in the lake, such as fish and zooplankton. pH values were within normal ranges during all monitoring events, with surface values varying between 7.01 to 8.51. In summary, Forest Hill Lake in 2022 had moderate water clarity and sufficient DO concentrations with the exception of deep-water anoxia in July, with pH, temperature, and specific conductance levels all within acceptable ranges for aquatic life.

Table 236. 2022 In-Situ Monitoring for Forest Hill Lake

***In-Situ* Monitoring for Forest Hill Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/20/2022	Forest Hill Lake - South	4.0	1.5	0.0	19.54	196.16	10.58	118.06	8.43
				1.0	19.27	195.93	10.53	116.90	8.43
				2.0	19.06	195.83	9.96	110.64	8.25
				3.0	18.04	194.52	7.08	74.90	7.81
				3.5	16.35	198.03	2.93	30.34	7.46
5/20/2022	Forest Hill Lake - North	2.8	1.5	0.0	19.81	197.18	10.37	116.29	8.40
				0.5	19.41	196.90	10.44	116.07	8.45
				1.0	19.24	196.70	10.32	114.47	8.39
				1.5	19.18	196.98	10.21	113.20	8.33
				2.0	19.11	197.53	10.00	110.50	8.25
				2.5	19.07	198.28	9.97	110.21	8.19
7/25/2022	Forest Hill Lake - South	3.8	1.0	0.0	29.21	252.34	7.99	107.16	7.72
				1.0	29.28	252.03	7.20	93.78	7.67
				2.0	29.21	251.68	6.40	85.98	7.57
				3.0	28.06	259.44	0.58	7.54	7.14
				3.5	25.43	287.76	0.04	0.29	7.01
7/25/2022	Forest Hill Lake - North	2.7	1.0	0.0	29.31	252.27	8.38	112.51	8.03
				1.0	29.24	252.29	7.59	101.13	7.85
				2.0	29.22	252.54	7.30	97.81	7.73
				2.5	29.11	256.93	5.88	78.49	7.54
10/3/2022	Forest Hill Lake - South	3.9	1.1	0.0	16.02	281.11	9.93	102.14	8.37
				1.0	16.10	280.74	9.86	101.85	8.51
				2.0	16.14	280.39	9.83	101.40	8.54
				3.0	16.11	280.84	9.80	100.83	8.59
				3.5	16.11	281.31	9.76	99.78	8.51
10/3/2022	Forest Hill Lake - North	2.5	1.2	0.0	15.71	284.05	9.92	101.17	8.38
				0.5	15.99	282.89	9.78	100.32	8.48
				1.0	16.00	283.04	9.72	99.49	8.49
				1.5	15.99	283.21	9.61	98.60	8.47
				2.0	15.99	282.95	9.57	98.58	8.48

Discrete Water Quality

TP concentrations varied between 0.02 mg/L to 0.05 mg/L during the 2022 events. Concentrations were highest in July at 0.04 mg/L at the surface and 0.05 mg/L in the deep sample. This increase in concentration corresponds with the anoxic conditions that were occurring in the southern portion of the lake. Without sufficient DO concentrations, the chemistry within the sediment along the bottom changes, resulting in the release of phosphorus.

SRP concentrations in all collected samples were below the recommended threshold of 0.005 mg/L. This is a positive sign for the lake, as SRP is the form of phosphorus that is most readily available for biological assimilation. Concentrations were below the minimum limit of detection (<0.002 mg/L) in May and July. In October, concentrations were 0.003 mg/L at the surface and 0.004 mg/L at the bottom.

Chlorophyll *a* concentrations ranged between 6.7 µg/L to 36.0 µg/L. Concentrations in May were 14.0 µg/L at the surface and 6.7 µg/L at the bottom. In July, there was a decrease in the surface concentration to 7.7 µg/L, and an increase at the deep sample to 36.0 µg/L. In October, concentrations increased at the surface to 14.0

µg/L and decreased at depth to 16.0 µg/L. Surface concentrations never exceed the recommended threshold and suggests that biological productivity was not at nuisance levels in the lake.

Nitrate-N concentrations in Forest Hill Lake ranged from 0.02 mg/L to 0.13 mg/L during the 2022 monitoring events. Nitrate-N levels were 0.02 mg/L at the surface and at depth in May. The deep sample in July yielded a concentration of 0.13 mg/L. Concentrations were 0.04 mg/L at the surface in October and 0.05 mg/L in the deeper portion of the water column. These concentrations, including the higher value in July, are well within the normal range for nitrate.

Ammonia-N values in Forest Hill Lake ranged between below the lab detection limit of 0.01 mg/L, up to 0.35 mg/L in 2022. Concentrations were below the detection limit at both stations in May. In July, the surface concentration had risen to 0.02 mg/L, while the deep likewise increased to 0.35 mg/L. This deep concentration suggests increased ammonification paired with decreased nitrification. Without sufficient DO, the process that naturally converts ammonia to nitrate is disrupted, resulting in the accumulation of ammonia. In October, ammonia-N levels were 0.08 mg/L at the surface. The deep concentration during this time was lower than the July sample at a concentration of 0.09 mg/L, the result of DO returning to normal levels throughout the water column.

TSS values ranged from 1 mg/L to 10 mg/L during the three monitoring events. In May, concentrations were 5 mg/L at the surface and 1 mg/L near the bottom. Surface concentrations dropped in July to 1 mg/L, while the deep concentration rose to 10 mg/L. Concentrations were 8 mg/L at the surface in October and 9 mg/L in the deep sample. These TSS values are within the recommended range for visual aesthetic and lake health.

Plankton and Macrophytes

During the May event, the most prevalent SAV species within the shallow areas was curlyleaf pondweed (*Potamogeton crispus*). This invasive species is not native to New Jersey but has become very prevalent in many lakes throughout the state. Curlyleaf pondweed often displaces native species, resulting in nuisance conditions when present in high densities. In July, the presence of brittle naiad was observed along the western shoreline of the lake and white water lily scattered throughout the nearshore areas. In October, the white water lily and curlyleaf pondweed were still present along the western shore, as well as leafy pondweed. No nuisance filamentous algae were observed during the monitoring events. There is an aeration system within the lake that may help with minimizing the presence of algal formation through the reduction of stagnant water conditions.

Forest Hill Lake had a consistent balance of zooplankton and phytoplankton during each of the three monitoring events in 2022. In May, there were 10 phytoplankton genera and 8 zooplankton genera identified, 11 phytoplankton genera and 8 zooplankton genera in July, and 10 phytoplankton genera and 7 zooplankton genera in October. Zooplankton generally had good representation across the three main zooplankton groups. Common zooplankton genera included *Bosmina*, *Microcylops* and *Gastropus*. The phytoplankton community was predominantly diatoms in the May event, followed by a shift to green algae and cyanobacteria dominance in the later events. Common phytoplankton genera included the cyanobacteria genus *Microcystis* in October and the green algae genera *Mougeotia* and *Spirgya*.

GORDON LAKE

In-situ Water Quality

Clarity values at Gordon Lake were good in May, with Secchi depths extending to the lake bottom at both stations; 1.6+ m at the North station and 2.8+ m at the South station. By August, however, clarity values had decreased to less than 1.0 m at both stations, with Secchi depths of 0.7 m at the North station and 0.9 m at the South station. Secchi values were similar in October, with a depth of 1.0 m at the North station and 0.8 m near the dam.

Temperatures measured during the May sampling showed a mixed water column at the South station, with temperatures between 18.56 °C and 17.44 °C over the course of 2.5 m. Temperatures had risen in August, which lead to the formation of a thermocline at the South station, with temperatures between 25.87 °C at the surface and 22.95 °C at 2.5 m. Temperatures were the coolest of the three monitoring events during October, varying between 11.86 °C and 12.58 °C at both stations.

DO concentrations measured in May showed a well oxygenated water column, with concentrations between 10.26 mg/L and 10.42 mg/L at the North station, and 10.08 mg/L to 12.34 mg/L at the South station. In August, DO concentrations declined at both stations, including anoxic conditions at the bottom of the water column at the South station. DO concentrations at the North station in August fluctuated from 7.34 mg/L at the surface to 1.81 mg/L at 2.0 m. The South station profile had values between 7.53 mg/L at the surface to 0.05 mg/L at 2.5 m. DO concentrations dropped rapidly below a depth of 1.0 m at both stations in August, indicating high biological oxygen demand. By October, DO concentrations had returned to well oxygenated conditions, with concentrations between 10.07 mg/L and 10.51 mg/L.

Specific conductivity values were within the normal range and varied between 155.91 µS/cm and 285.34 µS/cm during the 2022 monitoring events. pH values were also within normal ranges during each event, ranging between 6.84 and 8.71.

Table 237. 2022 In-Situ Monitoring for Gordon Lake

***In-Situ* Monitoring for Gordon Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/20/2022	Gordan Lake -North	1.6	1.6+	0.0	18.86	159.44	10.27	114.35	7.87
				0.5	18.84	159.41	10.26	113.75	7.90
				1.0	18.85	159.41	10.29	114.00	7.85
				1.5	18.83	159.49	10.42	115.46	7.96
5/20/2022	Gordan Lake - South	2.8	2.8+	0.0	18.56	160.46	10.08	111.81	7.81
				0.5	18.49	160.11	10.36	113.92	7.84
				1.0	18.40	155.91	10.33	113.26	7.88
				1.5	18.28	158.81	10.30	112.58	7.80
				2.0	18.12	163.36	10.23	111.00	7.75
				2.5	17.44	159.60	12.34	135.55	8.71
8/1/2022	Gordan Lake - North	2.3	0.7	0.0	26.09	202.43	7.34	93.41	7.61
				0.5	26.09	202.44	7.35	93.29	7.60
				1.0	26.04	202.19	7.19	91.09	7.58
				1.5	25.80	202.04	3.57	43.02	7.20
				2.0	25.77	206.14	1.81	21.48	6.95
8/1/2022	Gordan Lake - South	2.9	0.9	0.0	25.87	202.56	7.53	95.21	7.59
				1.0	26.08	202.40	7.33	93.05	7.58
				2.0	25.16	212.28	1.22	12.23	7.03
				2.5	22.95	285.34	0.05	0.54	6.84
10/6/2022	Gordan Lake - North	2.3	1.0	0.0	12.42	217.66	10.35	99.87	7.72
				1.0	11.96	218.62	10.36	98.66	7.60
				2.0	11.86	219.12	10.13	96.40	7.51
10/6/2022	Gordan Lake - South	2.8	0.8	0.0	12.58	217.49	10.51	101.47	7.47
				1.0	12.07	217.37	10.32	98.56	7.49
				2.0	11.96	217.61	10.08	95.92	7.46
				2.5	11.94	217.64	10.07	95.93	7.42

Discrete Water Quality

TP concentrations varied between 0.02 mg/L and 0.04 mg/L during the 2022 events. Concentrations were highest in July at 0.04 mg/L at the surface and 0.03 mg/L in the deep sample. This increase in concentration corresponds with the anoxic conditions that were occurring in the southern portion of the lake. Without sufficient DO concentrations, the chemistry within the sediment along the bottom changes, resulting in the release of phosphorus. It should be noted, however, that the deep water quality sample did not at any point display a higher concentration of total phosphorus than the surface sample. All TP concentrations in Gordon Lake were below the NJDEP threshold, indicating that phosphorus concentrations are within normal ranges.

SRP concentrations were generally below the recommended threshold of 0.005 mg/L. Concentrations were below the minimum limit of detection (<0.002 mg/L) in May and July. In October, concentrations were 0.001 mg/L at the surface and 0.007 mg/L at the bottom. The deep sample in October was the only sample above the recommended threshold for SRP during the year.

Chlorophyll *a* concentrations ranged between 1.4 µg/L and 44.0 µg/L. Concentrations were 7.0 µg/L in May at the surface and 1.4 µg/L near the bottom. In July, there was considerable increase in both surface and deep samples, with concentrations of 22.0 µg/L and 44.0 µg/L, respectively. This increase corresponds with the reduced Secchi depths and suggests increased phytoplankton densities within the water column. In October, concentrations increased at the surface to 37.0 µg/L, and decreased at depth to 30.0 µg/L. These elevated chlorophyll *a* values indicate that biological productivity was high at times in 2022 and was negatively impacting water clarity.

Nitrate-N concentrations ranged from 0.03 mg/L to 0.24 mg/L during the 2022 monitoring events. Nitrate-N levels were 0.03 mg/L in the surface and deep samples in May. The deep sample in July yielded a concentration of 0.24 mg/L. Concentrations were 0.12 mg/L at the surface in October and 0.09 mg/L in the deeper portion of the water column. These concentrations, including the higher value in July, are still within the normal range for nitrate.

Ammonia-N values ranged between 0.02 mg/L and 0.35 mg/L in 2022. Concentrations were high in May, with measured values of 0.35 mg/L in both surface and deep samples. In July, the surface concentration had fallen to 0.02 mg/L, while the deep concentration likewise decreased to 0.04 mg/L. Concentrations in October were consistent with those in July: 0.02 mg/L at the surface and 0.04 mg/L at the deep station.

TSS values ranged from 2 mg/L to 11 mg/L during the three monitoring events. In May, concentrations were low: 3 mg/L at the surface and 2 mg/L near the bottom. Surface concentrations rose in July to 11 mg/L, while the deep concentration rose to 4 mg/L. Concentrations were 9 mg/L at the surface in October and 2 mg/L in the deep sample. These TSS values are within the recommended range for visual aesthetic and ecological health.

Plankton and Macrophytes

The primary focus of the monitoring was at the lower lake during 2022. Within the upper lake there was visible white water lily, spatterdock and Eurasian watermilfoil. At the lower lake, white water lily was present in the shallow areas, with some fragments of fanwort (*Cabomba caroliniana*) observed in May. In August, observations were similar, with white water lily again observed in the nearshore areas, as well as fanwort fragments. Additionally, spatterdock was present in the northeast corner of the lake. In October, no new plant observations were made.

There were benthic algae along the bottom of the lake near the dam in May but no additional filamentous algae was noted during 2022. In October, there was cyanobacteria accumulation observed at the top of the water column throughout the lake.

In May, there were ten phytoplankton genera and seven zooplankton genera identified. In August, 7 phytoplankton genera and 8 zooplankton genera were observed, and 6 phytoplankton genera and 9 zooplankton genera were observed in October. Zooplankton generally had good representation across the three main zooplankton groups, with the cladoceran genera *Bosmina* and *Daphnia* noted as common, as well as the copepod genus *Microcyclops* and rotifer genus *Conochilus*. The phytoplankton community was predominantly dominated by cyanobacteria in May, including the genera *Dolichospermum* and *Aphanocapsa*.

HIGH CREST LAKE

In-situ Water Quality

High Crest Lake had good water clarity during the 2022 monitoring events, with all Secchi depths above the recommended threshold of 1.0 m. Water clarity was highest in May, where the South and North stations had Secchi depths of 2.3 m and 2.2 m, respectively.

Temperatures were variable during the three monitoring events, and the water column was thermally stratified at the South station in May and July. Temperatures in the lake during the May event ranged between 14.08 °C and 18.79 °C. Peak water temperatures rose to 29.31 °C in July and cooled to between 15.14 °C to 15.91 °C in October.

DO concentrations measured at both stations in May show a well oxygenated water column in the upper 3.0 m, followed by a rapid decrease to anoxic conditions below this depth. The same was true at the South station in July, where DO concentrations dropped from 8.53 mg/L at the surface to 0.02 mg/L at 4.5 m. This period of low oxygen concentration at the bottom of the lake can result in increased phosphorus release from the sediment, and subsequently an increase in algal growth, leading to poor water clarity and conditions.

Specific conductivity values were within the normal range and varied between 277.70 µS/cm and 353.81 µS/cm during the 2022 monitoring events. pH values were also within normal ranges during each event, ranging between 6.73 and 8.55.

Table 238. 2022 In-Situ Monitoring for High Crest Lake

In-Situ Monitoring for High Crest Lake 2022

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/20/2022	High Crest Lake - South	4.9	2.3	0.0	18.79	280.48	10.65	116.87	8.40
				1.0	18.74	280.16	10.64	116.56	8.45
				2.0	18.69	280.26	10.54	115.20	8.40
				3.0	17.33	277.70	10.16	108.07	8.13
				4.0	14.96	279.62	3.86	37.83	7.68
				4.5	14.08	282.97	0.96	9.45	7.18
5/20/2022	High Crest Lake - North	3.1	2.2	0.0	18.79	280.93	10.85	118.97	8.42
				1.0	18.75	280.24	10.77	117.84	8.45
				2.0	18.63	280.77	10.49	114.55	8.30
				3.0	17.88	281.11	7.22	77.71	7.81
7/25/2022	High Crest Lake - South	4.9	2.0	0.0	29.20	306.34	8.53	114.06	8.44
				1.0	29.21	306.15	8.34	111.47	8.55
				2.0	29.11	305.68	7.77	105.72	8.32
				3.0	27.74	299.72	3.50	45.04	7.71
				4.0	23.78	305.35	0.16	1.81	7.19
				4.5	21.92	353.81	0.02	0.18	6.73
7/25/2022	High Crest Lake - North	2.8	2.0	0.0	29.25	308.38	8.29	110.90	8.44
				1.0	29.31	308.22	8.11	108.47	8.41
				2.0	29.10	308.22	7.23	94.04	7.98
				2.5	29.02	309.31	4.30	56.29	7.57
10/3/2022	High Crest Lake - South	4.5	1.4	0.0	15.68	314.74	9.28	94.22	6.91
				1.0	15.87	314.55	9.24	94.28	7.27
				2.0	15.91	314.64	9.22	94.24	7.43
				3.0	15.88	314.42	9.23	94.61	7.54
				4.0	15.89	314.48	9.22	94.22	7.60
10/3/2022	High Crest Lake - North	2.3	1.5	0.0	15.31	322.44	9.48	95.92	7.55
				0.5	15.55	315.38	9.41	95.18	7.67
				1.0	15.56	314.96	9.39	95.36	7.73
				1.5	15.59	314.83	9.33	95.41	7.78
				2.0	15.14	314.95	9.23	92.61	7.79

Discrete Water Quality

TP concentrations varied between 0.01 mg/L and 0.08 mg/L during the 2022 events. Concentrations were highest at the deep station in July at 0.08 mg/L. This increase corresponds with the anoxic conditions that were occurring in the lake. Besides this spike in TP, all other samples were below the NJDEP threshold of 0.05 mg/L.

SRP concentrations in all collected samples were at or below the recommended threshold of 0.005 mg/L. Concentrations were below the minimum limit of detection (<0.002 mg/L) in May and July. In October, concentrations were 0.005 mg/L at the surface and 0.003 mg/L at the bottom. This late season increase may have been the result of fall turnover and the mixing of phosphorus from the hypolimnion to the epilimnion.

Chlorophyll *a* concentrations ranged between 2.1 µg/L and 53.0 µg/L. Concentrations were 4.9 µg/L in May at the surface and 9.3 µg/L near the bottom. In July, there was a decrease in the surface concentration to 2.1 µg/L, and an increase at the deep station to 53.0 µg/L. In October, concentrations increased at the surface to 16.0 µg/L and decreased at depth to 17.0 µg/L.

Nitrate-N concentrations ranged from 0.03 mg/L to 0.36 mg/L during the 2022 monitoring events. Nitrate-N levels were 0.05 mg/L at the surface and at depth in May. The deep sample in July yielded a concentration of 0.36 mg/L. Concentrations were 0.04 mg/L at the surface in October and 0.03 mg/L in the deeper portion of the water column. These concentrations are generally within the normal range for nitrate, although the concentration of 0.36 mg/L is slightly elevated. The elevated concentration in July may have been the result of organic matter decomposition or groundwater inputs to the lake.

Ammonia-N values ranged between 0.01 mg/L and 0.42 mg/L in 2022. Surface concentrations were low, with a concentration of 0.01 mg/L in May. In July, the surface concentration remained steady at 0.01 mg/L, while the deep concentration increased to 0.42 mg/L. This accumulation of ammonia supports the lack of oxygen, which, when present, allows for the chemical process of nitrification to occur; nitrification involves the conversion of ammonia to nitrate and nitrite. In October, ammonia-N levels increased at the surface, with a concentration of 0.08 mg/L. Deep concentrations were noticeable lower than in July, but still relatively elevated at 0.16 mg/L.

TSS values ranged from 1 mg/L to 10 mg/L during the three monitoring events. In May, concentrations were 1 mg/L at the surface and 6 mg/L near the bottom. Surface concentrations increased in July to 2 mg/L, while the deep concentration rose to 10 mg/L. The increased deep concentration supports the increased TP and ammonia-N concentrations, which are indicative of an anoxic hypolimnion and internal loading. TSS values were 5 mg/L at the surface in October and 2 mg/L in the deep sample. These TSS values are within the recommended range for visual aesthetic and lake health and correspond with the good Secchi depths.

Plankton and Macrophytes

Watershield was present in the shallow portion of the lake near the boat launch during all of the monitoring events in 2022. Watershield was also seen in the northern cove, most notably during the July monitoring event. Curlyleaf pondweed fragments were seen at the south station when collecting the deep sample in May. Tapegrass (*Vallisneria americana*) was also observed in the northern cove during July as well as near the launch area in dense quantities in October. The other SAV species noted were white water lily in the northern cove in July and sparse brittle naiad near the launch area in October.

There were some small accumulations of filamentous algae within the lake; however, this was only noted in May. Cyanobacteria was present throughout the lake, most notably during the October event.

High Crest Lake had a good balance of plankton genera richness during the 2022 season. In May, there were 8 phytoplankton genera and 4 zooplankton genera identified. In July, 8 phytoplankton genera and 12 zooplankton genera were identified. Finally, in October, 10 phytoplankton genera and 7 zooplankton genera were observed.

Zooplankton generally had good representation across the three main zooplankton groups, with the cladoceran genus *Bosmina* observed to be common, particularly in the early season. The phytoplankton community was predominantly diatoms during the May event, followed by a shift to green algae and cyanobacteria dominance in the later events. Common phytoplankton genera included the cyanobacteria genus *Microcystis* in October and the green algae genus *Mougeotia*. Cyanobacteria were notably the most abundant in the July sample, including the genera *Dolichospermum* and *Aphanocapsa*.

JOHNS LAKE

In-situ Water Quality

Clarity values at Johns Lake were good during each of the 2022 monitoring events, and were consistently at or above the recommended threshold of 1.0 m. In May, Secchi depths were 1.1 m at the South station and 1.4 m at the North station. By July, however, clarity values had decreased slightly to 1.1 m at the South station and 1.0 m at the North station. Secchi values were the highest in October, with a depth of 1.8+ m at the South station and 1.5+ m at the North station; this indicates that water clarity was to the bottom of the lake.

Temperatures during the May sampling showed a thermal gradient at the South station, with temperatures between 19.58 °C and 15.67 °C over the course of 2.0 m. Temperatures had risen in July, resulting in relatively uniform temperatures within the water column. Temperatures at the South station varied from 29.78 °C at the surface to 28.53 °C at 1.5 m, and the North station had a temperature of 29.39 °C at the surface and 28.57 °C at 1.5 m. Temperatures were the coolest of the three monitoring events during October, with temperatures varying between 14.12 °C and 14.22 °C within the lake.

DO concentrations within the lake in May were between 5.13 mg/L and 9.89 mg/L. In July, DO concentrations at the South station ranged from 6.74 mg/L at the surface to 3.05 mg/L at 1.5 m. While not hypoxic, DO concentrations around 3.00 mg/L can put stress on some organisms within the lake ecosystem, including fish and zooplankton. DO concentrations remained higher at the North station, ranging from 7.05 mg/L at the surface down to 6.01 mg/L at a depth of 1.5 m. By October, DO concentrations had returned to well oxygenated conditions, with concentrations between 8.73 mg/L and 9.14 mg/L.

Specific conductivity values were within the normal range and varied between 256.60 µS/cm and 408.99 µS/cm during the 2022 monitoring events. It is worth noting that conductivity increased with each successive sampling event. pH values were also within normal ranges during each event, ranging between 7.09 and 7.93.

Table 239. 2022 In-Situ Monitoring for Johns Lake

In-situ Monitoring for Johns Lake 2022

Date	Station	Depth (m) Total	Depth (m) Secchi	Sample	Temperature °C	Specific Conductance µS/cm	Dissolved Oxygen mg/L	Dissolved Oxygen % Sat.	pH S.U.
5/20/2022	Johns Lake -South	2.2	1.1	0.0	19.58	261.81	9.15	103.64	7.93
				0.5	18.93	265.01	9.89	108.82	7.91
				1.0	18.46	267.21	8.30	89.78	7.71
				1.5	17.82	260.73	8.88	96.13	7.63
5/20/2022	Johns Lake - North	1.5	1.4	2.0	15.67	256.60	5.13	51.42	7.30
				0.0	18.86	257.56	8.87	96.97	7.55
				0.5	18.71	258.69	8.50	93.94	7.52
7/25/2022	Johns Lake - South	2.0	1.1	1.0	18.32	261.48	7.38	79.83	7.40
				0.0	29.78	355.98	6.74	91.26	7.44
				0.5	29.21	356.50	6.57	88.00	7.43
				1.0	28.95	355.92	5.49	73.17	7.27
7/25/2022	Johns Lake - North	1.7	1.0	1.5	28.53	357.00	3.05	39.42	7.09
				0.0	29.39	358.17	7.05	94.72	7.44
				0.5	29.46	357.66	7.08	94.90	7.47
				1.0	28.93	357.75	6.76	90.51	7.46
10/3/2022	Johns Lake - South	1.8	1.8+	1.5	28.57	373.69	6.01	72.64	7.29
				0.0	14.17	407.01	9.13	90.14	7.80
				0.5	14.18	406.88	9.14	90.01	7.81
				1.0	14.19	406.83	9.13	90.09	7.81
				1.5	14.20	406.87	9.13	90.32	7.80
10/3/2022	Johns Lake - North	1.5	1.5+	0.0	14.12	408.99	8.83	87.25	7.64
				0.5	14.20	408.63	8.77	86.76	7.66
				1.0	14.22	408.59	8.73	86.31	7.69

Discrete Water Quality

TP concentrations varied between 0.01 mg/L to 0.04 mg/L during the 2022 events. Concentrations were the highest at both stations in July, with a concentration of 0.04 mg/L at the surface and at depth. Concentrations were low in October, with a concentration of 0.01 mg/L at the surface and 0.02 mg/L near the bottom. All TP concentrations in Johns Lake were below the NJDEP threshold and indicate that phosphorus concentrations are within normal ranges.

SRP concentrations in May and July were below the recommended threshold of 0.005 mg/L, with a concentration of 0.001 mg/L at both stations during those events. In October, concentrations were once again 0.001 mg/L at the surface, but the deep concentration had increased to 0.018 mg/L. The deep sample in October was the only sample above the recommended threshold for SRP during the year. This is an elevated SRP concentration.

Chlorophyll *a* concentrations ranged between 2.3 µg/L and 18.0 µg/L. Concentrations were 4.5 µg/L in May at the surface and 6.9 µg/L near the bottom. In July, there was an increase in both surface and deep samples, with concentrations of 9.4 µg/L and 18.0 µg/L, respectively. This increase corresponds with the reduced Secchi depths and suggests increased plankton productivity within the water column. In October, concentrations dropped to the lowest of the season: 2.3 µg/L at the surface and 2.4 µg/L near the bottom.

Nitrate-N concentrations ranged from 0.07 mg/L to 0.20 mg/L during the 2022 monitoring events. Nitrate-N levels were 0.20 mg/L at the surface and 0.17 mg/L at the deep station in May. Concentrations at both depths decreased in July, to 0.13 mg/l at the surface and 0.07 mg/L in the deeper part of the water column. By October, concentrations were 0.08 mg/L at the surface and at depth.

Ammonia-N values ranged between 0.04 mg/L and 0.35 mg/L in 2022. Concentrations were the same in May and July: 0.130 mg/L at the surface and 0.350 mg/L near the bottom. This elevated ammonia level near the surface can be a contributor of algal growth observed during the 2022 growing season. Concentrations in October were much lower than those in May and July, with a concentration of 0.040 mg/L at both stations.

TSS values ranged from 1 mg/L to 7 mg/L during the three monitoring events. In May, concentrations were the highest of the season at 7 mg/L at the surface and 4 mg/L near the bottom. Concentrations in July and October were consistently 1 mg/L. These TSS values are very positive and support good water quality as they are well within the recommended range.

Plankton and Macrophytes

During the early part of the growing season, curlyleaf pondweed was the most abundant SAV species noted within Johns Lake. It was observed in moderate densities and was present throughout much of the lake. By July, two other species were noted: brittle and slender naiad. By the end of the growing season in October, curlyleaf pondweed was the most commonly noted plant once again.

The only observations of algae growth were of benthic filamentous algae throughout the lake in July and October.

The plankton community at Johns Lake was diverse during the 2022 season. In May, there were 6 phytoplankton genera and 4 zooplankton genera identified. In July, 7 phytoplankton genera and 10 zooplankton genera were identified. Finally, 9 phytoplankton genera and 9 zooplankton genera were observed in October. Zooplankton generally had good representation across the three main zooplankton groups, with the copepod genus *Skistodiaptomus* being one of the most common genera in the samples. The phytoplankton community was predominantly represented by diatoms in the May event, followed by a shift to green algae dominance in the later events.

KITCHELL LAKE

In-situ Water Quality

Kitchell Lake had low water clarity in 2022 during the site visits in May, August and October. Only the May event at the North station achieved the 1.0 m minimum recommended threshold for Secchi depth, while all other values during the season were 0.8 m or 0.9 m.

Temperatures in the lake during the May event were between 19.56 °C and 21.26 °C. By August, temperatures had warmed, ranging between 26.75 °C and 27.05 °C. There was no thermal stratification present during the August monitoring. Temperatures had cooled by October, ranging between 12.15 °C and 19.70 °C.

DO concentrations throughout the lake were good during each of the three monitoring events, and no hypoxic or anoxic conditions were measured. Concentrations during the season fluctuated from 6.48 mg/L to 11.21 mg/L. The higher DO concentrations were recorded near the bottom in October and suggest plant growth and biological productivity.

Specific conductivity values were within the normal range and varied between 201.41 µS/cm and 523.13 µS/cm during the 2022 monitoring events. pH values were also within normal ranges during each event, ranging between 7.54 and 8.00.

Table 240. 2022 In-Situ Monitoring for Kitchell Lake

In-Situ **Monitoring for Kitchell Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/17/2022	Kitchell Lake- North	2.5	1.0	0.0	21.24	523.13	9.66	112.94	7.79
				0.5	21.26	519.24	9.61	112.98	7.78
				1.0	20.89	483.74	9.86	114.82	7.72
				1.5	19.99	478.81	9.94	113.63	7.68
				2.0	19.56	478.75	8.92	99.42	7.54
5/17/2022	Kitchell Lake - South	2.5	0.9	0.0	21.21	433.30	10.13	118.43	7.81
				0.5	21.23	433.48	10.16	118.69	7.81
				1.0	21.19	433.74	10.12	118.15	7.81
				1.5	20.83	434.68	10.15	117.60	7.81
				2.0	20.39	436.54	10.30	118.30	7.81
8/1/2022	Kitchell Lake - North	2.4	0.9	0.0	26.86	339.03	7.91	101.55	8.00
				0.5	27.01	337.31	6.84	88.37	7.66
				1.0	27.01	337.34	6.49	82.93	7.57
8/1/2022	Kitchell Lake - South	2.4	0.9	0.0	26.95	337.19	6.59	85.23	7.54
				0.5	26.91	337.09	6.48	82.99	7.51
				1.0	26.75	338.98	8.07	103.49	7.79
				1.5	27.05	338.06	7.95	102.42	7.77
10/6/2022	Kitchell Lake - North	1.7	0.9	0.0	14.68	304.1	11.15	112.13	7.77
				1.0	12.15	201.41	11.21	107.53	7.87
10/6/2022	Kitchell Lake - South	1.7	0.8	0.0	19.70	304.10	11.15	112.13	7.77
				1.0	12.29	301.41	11.21	107.53	7.87

Discrete Water Quality

Surface TP concentrations at Kitchell Lake varied between 0.02 mg/L in May and October, up to 0.04 mg/L in August. Deep TP concentrations were 0.02 mg/L in May and 0.03 mg/L in August and September. All TP concentrations were below the NJDEP threshold in 2022.

SRP concentrations in all collected samples were at or below the recommended threshold of 0.005 mg/L. Surface concentrations were highest in May at 0.004 mg/L, followed by a decline to below the lab detection limit of 0.002 mg/L for the remainder of the season. Deep SRP concentrations were below the detection limit for all three monitoring events.

Chlorophyll *a* concentrations ranged between 2.4 µg/L and 29.0 µg/L over the course of the monitoring season. Concentrations were 2.4 µg/L in May at the surface and 9.8 µg/L at depth. By August, concentrations had risen at both stations, to a concentration of 22.0 at the surface and 15.0 near the bottom. Concentrations increased again in October, resulting in the highest of the season at 27.0 µg/L and 29.0 µg/L at surface and depth, respectively. These concentrations indicate that there is planktonic growth that progressed over the course of the season.

Nitrate-N surface concentrations in Kitchell Lake ranged from 0.03 mg/L to 0.11 mg/L during the 2022 monitoring events. Deep concentrations of nitrate-N were 0.05 mg/L in May, 0.04 mg/L in August and 0.11 mg/L in October.

Ammonia-N values in Kitchell Lake ranged between 0.01 mg/L and 0.16 mg/L in 2022. With no anoxia measured in the lake, the conversion of ammonia to nitrate and nitrite resulted in little ammonia accumulation.

TSS values ranged from 1 mg/L to 7 mg/L during the three monitoring events. In May, concentrations were 2 mg/L at the surface and 1 mg/L near the bottom. Surface concentrations increased in August to 6 mg/L, while the deep concentration rose to 4 mg/L. TSS values were 5 mg/L at the surface in October and 7 mg/L in the deep sample. These TSS values are within the recommended range for visual aesthetic and lake health and correspond with the good Secchi depths.

Plankton and Macrophytes

SAV density at Kitchell Lake was very low during each of the 2022 monitoring events, with no SAV species being observed during each event. There was a planktonic cyanobacteria scum that had formed near the dam in October.

Kitchell Lake had a good balance of phytoplankton and zooplankton during the May sampling event, with 10 identified genera for each. These genera included zooplankton within the groups of rotifers, copepods, and cladoceran, and phytoplankton within the groups of green algae and diatoms. In August, there was a noticeable increase in the amount of the cyanobacteria genus *Dolichospermum,* as well as the diatom genus *Synedra*. The October event yielded 11 phytoplankton genera and 6 zooplankton genera. Some of the most common plankton identified were the phytoplankton genera *Dolichospermum* and *Fragilaria,* and the zooplankton genus *Bosmina*.

LINDY'S LAKE

In-situ Water Quality

Lindy's Lake had fair water clarity during the monitoring events in 2022, with Secchi depths between 1.2 m and 2.0 m. Secchi depths were the lowest in August, with measurements of 1.2 m at both stations. The South station in October had the highest Secchi depth at 2.0 m, which indicates good water clarity. It is worth noting that the blue coloration dye used at Lindy's Lake does impact the Secchi depth, and by extension the depth that light can penetrate within the water column.

Temperatures in May at the South station ranged from 21.73 °C at the surface to 7.30 °C at 7.0 m. This thermal stratification was present in May and August but had subsided by the October monitoring. The water column at the North station never exhibited thermal stratification and had very consistent temperatures from surface to bottom during each event. Temperatures at the South station in August ranged from 26.73 °C at the surface to 8.37 °C at 6.5 m. Thermal stratification reduces the ability for water to mix within the water column and can lead to DO depletion in the hypolimnion. Temperatures in October were the coolest of the monitoring events, with temperatures in the lake ranging between 12.51 °C and 14.00 °C.

The profiles measured at the North station showed a consistently well oxygenated water column during each of the monitoring events, with DO concentrations never falling below 6.33 mg/L. The South station, however, exhibited anoxia during the May and August sampling as a result of the previously mentioned thermal stratification. The DO profile in May went from 10.29 mg/L at the surface to 12.86 mg/L at 2.0 m, and then declined below this depth and became anoxic in the bottom 3.0 m of the water column. Similarly, in August, there was a rapid decrease in oxygen beneath the upper 2.0 m of the water column, becoming anoxic at 3.0 m. Anoxia was still present at the bottom of the water column at the South station in October, with DO concentrations falling from 9.41 mg/L at the surface to 0.35 mg/L at 5.5 m.

Conductivity levels were fairly high and varied between 782.78 µS/cm to 869.57 µS/cm. This indicates that there are a lot of ions within the lake which is reflective of runoff form the surrounding watershed. pH values were generally within normal ranges during all monitoring events. In May, however, the pH was as high at 9.26 at 2.0m. There was also a corresponding increase of DO at this location in the water column and suggests an early season accumulation of phytoplankton.

Table 241. 2022 In-Situ Monitoring for Lindy's Lake

In-Situ Monitoring for Lindy's Lake 2022

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/16/2022	Lindy's Lake - North	1.3	1.2	0.0	22.43	814.12	9.99	120.33	8.78
				0.5	22.16	811.76	9.87	117.65	8.78
				1.0	21.13	810.53	8.54	99.90	8.48
5/16/2022	Lindy's Lake -South	7.3	1.5	0.0	21.73	809.73	10.29	122.39	8.93
				1.0	19.41	803.30	12.20	139.80	9.17
				2.0	15.97	782.78	12.86	135.54	9.26
				3.0	13.27	788.42	12.13	120.77	8.85
				4.0	11.25	798.90	3.46	28.93	7.79
				5.0	9.50	793.90	0.90	5.55	7.50
				6.0	8.07	812.45	0.03	0.02	7.22
				7.0	7.30	825.28	0.00	0.00	7.22
8/2/2022	Lindy's Lake - North	1.3	1.2	0.0	26.31	868.20	6.62	85.48	8.08
				0.5	25.66	869.57	6.47	82.57	8.13
				1.0	25.36	867.55	6.33	80.63	8.10
8/2/2022	Lindy's Lake - South	6.7	1.2	0.0	26.73	869.50	6.79	88.15	8.33
				1.0	25.86	850.20	5.70	72.55	8.10
				2.0	24.94	861.17	4.69	58.65	7.81
				3.0	17.99	805.25	0.35	2.63	7.28
				4.0	14.67	796.83	0.01	0.08	7.06
				5.0	11.14	797.01	0.00	0.00	6.90
				6.0	8.96	822.95	0.00	0.00	6.70
				6.5	8.37	837.78	0.00	0.00	6.64
10/10/2022	Lindy's Lake - North	1.2	1.2+	0.0	13.87	823.64	9.70	96.23	7.93
				0.5	13.37	828.81	9.94	97.86	7.93
				1.0	13.33	863.11	9.99	98.22	7.86
10/10/2022	Lindy's Lake - South	5.8	2.0	0.0	14.00	836.51	9.41	93.45	7.83
				1.0	13.57	835.82	9.05	89.29	7.75
				2.0	13.41	835.46	8.75	86.13	7.68
				3.0	13.17	833.68	7.16	68.29	7.51
				4.0	12.94	832.79	5.56	53.1	7.38
				5.0	12.51	832.13	1.53	11.02	7.17
				5.5	12.81	831.07	0.35	2.92	7.06

Discrete Water Quality

TP concentrations varied between 0.01 mg/L to 0.26 mg/L during the 2022 events. The August deep sample had the highest value of the season at 0.26 mg/L, and this is supported by the hypolimnetic anoxia occurring at that time. Without sufficient DO concentrations, the chemistry within the sediment along the bottom changes, resulting in the release of phosphorus. Surface concentrations never exceeded 0.02 mg/L, which is below the NJDEP threshold and beneficial for combating nuisance algal growth.

SRP concentrations in all collected samples were below the recommended threshold of 0.005 mg/L and never exceeded 0.002 mg/L. Concentrations were below the minimum limit of detection (<0.002 mg/L) for all samples in 2022 except for the deep station in October, which had a concentration of 0.002 mg/L.

Chlorophyll *a* concentrations ranged between 5.5 µg/L to 8.0 µg/L. Concentrations in May were 7.8 µg/L at the surface and 7.2 µg/L near the bottom. In July, there was a decrease in the surface concentration to 6.8 µg/L, and an increase at the deep station to 8.0 µg/L. In October, concentrations decreased again at the surface to

5.5 µg/L and at depth to 7.1 µg/L. Surface concentrations never exceed the recommended threshold of 20 µg/L which suggests that biological productivity was not at nuisance levels in the lake.

Nitrate-N concentrations in Lindy's Lake ranged from below the lab detection limit of 0.01 mg/L to 0.11 mg/L during the 2022 monitoring events. Nitrate-N levels were 0.10 mg/L at the surface and 0.11mg/L at the deeper station in May. The deep sample in August yielded a concentration of 0.02 mg/L; nitrate doesn't accumulate in the anoxic hypolimnion like phosphorus. Concentrations were 0.09 mg/L at the surface in October and 0.07 mg/L in the deeper portion of the water column.

Ammonia-N concentrations varied from below the lab detection limit of 0.01 mg/L, up to 0.07 mg/L in 2022. Concentrations in May were 0.01 mg/L at the surface and 0.07 mg/L near the bottom. In August, the surface concentration had risen to 0.05 mg/L while the deep had decreased to 0.03 mg/L. This deep concentration, paired with lower nitrate concentration, indicates that nitrogen levels are low within Lindy's Lake. In October, ammonia-N levels were lower at both stations; below the detection limit of 0.01 mg/L at the surface and 0.01 mg/L in the deeper water.

TSS values were measured at 1 mg/L in every sample during the 2022 sampling events. This indicates that there are not high concentrations of sediment, planktonic particulates or other organic matter within the water column.

Plankton and Macrophytes

Due to the blue dye that is used within Lindy's Lake, observing SAV is difficult throughout much of the waterbody. No noticeable SAV growth was noted during each of the monitoring events in 2022. The only growth noted was the presence of small amounts of benthic algae in the northern portion of the lake in all three site visits.

Lindy's Lake had a balance of phytoplankton and zooplankton diversity in May, with 7 genera identified for both. By July, the number of identified phytoplankton genera had risen to 24, with the green algae *Gloeocystis* being the most common. Twelve zooplankton genera were present in August, with the majority being various genera of rotifers. Community richness had decreased by October, with 11 genera of phytoplankton and nine genera of zooplankton. *Bosmina* was abundant in the October sample, as well as the diatom *Stephanodiscus*.

LAKE LOOKOVER

In-situ Water Quality

Lake Lookover had good water clarity in 2022, reflected by Secchi depths ranging between 1.2 m in August up to 2.5+ m in May. All Secchi depths were consistently above the recommended threshold of 1.0 m.

Temperatures measured during the May sampling showed a thermal gradient along the bottom of the water column at the North station, with temperatures between 20.16 °C and 17.85 °C over the course of 2.0 m. Temperatures had risen in August, creating a fairly uniform water column, with temperatures in the lake between 25.10 °C and 26.57 °C. Temperatures were the coolest of the three monitoring events during October, and temperatures varied between 11.04 °C and 11.80 °C.

DO concentrations within Lake Lookover never reached hypoxic or anoxic conditions. DO concentrations fluctuated between 4.35 mg/L and 10.40 mg/L during the three monitoring events.

Specific conductivity values were within the normal range and varied between 231.55 µS/cm and 273.35 µS/cm in May, August and October. pH values were also within normal ranges during each event, ranging between 7.01 and 7.61.

Table 242. 2022 In-Situ Monitoring for Lake Lookover

***In-Situ* Monitoring for Lake Lookover 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/17/2022	Lake Lookover - South	1.6	1.6+	0.0	19.94	268.98	8.51	97.78	7.55
				0.5	19.83	268.38	8.51	97.68	7.36
				1.0	19.56	270.09	8.63	98.47	7.30
				1.5	19.35	273.12	7.81	88.34	7.10
5/17/2022	Lake Lookover - North	2.5	2.5+	0.0	20.16	272.72	8.97	103.67	7.23
				0.5	20.16	273.00	8.96	103.15	7.28
				1.0	20.11	273.35	8.87	102.20	7.31
				1.5	19.93	273.33	8.92	102.94	7.32
				2.0	17.85	269.59	10.40	115.42	7.45
8/3/2022	Lake Lookover - South	1.5	1.2	0.0	26.57	240.97	6.71	86.72	7.61
				0.5	25.90	245.70	6.02	73.84	7.38
				1.0	25.44	245.01	5.38	67.22	7.24
8/3/2022	Lake Lookover - North	2.3	1.2	0.0	26.42	232.73	6.01	77.31	7.31
				1.0	25.60	238.38	5.79	73.39	7.18
				2.0	25.10	238.33	4.35	54.33	7.01
10/5/2022	Lake Lookover - South	2.0	2.0+	0.0	11.80	236.23	9.75	93.26	7.43
				1.0	11.78	236.39	9.69	92.82	7.43
				1.5	11.69	236.75	9.71	93.02	7.32
10/5/2022	Lake Lookover - North	1.5	1.5+	0.0	11.13	234.04	10.07	95.16	7.46
				1.0	11.04	231.55	10.11	95.48	7.42

Discrete Water Quality

TP concentrations were low during each event throughout the 2022 season at Lake Lookover. Concentrations were 0.01 mg/L in the surface and deep samples in May and August. In October, the surface TP concentration remained at 0.01 mg/L, while the deep sample had a concentration below the lab detection limit of 0.01 mg/L. SRP concentrations were also very low and were consistently below the lab detection limit of 0.002 mg/L for all samples. These results show that phosphorus concentrations are low within the lake, resulting in a reduced likelihood for nuisance algal or cyanobacteria growth.

Chlorophyll *a* concentrations were low during all three sampling events and ranged from 1.1 µg/L to 4.1 µg/L. These values indicate that biological productivity was low in 2022. TSS concentrations varied between 1 mg/L and 10 mg/L. The highest concentration was at the deep station in August. TSS concentrations were within the optimal range and support positive water clarity.

Nitrate-N concentrations gradually rose during each sampling event in 2022 and were equivalent at both the surface and deep concentrations for each event. Concentrations were 0.05 mg/L in May, 0.06 mg/L in August and 0.07 mg/L in October.

Ammonia-N concentrations at the surface were 0.05 mg/L in May, followed by a decline to 0.01 mg/L in August and 0.02 mg/L in October. The deep concentrations were 0.14 mg/L in May, 0.01 mg/L in August and 0.02 mg/L in October. The nitrogen parameter concentrations were within normal ranges for a healthy lake and were consistently low.

Plankton and Macrophytes

Lake Lookover is a high density SAV system that is made up of a variety of different species. The composition of the plant communities and their distribution throughout the lake do not pose apparent challenges to the health of the lake system but may be present at densities that result in complaints.

During the May event, benthic green algae was noted in the shallow regions of the lake. Watershield and white water lily were also present in these shallow areas and were slightly more prevalent in the southern portion of the lake. Fanwort and common bladderwort (*Utricularia vulgaris*) were noted as present on the anchor at the South station. Shallower areas north of the beach had low abundances of leafy pondweed (*Potamogeton foliosus*) and low-water milfoil (*Myriophyllum humile*), neither of which were problematic. Observations were similar in August, with the highest concentration of SAV growth located within the shallower areas. Common species noted were fanwort, low-water milfoil, common bladderwort, white water lily, watershield and several native pondweeds. By October, the density of plants had generally reduced; however, there was still dense fanwort in the near shore areas as well as white water lily.

The plankton community at Lake Lookover showed a progression of genera richness during the 2022 season. In May, there were 4 phytoplankton genera and 9 zooplankton genera identified. In August, 22 phytoplankton genera and 10 zooplankton genera were identified. Finally, 14 phytoplankton genera and 9 zooplankton genera were observed in October. Zooplankton generally consisted of copepods and rotifers, with calanoid copepods and copepod nauplii being some of the most prevalent. The phytoplankton community was generally represented by green algae, with some cyanobacteria genera identified as well. The green algae *Pediastrum* and *Ankistodesmus* were frequently identified throughout the year, and the cyanobacteria genus *Aphanocapsa* was observed with intermediate frequency.

LOWER MOUNT GLEN LAKE

In-situ water quality

Two sampling stations were analyzed at Lower Mount Glen Lake during the 2022 season, including a Dam and

South station. Sampling events took place on 24 May, 2 August and 10 October 2022. Surface temperatures were comparable across both sampling stations within Lower Mount Glen Lake throughout the 2022 season. Temperatures ultimately ranged between a minimum of 13.29 °C during October and a maximum of 26.29 °C during August. Thermal stratification was noted during both the May and August sampling events.

Surface dissolved oxygen (DO) was ample throughout the season, with concentrations ranging from 7.00 mg/L in October (Dam) to 8.75 mg/L in August (Dam). While thermal stratification was observed during the May event, DO remained abundant throughout the water column. Persistent thermal stratification through August affected oxygen concentrations in the deeper waters. The South station dropped from surface measures of 8.68 mg/L to 4.85 mg/L at 2.5 m, while the Dam station declined from 8.75 mg/L at the surface to a low of 0.06 mg/L at 4.0 m. Anoxic conditions (DO<1 mg/L) were established at 3.0 m at the Dam station during this event. The waterbody was well oxygenated throughout the water column by the October event.

Clarity within Lower Mount Glen Lake was adequate throughout the sampling season with Secchi measures consistently greater than 1.0 m. Secchi depth ultimately ranged between 1.3 m at both stations in August up to 2.8 m at both sampling stations in May. pH measures were relatively comparable at the South and Dam stations during each sampling event. Surface measures varied from a minimum of 7.17 at the Dam during October to a maximum value of 8.59 at the Dam during August. Highest pH measures were noted at the height of the summer, which can be attributed to the elevated cyanobacteria densities observed, with an abundance of *Lyngbya* and *Pseudanabaena*. pH declined slightly with depth during the May and October events, but sharper declines were observed in August due to anoxic conditions causing an increase in bacterial respiration.

Table 243. 2022 In-Situ Monitoring for Lower Mt. Glen Lake

***In-Situ* Monitoring for Lower Mt. Glen Lake 2022**									
Date	**Station**	**Depth (m)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
		Total	**Secchi**	**Sample**	**°C**	**µS/cm**	**mg/L**	**% Sat.**	**S.U.**
5/24/2022	Lower Mt. Glen - South	2.8	2.8+	0.0	21.50	366.79	7.89	91.60	7.54
				1.0	21.52	366.86	7.86	90.68	7.57
				2.0	19.32	356.21	7.91	87.66	7.53
				2.5	17.07	351.92	8.64	91.01	7.48
5/24/2022	Lower Mt. Glen - Dam	3.9	2.8	0.0	21.36	367.22	8.03	92.63	7.52
				1.0	21.41	366.57	7.74	89.53	7.53
				2.0	19.29	354.85	8.12	89.51	7.54
				3.0	16.03	347.66	8.24	83.98	7.52
				3.5	14.08	352.93	7.09	70.24	7.19
8/2/2022	Lower Mt. Glen - South	2.6	1.3	0.0	26.29	413.60	8.68	111.59	8.54
				1.0	25.96	413.07	8.59	109.52	8.52
				2.0	25.58	419.43	6.77	82.05	7.90
				2.5	24.99	420.62	4.85	58.20	7.42
8/2/2022	Lower Mt. Glen - Dam	4.2	1.3	0.0	26.27	413.17	8.75	112.53	8.59
				1.0	26.00	413.28	8.58	109.23	8.49
				2.0	25.60	409.96	7.83	95.11	7.91
				3.0	21.38	415.14	0.41	4.26	6.98
				4.0	18.05	562.82	0.06	0.75	6.85
10/10/2022	Lower Mt. Glen - South	2.5	2.4	0.0	13.77	431.84	7.95	75.28	7.44
				0.5	13.50	431.95	6.28	61.60	7.30
				1.0	13.42	432.06	6.29	61.68	7.24
				1.5	13.36	431.99	6.31	61.68	7.19
				2.0	13.29	432.18	6.28	61.42	7.15
10/10/2022	Lower Mt. Glen - Dam	3.6	2.7	0.0	13.73	432.35	7.00	67.73	7.17
				1.0	13.58	431.74	6.69	65.61	7.14
				2.0	13.41	431.96	6.67	65.38	7.12
				3.0	13.36	432.19	6.68	65.34	7.10
				3.5	13.34	432.49	6.67	65.20	7.07

Discrete water quality

Surface TP concentrations were consistently below the NJDEP surface water standard of 0.05 mg/L at Lower Mount Glen Lake during the 2022 season. Concentrations of 0.02 mg/L were measured during the first two sampling events before declining to 0.01 mg/L in October. Deep-water TP concentrations in May and October remained consistent with their surface counterparts, while concentrations spiked to 0.10 mg/L in August. This increase in TP can be attributed to the anoxic conditions noted in the bottom water causing internal loading of phosphorus. SRP concentrations were consistently low in the surface and deep water during each event, never exceeding the lab detection limit of 0.001 mg/L throughout 2022.

Chlorophyll *a* concentrations were low in the surface and deep water during both the May and October sampling events, with concentrations below 4.0 µg/L. The August event yielded peak seasonal chlorophyll *a* with surface measures of 17.0 µg/L and deep-water measure of 230.0 µg/L. A cyanobacteria bloom comprised of *Lyngbya*, a predominantly benthic genera, and *Pseudanabaena* was observed during this event. TSS concentrations followed a similar pattern, with the May and October events yielding concentrations of either 1 mg/L or 2 mg/L. The August event was characterized by a surface measure of 5 mg/L and a deep measure of 80 mg/L.

Nitrogen concentrations were highly variable throughout the 2022 season. Nitrate-N concentrations were highest during the May sampling event with a surface concentration of 0.45 mg/L and a deep concentration of 0.43 mg/L. Nitrate concentrations are often elevated early in the growing season, before productivity ramps up. Surface nitrate-N concentrations drastically declined to 0.005 mg/L by the August event, as the cyanobacteria bloom observed likely depleted this resource in the surface water. The surface concentrations increased to 0.21 mg/L by October. Deep-water concentrations declined as the season progressed, from a maximum concentration of 0.43 mg/L in May to a minimum concentration of 0.22 mg/L in October. Ammonia-N in the surface water was low during the first two sampling events, both yielding 0.02 mg/L. An increase to 0.60 mg/L was observed during the final event. Deep-water ammonia-N concentrations were similar to those noted in the surface, ranging between 0.03 mg/L and 0.53 mg/L. Both nitrogen parameters were elevated at times throughout the season.

Plankton and macrophytes

The phytoplankton community within Lower Mount Glen was healthy and diverse during the May sampling event, comprised of a mixture of 15 identified genera. The sample was dominated by the dinoflagellate *Gloeodinium*. By the August event, richness declined to 7 identified genera. The community was cyanobacteria dominated during this event, with both *Lyngbya* and *Pseudanabaena* listed as abundant. The October sampling event yielded a dense phytoplankton community with dominance shared by the diatom *Asterionella*, cyanobacteria *Aphanizomenon* and cryptomonad *Chroomonas*. The zooplankton community was healthy and diverse throughout the season, with identified genera ranging between 9 and 14 genera. The community often yielded an abundance of the cladoceran genus *Daphnia* and copepod nauplii and the genus *Diaptomus*.

Overall, macrophytes were observed in Lower Mount Glen Lake during the 2022 season but did not pose a problem for its intended use or health.

UPPER MOUNT GLEN LAKE

In-situ water quality

Two sampling stations were analyzed at Upper Mount Glen Lake during the 2022 season, including a Dam and Mid-Lake station. Sampling events took place on 24 May, 2 August and 10 October 2022. Surface temperature ranged between a minimum of 12.59 °C at the Mid-Lake station during October to a maximum of 24.45 °C at the Dam in August. Due to the shallow nature of this waterbody, thermal stratification was not observed at any point during the sampling season. The waterbody was well-mixed thermally at each sampling station. Surface DO was ample at each sampling station throughout the season. DO concentrations ranged from 5.86 mg/L at the Dam in August to 8.75 mg/L at the Mid-Lake station in May. Slight declines in DO were noted with depth at the majority of sampling events. DO was lowest during the August event, but only declined to minimum concentrations of 4.47 mg/L at 1.0 m, precluding anoxic conditions.

Secchi depths ranged from a low of 0.5 m to a high of 1.2 m. Secchi depth fell below the recommended 1.0 m threshold at the Mid-Lake station during May and August and at the Dam during August. pH remained relatively consistent across the 2022 sampling season, with measures ranging between 6.95 and 7.67. Slight declines were observed with depth during each event, but overall pH did not experience major variations. pH values remained within a healthy range throughout the season.

Table 244. 2022 In-Situ Monitoring for Upper Mt. Glen Lake

***In-Situ* Monitoring for Upper Mt. Glen Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/24/2022	Upper Mt. Glen - Dam	1.4	1.2	0.0	21.33	423.68	7.78	90.06	7.58
				0.5	21.45	422.92	7.74	89.57	7.59
				1.0	21.06	421.73	6.41	73.84	7.48
5/24/2022	Upper Mt. Glen - Mid-Lake	0.6	0.5*	0.0	20.74	417.33	8.75	99.68	7.67
				0.5	20.07	395.27	8.32	93.50	7.65
8/2/2022	Upper Mt. Glen - Dam	1.2	0.5	0.0	24.45	566.69	5.86	71.45	7.51
				0.5	24.40	567.30	5.77	71.57	7.45
				1.0	24.04	567.49	4.47	54.60	7.32
8/2/2022	Upper Mt. Glen - Mid-lake	1.0	0.5	0.0	24.32	575.83	6.06	75.02	7.52
				0.5	24.08	570.56	4.57	53.23	7.36
10/10/2022	Upper Mt. Glen - Dam	1.5	1.2	0.0	13.02	383.88	6.25	60.35	7.40
				0.5	12.73	384.34	6.15	59.36	7.25
				1.0	12.68	384.15	6.09	58.24	7.14
10/10/2022	Upper Mt. Glen - Mid-lake	0.8	0.8+	0.0	12.59	398.61	6.95	62.18	7.12
				0.5	12.22	391.92	5.33	50.29	6.95

*secchi covered by plants

Discrete water quality

Surface TP concentrations were measured within a wide range during the 2022 season, ranging from a minimum concentration of 0.02 mg/L in October to a maximum of 0.09 mg/L in August. Only the August event contravened the NJDEP surface threshold of 0.05 mg/L. Deep-water TP concentrations were relatively comparable to their surface counterparts, with concentrations between 0.02 mg/L and 0.10 mg/L. A slight increase in deep-water TP was observed in both the May and August events. SRP concentrations remained low in the surface water throughout the season, yielding concentrations of either 0.001 mg/L or 0.002 mg/L. Deep-water SRP was highest during the May event at 0.003 mg/L, before declining to 0.001 mg/L for the remainder of the season.

Chlorophyll *a* concentrations were lowest during the May sampling event, with a concentration of 1.3 µg/L noted in the surface and deep samples. Chlorophyll *a* spiked during the August sampling event to a surface measure of 48.0 µg/L and a deep-water concentration of 55.0 µg/L. This parameter declined back to lower concentrations by the final sampling event yielding 7.5 µg/L and 7.8 µg/L in the surface and deep samples, respectively. TSS concentrations were especially low during the May and October events, yielding measures of 1.0 mg/L at each sampling station and depth. Higher TSS concentrations up to 19.0 mg/L were noted during the August event.

Nitrate-N concentrations were relatively consistent at the surface and deep sampling depths during each sampling event. Lowest concentrations were noted during the August sampling event with a measure of 0.03 mg/L at the surface and deep. Nitrate-N concentrations increased to seasonal maximums during the October event, with a concentrations of 0.36 mg/L at the surface and 0.35 mg/L at depth. Surface ammonia-N concentrations increased as the season progressed, with a minimum concentration of 0.02 mg/L noted in May, increasing to a maximum concentration of 0.11 mg/L during October. Ammonia-N concentrations in the deep samples were relatively comparable to those at the surface during the first two sampling events; however, measures doubled compared to the surface during the October event (0.22 mg/L).

Plankton and macrophytes

The phytoplankton community within Upper Mount Glen Lake was relatively light in richness during the May event. A total of 7 genera were identified, made up of diatoms, chrysophytes, euglenoids, dinoflagellates and cryptomonads. Richness persisted through the August event; however, densities increased overall. The community was dominated by the euglenoid *Trachelomonas* with moderate densities of the diatom *Synedra* and the dinoflagellate *Ceratium*. Peak seasonal richness was observed during the October event, with 11 identified genera. Dominance was exerted by *Chroomonas* at this time. Low densities of cyanobacteria were noted during the 2022 season. Zooplankton richness was highest during the May event with 11 genera, before declining to 5 genera by the remaining two events. This lake was typically copepod dominant throughout the 2022 season, with an abundance of rotifers noted during the height of the season.

Upper Mount Glen Lake contained curlyleaf pondweed throughout the waterbody during the May sampling event. This growth was not observed by August, and the main plant growth was from spatterdock densities along the shorelines. Duckweed was observed along the southern shoreline during the August and October sampling events. A single water chestnut plant (*Trapa natans*) was identified along the southern edge during the May event.

MT. LAUREL LAKE

In-situ water quality

Two sampling stations were analyzed at Mt. Laurel Lake during the 2022 season, including an Upper and Lower station, which are located in the southern and northern portions of the lake, respectively. Sampling events took place on 17 May, 3 August and 13 October 2022. Surface temperatures ranged from 13.91 °C at the Upper station in October to 27.31 °C at the Lower station in August. Overall, the May sampling yielded a relatively mixed water column at both stations, only showing slight declines in the bottom half meter at the Lower station. A slight thermal gradient was noted at both stations during the August event. The October sampling event yielded a thermally mixed water column.

Surface DO concentrations varied across each sampling event, with a minimum concentration of 4.67 mg/L at the Upper station in August to maximum concentration of 10.24 mg/L at the Lower station in October. Both the May and October sampling events yielded a very well-oxygenated water column, while the August event showed more depressed concentrations, especially at the Upper station. While lower DO was noted, anoxic conditions were not identified during the 2022 season.

Clarity was consistently above the recommended threshold throughout the season at this waterbody, ranging from 1.3 m to 2.0 m. pH was consistently higher at the Lower station in comparison to the Upper station. Overall, the surface pH ranged between 7.20 and 8.13. Slight declines were noted with depth during all sampling events, with the exception of the Upper station during the May event, which experienced a very slight increase with depth.

Table 245. 2022 In-Situ Monitoring for Mt. Laurel Lake

***In-Situ* Monitoring for Mt. Laurel Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/17/2022	Mt. Laurel Lake - Upper	1.9	1.6	0.0	20.57	371.01	8.22	96.01	7.30
				0.5	20.58	371.04	8.22	95.93	7.31
				1.0	20.52	374.00	8.30	96.85	7.35
				1.5	20.05	387.98	8.35	95.71	7.39
5/17/2022	Mt. Laurel Lake - Lower	2.0	2.0+	0.0	20.09	415.99	10.19	117.59	8.13
				0.5	20.07	422.38	10.17	117.38	8.14
				1.0	19.64	426.80	10.07	114.64	8.00
				1.5	18.90	426.44	10.72	123.44	8.09
8/3/2022	Mt. Laurel Lake - Upper	1.4	1.3	0.0	26.81	358.30	4.67	60.48	7.20
				0.5	25.94	360.99	4.18	53.27	7.08
				1.0	25.38	358.99	3.90	48.95	6.97
8/3/2022	Mt. Laurel Lake - Lower	1.8	1.5	0.0	27.31	358.07	8.61	112.56	7.92
				1.0	26.29	358.15	8.22	106.15	7.72
				1.5	25.98	359.79	5.51	74.71	7.21
10/13/2022	Mt. Laurel Lake - Upper	1.6	1.6+	0.0	13.91	368.80	9.87	99.30	7.60
				0.5	13.70	369.84	9.83	98.62	7.47
				1.0	13.67	369.09	9.77	98.00	7.36
				1.5	13.71	368.81	9.61	96.53	7.25
10/13/2022	Mt. Laurel Lake - Lower	1.3	1.3+	0.0	14.37	378.26	10.24	104.27	7.95
				1.0	13.89	383.02	10.37	104.88	7.88

Discrete water quality

TP concentrations were low throughout the 2022 season in the surface water of Mt. Laurel Lake. Concentrations remained below the NJDEP standard of 0.05 mg/L during each event, with concentrations ranging between below the lab detection limit of 0.01 mg/L (October) and 0.01 mg/L (May and August). Deep-water TP concentrations yielded a slightly wider range, with measures ranging from below the lab detection limit of 0.01 mg/L to 0.03 mg/L. While a slight increase from 0.01 mg/L to 0.03 mg/L was noted during the August event, TP remained below recommended standards. SRP concentrations were consistent throughout the season, with concentrations below the lab detection limit of 0.002 mg/L at all sampled depths.

Chlorophyll a concentrations also remained low through the growing season, with measures ranging from 1.1 µg/L to 6.4 µg/L. Lowest chlorophyll a concentrations were noted during the May sampling, before increasing slightly by the remaining two events. TSS concentrations were especially low throughout the season. TSS remained between concentrations of 1 mg/L and 3 mg/L.

Overall, Mt. Laurel Lake is not considered a nutrient-rich lake based on the 2022 data. Nitrate-N concentrations were highest in the surface water in May, with a concentration of 0.07 mg/L. Nitrate-N declined to 0.04 mg/L at the surface and at depth by the August event. This measure persisted through the remainder of the season at the surface. Deep-water nitrate-N concentrations were comparable to their surface counterparts during the first two sampling events, before increasing to a seasonal maximum of 0.13 mg/L in October. Ammonia-N concentrations increased as the season progressed at both the surface and deep. Surface concentrations increased from below the lab detection limit of 0.01 mg/L in May to 0.04 mg/L in October, while deep-water ammonia-N spiked from below the detection limit to 0.60 mg/L.

Plankton and macrophytes

The phytoplankton community yielded moderate to high species richness throughout the season, ranging from 8 to 12 identified genera. The May sampling event was chrysophyte dominated with an abundance of *Dinobryon*. August densities were lower overall in comparison to the May event, but higher species richness was observed. Moderate cyanobacteria, chrysophytes and dinoflagellates were noted at this time. Peak densities were observed during the October event, with co-dominance shared by the chrysophytes *Dinobryon* and *Ochromonas* and cyanobacteria *Microcystis*. Zooplankton richness was relatively consistent throughout the 2022 season, yielding either 9 or 11 identified genera. A diverse mixture of cladocerans, copepods and rotifers were noted during each sampling event.

The southern basin of Mt. Laurel Lake (Known as Upper Mt. Laurel and located south of Warwick Turnpike) has extensive sedimentation and has extremely dense plant growth at the southern end. By the May sampling event, a variety of plant growth were observed, including Eurasian watermilfoil, spatterdock, fanwort, curlyleaf pondweed and leafy pondweed at the southern end of the lake, common bladderwort (*Utricularia vulgaris*) towards the middle deeper waters and some Eurasian watermilfoil and curlyleaf pondweed in the northern basin. A similar macrophyte community was observed during the remaining two events.

MOUNTAIN SPRINGS LAKE

In-situ water quality

Two sampling stations were analyzed at Mountain Springs Lake during the 2022 season, including a Dam and Mid-Lake station. Sampling events took place on 1 June, 25 July and 3 October 2022. Surface temperatures were consistent at both sampling stations during each sampling event. Surface temperatures ranged from a minimum of 14.16 °C at the Mid-Lake station in October to a maximum of 27.96 °C at the Dam station in July. A thermal gradient was present during the June event, with temperatures declining over 2.00 °C from 1.0 m to 2.0 m. A weak thermal gradient was observed at the Dam station during the July event, only dropping in the bottom half meter of the lake.

DO was highest during the June sampling event, with a maximum surface concentration of 7.75 mg/L measured. DO oscillated greatly throughout the water column, increasing steadily to measures greater than 10.00 mg/L at 1.5 m. DO declined overall during the July event, with surface concentrations ranging from 5.97 mg/L (Dam) and 6.44 mg/L (Mid-Lake). DO declined sharply in the bottom meter at the Dam and Mid-Lake station, with concentrations of 1.05 mg/L and 0.27 mg/L, respectively.

Clarity remained well above recommended thresholds during the 2022 sampling season. Secchi depths ranged from 1.6 m to 2.2 m or were clear to the sediments. Overall, surface pH ranged from measures of 6.98 to 7.87. pH was slightly higher at the Dam station during both the June and July sampling events. pH declined slightly with depth during each sampling event, but the poor DO concentrations noted in August led to sharper declines from surface measures. Surface pH measures ranged from 6.98 at the Mid-Lake station during July to 7.87 at the Dam station during June. pH values remained within a healthy range throughout the season.

Table 246. 2022 In-Situ Monitoring for Mountain Springs Lake

In-Situ Monitoring for Mountain Springs Lake 2022									
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
6/1/2022	Mountain Springs - Dam	2.5	2.0	0.0	23.16	86.69	7.75	93.38	7.87
				0.5	23.08	86.50	8.36	100.61	7.69
				1.0	22.47	86.18	9.98	118.51	7.63
				1.5	21.53	86.42	10.46	122.63	7.62
				2.0	20.32	92.75	9.42	106.98	7.48
6/1/2022	Mountain Springs - Mid-Lake	2.4	2.0	0.0	23.01	86.75	7.61	91.75	7.48
				0.5	23.14	86.70	7.39	90.17	7.41
				1.0	22.70	86.32	9.66	115.02	7.43
				1.5	21.40	88.26	10.01	116.94	7.38
				2.0	19.94	95.45	8.73	98.70	7.23
7/25/2022	Mountain Springs - Dam	2.0	1.6	0.0	27.96	95.39	5.97	78.76	7.33
				0.5	27.98	95.32	5.91	78.87	7.29
				1.0	27.97	95.23	6.01	79.47	7.18
				1.5	27.74	96.00	4.31	56.67	6.96
				1.8	26.66	100.54	1.05	9.13	6.66
7/25/2022	Mountain Springs- Mid-Lake	2.1	1.7	0.0	27.86	95.29	6.44	85.20	6.98
				0.5	27.96	95.12	6.38	84.56	6.39
				1.0	27.93	95.26	6.23	81.35	7.01
				2.0	27.71	112.04	0.27	112.06	6.61
10/3/2022	Mountain Springs - Dam	2.2	2.2+	0.0	14.16	91.76	7.74	77.06	6.99
				0.5	14.20	91.70	7.71	76.87	6.94
				1.0	14.21	91.64	7.70	76.83	6.96
				1.5	14.20	91.64	7.71	76.88	6.93
				2.0	14.19	91.65	7.71	77.05	6.92
10/3/2022	Mountain Springs - Mid-lake	1.5	1.5+	0.0	14.33	91.91	7.45	74.45	7.31
				0.5	14.36	91.64	7.43	74.17	7.25
				1.0	14.34	91.63	7.55	75.59	7.16

Discrete water quality

TP concentrations were consistently low throughout the 2022 season, ranging between 0.01 mg/L and 0.02 mg/L in both the surface and deep water. TP concentrations were well below the NJDEP standard threshold. SRP concentrations were low during the first two sampling events, yielding concentrations of below the lab detection limit of 0.002 mg/L at each sampling depth. By the October sampling, surface SRP remained low with concentrations of 0.002 mg/L; however, deep-water concentrations spiked to 0.009 mg/L.

The May sampling event yielded peak chlorophyll *a* concentrations, with a surface measure of 6.4 µg/L, and a higher measure of 9.0 µg/L in the deep water. This sampling event was accompanied by elevated cyanobacteria concentrations, explaining the increased concentrations in relation to the rest of the season. The remaining two sampling events yielded concentrations between 1.9 µg/L and 4.1 µg/L. TSS concentrations were especially low throughout the season, with concentrations of either 1 mg/L or 4 mg/L (October Surface).

Surface nitrate-N concentrations were low throughout the season, with peak concentrations of 0.04 mg/L noted during June and July declining to 0.03 mg/L in October. Deep-water nitrate-N yielded a higher range of 0.07

mg/L in June, declining steadily to 0.04 mg/L by October. Deep-water samples yielded higher nitrate concentrations than their surface counterparts. While nitrates declined, ammonia-N concentrations increased as the season progressed. The surface and deep water samples yielded concentrations below the lab detection limit of 0.01 mg/L during the June event, before increasing slightly to 0.01 mg/L in the surface water of the July event. Ammonia-N spiked to a peak concentration of 0.08 mg/L at the surface and 0.16 mg/L at the deep.

Plankton and macrophytes

The June sampling event was characterized by relatively low phytoplankton species richness with 6 identified genera. This community was dominated by the colonial cyanobacteria *Microcystis*, with moderate densities of a variety of genera including *Dinobryon*, *Trachelomonas* and *Ceratium*. Peak seasonal richness was observed during the August event with 19 identified genera. This sample was dominated by the diatom *Cyclotella*. Richness remained high during the final event but shifted back to a cyanobacteria-dominated community. The zooplankton community yielded a mixture of copepods, cladocerans and rotifers in moderate densities throughout the majority of the season. The July sampling event was comprised of a mixture of copepods and rotifers only.

Mountain Springs Lake was mainly comprised of a lightly populated macrophyte community and was not an area of concern during the 2022 season. Plants were not observed early on in the season in June. By the July event, leafy pondweed and common bladderwort were identified within the swim lanes in the lake, as emergent vegetation such as white water lily was observed along the northern corner. A relatively similar community persisted through the October event.

PINECLIFF LAKE

In-situ water quality

Two sampling stations were analyzed at Pinecliff Lake during the 2022 season, including a North and South station. Sampling events took place on 17 May, 26 July and 5 October 2022. Temperatures were relatively comparable across both sampling stations throughout the season. Surface temperatures ranged from minimum of 11.50 °C at the South station in October to 28.30 °C at the North station in July. Overall, the water column remained thermally mixed throughout the season, although a slight thermal gradient did form at the South station during the July event. Temperatures dropped less than 2° C from surface to the bottom during the July event. Ample DO was measured in the surface waters during each sampling event, ranging from 9.37 mg/L in May to 10.03 mg/L in October. The water column was mixed and well-oxygenated during both the May and October events. The July event was characterized by elevated DO in the surface waters, followed by steady declines with depth, dropping to a minimum concentration of 4.74 mg/L at the North station. Anoxic conditions were not observed at this waterbody during the 2022 season.

Water clarity was highest during the May sampling event, with both stations yielding Secchi depths of 1.5 m. Clarity declined below the recommended threshold of 1.0 m by July and remained below the recommended threshold through October, with Secchi depths ranging from 0.5 m and 0.9 m. Overall, visibility was poor at this lake. Surface pH measures varied considerably more than some of the other waterbodies, with minimum values of 7.39 at the North station in October to maximum values of 8.95 at the South station in July. The elevated measures in July were likely caused by increased green algae and cyanobacteria densities; pH values increase with increased photosynthetic activity. Slight declines in pH with depth were typically observed throughout the season.

Table 247. 2022 In-Situ Monitoring for Pinecliff Lake

In-Situ Monitoring for Pinecliff Lake 2022									
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/17/2022	Pinecliff - South	2.0	1.5	0.0	20.50	419.38	9.38	107.15	7.91
				0.5	20.48	419.47	9.37	107.30	7.91
				1.0	20.44	419.19	9.35	107.30	7.90
				1.5	19.86	419.31	9.05	101.30	7.83
5/17/2022	Pinecliff - North	2.8	1.5	0.0	20.88	415.16	9.52	109.61	8.09
				1.0	20.86	414.76	9.50	109.46	8.11
				2.0	20.82	415.19	9.47	109.11	8.09
				2.5	20.71	414.38	9.45	108.36	8.06
7/26/2022	Pinecliff - South	2.1	0.6	0.0	28.27	377.18	9.98	130.26	8.95
				0.5	28.09	375.15	9.50	124.58	8.86
				1.0	27.72	376.35	8.67	111.99	8.34
				1.5	26.57	382.09	7.09	79.15	8.04
				2.0	26.40	384.04	5.06	62.95	7.83
7/26/2022	Pinecliff - North	3.0	0.5	0.0	28.30	379.67	9.59	125.50	8.90
				1.0	27.58	379.64	6.93	89.73	8.25
				2.0	27.51	380.95	5.74	73.36	7.91
				2.5	27.13	381.07	4.74	58.84	7.54
10/5/2022	Pinecliff - South	2.3	0.9	0.0	11.50	396.66	10.03	93.41	7.84
				0.5	11.29	398.16	9.96	92.75	7.68
				1.0	11.27	398.07	9.96	92.97	7.58
				1.5	11.25	398.07	9.96	92.49	7.50
				2.0	11.24	398.05	9.93	92.29	7.47
10/5/2022	Pinecliff - North	2.9	0.5	0.0	11.79	395.58	9.37	88.29	7.39
				1.0	11.82	395.81	9.32	87.82	7.37
				2.0	11.78	396.25	9.26	87.27	7.34
				2.5	11.77	396.47	9.24	87.26	7.34

Discrete water quality

Surface TP concentrations increased from minimum measure of 0.02 mg/L in May to a maximum measure of 0.07 mg/L as the 2022 season progressed at Pinecliff Lake. The July sampling event yielded a surface concentration equal to the NJDEP standard but contravened that by October. Deep-water TP experienced a wider range of values, with the May event yielding a concentration of 0.03 mg/L and the July event yielding 0.10 mg/L. Anoxia was not observed during this sampling event that would indicate internal phosphorus loading; however, DO did experience sharp declines with depth. SRP concentrations were low in the surface water during each sampling event, yielding concentrations below the lab detection limit of 0.002 mg/L throughout the season. Deep-water SRP was highest during the May event with a measure of 0.004 mg/L before declining below the detection limit for the rest of the season.

Chlorophyll *a* concentrations were very low during the May sampling event, but spiked to a seasonal maximum of 51 µg/L in the surface water of the July event. Chlorophyll measures remained elevated throughout the water column. Elevated concentrations persisted through the final event, dropping slightly to 44 µg/L at the surface.

Similarly, the May sampling event yielded TSS concentrations of 3 mg/L at the surface and 2 mg/L at depth, which increased during the remainder of the season. Peak concentrations of 38 mg/L were observed in the deep waters of the July event, with TSS concentrations ranging between 31 mg/L and 36 mg/L in October.

Nitrate-N concentrations within Pinecliff Lake ranged between 0.06 mg/L in the surface water during July and 0.19 mg/L at the surface and deep in October. Deep-water nitrates yielded slightly higher concentrations than those noted at the surface. Ammonia-N concentrations were highly variable, with peak measures of 0.14 mg/L measured during the May sampling at both sampling depths. Seasonal low concentrations were measured in July, declining to 0.01 mg/L throughout the water column. Surface and deep measures increased to 0.04 mg/L and 0.08 mg/L during the final event.

Plankton and macrophytes

The phytoplankton community observed during the May sampling event was dominated by *Dinobryon*. Overall, low densities of the remaining 9 genera were noted, with exception to moderate densities of the green algae *Pediastrum*. Peak seasonal richness of 19 genera was observed during the July event. *Pediastrum* overtook *Dinobryon* as the dominant organism during this event. Moderate cyanobacteria densities were also noted during this event with a total of 6 genera noted as either rare, present or common. Densities declined overall by the final event, with a mixture of diatoms, green algae and cyanobacteria identified. The zooplankton community was dense and species richness was high during each sampling event in 2022. A mixture of cladocerans, copepods and rotifers were identified during each event; however, cladocerans were typically the dominant species in the sample.

Pinecliff Lake yielded generally low visibility. Most SAV observations made during the 2022 season were based on fragments and general observations along the launch area. Fragments of Eurasian watermilfoil was observed floating at the launch during each sampling event. Fragments of brittle naiad were also identified along the launch during the July sampling event.

POST BROOK FARMS LAKE

In-situ water quality

Two sampling stations were analyzed at Post Brook Farms Lake during the 2022 season, including a North and Dam station. Sampling events took place on 16 May, 1 August and 6 October 2022. Surface temperatures ranged from a minimum of 13.13 °C in October to a maximum of 25.85 °C in August. A strong thermal gradient was evident at both sampling stations during the May event, dropping sharply from a maximum surface temperature of 22.37 °C at the North station to a minimum temperature of 12.58 °C at 2.0 m of the Dam station. Thermal stratification persisted at the Dam station during the August event, while the water column in the North was thermally mixed. By the final event, the waterbody yielded relatively consistent temperatures from surface to sediment.

DO concentrations were lowest during the May sampling event, with a surface measure of 7.80 mg/L at the Dam station and 8.10 mg/L at the North station. At both sampling stations, DO increased at a depth of 1.0 m relative to the surface concentrations before declining with depth. Surface DO increased to peak seasonal concentrations by the August event, with a concentration of 9.88 mg/L at the Dam station. DO concentrations at both sampling stations declined sharply in the bottom meter of the waterbody, becoming anoxic at 2.0 m at the Dam station. Ample DO was reestablished by the final event, with only slight declines observed with depth.

Clarity was relatively consistent throughout the 2022 season, with Secchi depths of 1.2 m noted at both stations during the May and August events. A very slight increase to a maximum Secchi depth of 1.4 m was noted in October. Overall, surface pH varied between 7.42 to 8.27. pH peaked during the August sampling event at both sampling stations. pH declined sharply in the bottom meter of the waterbody during this event. This event coincided with a cyanobacteria bloom yielding visible floating colonies.

Table 248. 2022 In-Situ Monitoring for Post Brooks Farms Lake

***In-Situ* Monitoring for Post Brooks Farms Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/16/2022	Post Brook Farms - Dam	2.5	1.2	0.0	21.42	344.09	7.80	92.47	7.84
				0.5	20.60	345.92	7.87	91.72	7.72
				1.0	16.59	341.52	9.12	97.84	7.68
				1.5	13.96	340.35	8.30	83.57	7.35
				2.0	12.58	343.36	5.81	56.55	7.00
5/16/2022	Post Brook Farms - North	2.1	1.2	0.0	22.37	347.78	8.10	97.43	7.42
				0.5	21.95	346.49	7.67	91.90	7.44
				1.0	17.55	338.05	8.91	97.92	7.53
				1.5	14.14	341.19	7.65	75.22	7.43
8/1/2022	Post Brook Farms - Dam	2.7	1.2	0.0	25.85	375.24	9.88	125.95	8.27
				1.0	25.91	374.53	9.08	115.32	8.12
				2.0	24.59	376.39	0.44	4.79	7.08
				2.5	22.29	446.13	0.08	0.88	6.68
8/1/2022	Post Brook Farms - North	2.0	1.2	0.0	25.54	376.43	9.48	120.37	8.24
				0.5	25.95	375.87	9.41	119.32	8.30
				1.0	25.95	374.79	8.42	102.06	7.99
				1.5	25.64	376.56	3.86	42.61	7.30
10/6/2022	Post Brook Farms - Dam	2.5	1.4	0.0	13.13	365.53	8.98	88.38	7.58
				1.0	12.33	362.97	8.95	86.77	7.45
				2.0	12.14	363.86	8.72	83.98	7.29
10/6/2022	Post Brook Farms - North	2.2	1.3	0.0	13.39	367.83	9.50	93.54	7.44
				1.0	12.35	366.45	8.96	86.48	7.47
				2.0	12.17	365.26	8.77	83.99	7.42

Discrete water quality

TP concentrations in the surface water of Post Brook Farms Lake remained below the NJDEP standard throughout the season, with concentrations of either 0.02 mg/L or 0.04 mg/L. While the May and October sampling events yielded low TP measures at depth, a spike to 0.007 mg/L was observed during the August event due to anoxic conditions established in the bottom meter of the lake. SRP concentrations were low in the surface water during each sampling event. Deep-water SRP increased as the season progressed from a concentration below the lab detection limit of 0.002 mg/L in May to 0.005 mg/L in October.

Similar to other waterbodies included in this report, minimum chlorophyll *a* concentrations were observed during the May event. Concentrations spiked to a seasonal maximum of 25 µg/L at the surface and 66 µg/L in the deep sample during August. This sampling event was characterized by a bloom of the cyanobacteria *Aphanizomenon* and a dense phytoplankton community overall. A decline in concentrations was noted in October, dropping below 20 µg/L throughout the water column. By the final event productivity remained high with an abundance of the cyanobacteria *Dolichospermum*, but a marked decline was noted from the previous event. TSS concentrations were low throughout the season mainly yielding 1 mg/L at each sampling depth. An increase to 9 mg/L was observed in the deep sample during the August event.

Elevated nitrate-N concentrations were noted during the May sampling event, with surface and deep measures of 0.63 mg/L and 0.68 mg/L, respectively. As productivity increased by the August event, nitrate-N concentrations greatly declined to 0.08 mg/L (surface) and 0.15 mg/L (deep). Surface and deep nitrate-N concentrations of 0.15 mg/L persisted through the final event. Ammonia-N concentrations increased as the season progressed, from a surface measure of 0.05 mg/L during May and August to 0.08 mg/L in October. Deep water ammonia-N increased at a faster rate, spiking from 0.05 mg/L in May to 0.16 mg/L by October.

Plankton and macrophytes

A relatively sparse phytoplankton community was noted during the May sampling event at Post Brook Farms Lake. The community was comprised of moderate densities of *Chlorella*, *Trachelomonas* and *Ceratium*, while the remaining 4 genera were observed in low densities. Peak seasonal richness was noted in August, with a total of 11 identified genera. Densities greatly increased by this event and co-dominance was exerted by *Aphanizomenon* and *Ceratium*. A cyanobacteria bloom was identified during this event. Co-dominance was shared by *Dolichospermum* and *Chroomonas* during the final event, which also experienced elevated cyanobacteria densities. The early season zooplankton community was characterized as dense, and dominance was shared by the cladoceran *Daphnia* and copepod nauplii. Rotifers dominated the system by the August event. Community composition shifted to cladoceran-dominated by the October event, as *Daphnia* regained dominance.

Water chestnut was observed during one of the stream sampling events but overall, the plant was not observed during the majority of the 2022 season. Rooted macrophytes were not noted during any of the lake sampling events. Duckweed was observed at the beach during the August event.

SHADY LAKE

In-situ water quality

Two sampling stations were analyzed at Shady Lake during the 2022 season, including a Dam and Mid-Lake station. Sampling events took place on 20 May, 1 August and 6 October 2022. Surface temperatures were typically comparable across both sampling stations during the 2022 season. Temperatures ultimately ranged from a minimum temperature of 11.74 °C during October to a maximum temperature of 25.98 °C in August. Temperatures were consistent throughout the water column during each sampling event. The August event was characterized by a slight increase in temperature with depth. Thermal stratification was not observed.

DO was ample throughout the water column during the May sampling event, with measures ranging from 7.34 mg/L to 8.23 mg/L. DO increased slightly with depth during this event. A marked decline in surface DO was noted by August, with a concentration of 3.33 mg/L at the Dam station and 5.69 mg/L at the Mid-Lake station. DO declined with depth during this event but did not decline to anoxic conditions in the bottom water. Ample DO was reestablished by the October event.

Water clarity was consistently above the recommended threshold of 1.0 m, with Secchi depths varying between 1.1 m and 2.0 m throughout the season. The lowest clarity was noted during the August event; however, clarity was impeded by plant growth. pH values were highest at Shady Lake during the May sampling event, reaching a peak surface measure of 9.03. Slight increases were observed with depth during this event. This event was characterized by a dense phytoplankton community as well as moderate plant growth, with spatterdock and coontail observed. pH leveled out by the August and October events, dropping to values between 7.29 and 7.67. The phytoplankton community declined in abundance by this event. Photosynthetic activity associated with plant and algae growth results in increased pH values.

Table 249. 2022 In-Situ Monitoring for Shady Lake

In-Situ Monitoring for Shady Lake 2022									
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/20/2022	Shady Lake - Dam	1.9	1.4	0.0	19.64	526.35	7.34	82.72	9.03
				0.5	19.51	525.82	7.46	83.87	9.08
				1.0	19.46	524.59	7.52	84.71	9.08
				1.5	19.32	525.29	7.76	87.08	9.13
5/20/2022	Shady Lake - Mid-lake	1.6	1.4	0.0	19.46	524.97	8.01	89.71	8.96
				0.5	19.50	522.61	7.94	89.13	9.03
				1.0	19.35	522.69	8.00	89.71	9.05
				1.5	18.86	519.82	8.23	91.41	9.02
8/1/2022	Shady Lake - Dam	1.9	1.3	0.0	25.58	534.06	3.33	42.10	7.41
				0.5	26.21	533.84	2.99	37.83	7.35
				1.0	26.24	534.07	2.82	35.76	7.31
				1.5	26.23	533.55	2.63	33.39	7.29
8/1/2022	Shady Lake - Mid-Lake	1.4	1.1*	0.0	25.98	531.92	5.69	72.19	7.53
				0.5	26.09	531.78	5.56	70.63	7.46
				1.0	26.07	531.97	5.50	69.84	7.43
10/6/2022	Shady Lake - Dam	2.0	2.0+	0.0	11.83	477.45	9.86	93.79	7.67
				0.5	11.77	477.31	10.09	96.06	7.52
				1.0	11.69	476.93	9.85	93.45	7.44
				1.5	11.66	477.60	9.35	93.40	7.41
10/6/2022	Shady Lake - Mid-Lake	1.4	1.4+	0.0	11.74	452.83	9.92	94.34	7.46
				0.5	11.58	453.13	10.07	95.96	7.43
				1.0	11.51	451.84	10.27	97.06	7.43

*secchi covered by plants

Discrete water quality

TP concentrations were typically consistent from surface to deep samples during each sampling event. Overall, TP ranged from 0.01 mg/L to 0.04 mg/L, and at no point contravening the NJDEP threshold. Similarly, SRP concentrations remained low throughout the season, with both surface and deep samples yielding concentrations of either below the lab detection limit of 0.002 mg/L (August and October) or 0.002 mg/L (May).

Chlorophyll *a* concentrations in the surface water ranged between a seasonal minimum of 2.5 µg/L in May to 13 µg/L in August. Deep-water concentrations were comparable to their surface counterparts. Overall, TSS concentrations were low, with concentrations ranging from 1 mg/L in the deep sample in October to 9 mg/L in the surface water in August.

Nitrate-N concentrations were relatively consistent regardless of depth during the 2022 season. Concentrations ultimately ranged from 0.05 mg/L in August to 0.09 mg/L in October. The May sampling event at Shady Lake was characterized by elevated ammonia-N concentrations, with a seasonal maximum of 0.28 mg/L at the surface and 0.35 mg/L in the deep sample. Ammonia-N experienced a sharp decline during the remainder of the season in both the surface and deep water, dropping to a minimum concentration below the lab detection limit of 0.01 mg/L.

Plankton and macrophytes

The phytoplankton community composition was characterized by an abundance of *Synedra* and the filamentous green algae *Spirogyra,* alongside lower densities of various other diatoms, green algae, cyanobacteria and euglenoids. Peak seasonal richness was noted during the August event with a total of 20 identified genera. Dominance was exerted by *Trachelomonas* at this time, with moderate densities of *Navicula*, *Ankistrodesmus*, *Micrasterias*, *Lyngba*, *Euglena* and *Ceratium*. Densities greatly declined by the October event as the majority of identified genera were listed as present or rare. The zooplankton community was the densest during the May sampling event. Dominance was exerted by *Bosmina* at that time. Densities greatly declined by August with low densities of the 6 genera observed. Comparable compositions were observed during the October event.

The macrophyte community during the May sampling event was characterized by approximately 40% cover of Spatterdock and the presence of coontail. A relatively similar community was observed in August with patchy spatterdock, moderate densities of coontail and low densities of northern snailseed pondweed (*Potamogeton spirillus*) near the western shore/cove. By October, coontail was noted on the lake bottom throughout the lake and spatterdock was identified in similar densities as previous events. Duckweed was also observed near the western shore/cove.

UPPER GREENWOOD LAKE

In-situ water quality

Two sampling stations were analyzed at Upper Greenwood Lake during the 2022 season, including a Dam and South station. Sampling events took place on 17 May, 26 July and 5 October 2022. Surface temperatures were variable across sampling stations during each sampling event, with higher temperatures routinely measured at the Dam station. Surface temperatures ranged between 10.78 °C at the South station in October and 28.31 °C at the Dam station in August. Thermal stratification was not observed during the 2022 season, and the waterbody was well-mixed thermally at each sampling station. DO was ample throughout the season, with surface concentrations ranging from 7.24 mg/L in July to 10.33 mg/L in October. Adequate DO was noted from the surface to bottom during each sampling event, declining to a minimum concentration of 6.92 mg/L at the South station during July.

Water clarity was consistently adequate, with Secchi depths ranging from 1.2 m at the South station in May to 2.8 m at the Dam in October. Clarity extended to the sediments at the South station in July and both stations in October. The poorest Secchi depths were noted in May, caused by a dense phytoplankton community. pH was relatively consistent during each sampling event, with surface measures between 7.53 and 7.95. Slight declines were observed with depth, but overall pH measures were comparable throughout the water column.

Table 250. 2022 In-Situ Monitoring for Upper Greenwood Lake

In-Situ Monitoring for Upper Greenwood Lake 2022									
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/17/2022	Upper Greenwood - South	1.8	1.2	0.0	19.69	507.21	8.79	110.79	7.67
				0.5	19.84	506.11	8.74	110.74	7.64
				1.0	19.88	505.11	8.73	100.23	7.63
				1.5	19.88	505.07	8.73	100.47	7.63
5/17/2022	Upper Greenwood - Dam	2.7	1.6	0.0	21.18	526.08	9.41	110.76	7.95
				0.5	21.17	526.07	9.39	110.56	7.96
				1.0	21.12	525.38	9.39	110.96	7.94
				1.5	20.94	524.08	9.35	109.90	7.97
				2.0	20.77	524.16	9.15	106.89	7.86
				2.5	20.75	524.59	9.16	106.49	7.81
7/26/2022	Upper Greenwood - South	1.8	1.8+	0.0	27.34	380.38	7.24	94.89	7.86
				0.5	27.36	380.24	7.22	94.54	7.76
				1.0	27.28	379.76	7.10	92.51	7.64
				1.5	27.04	378.53	6.92	89.88	7.50
7/26/2022	Upper Greenwood - Dam	2.7	2.1	0.0	28.31	397.36	7.35	97.81	7.72
				0.5	28.33	396.67	7.30	97.40	7.64
				1.0	28.35	396.34	7.30	97.34	7.57
				1.5	28.18	393.82	7.21	95.78	7.50
				2.0	27.84	384.55	7.18	95.90	7.51
				2.5	27.75	384.92	7.96	105.31	7.63
10/5/2022	Upper Greenwood - South	1.8	1.8+	0.0	10.78	376.30	10.33	96.61	7.67
				0.5	10.75	376.66	10.30	96.59	7.57
				1.0	10.74	376.59	10.29	96.44	7.54
				1.5	10.74	376.75	10.30	96.46	7.51
10/5/2022	Upper Greenwood - Dam	2.8	2.8+	0.0	12.11	379.80	9.69	93.61	7.53
				1.0	12.12	379.61	9.66	93.19	7.50
				2.0	12.13	379.54	9.63	93.19	7.49
				2.5	12.13	379.52	9.62	93.28	7.50

Discrete water quality

TP concentrations were relatively consistent in the surface and deep samples during each sampling event. Overall, TP ranged from 0.01 mg/L to 0.02 mg/L, remaining well below the NJDEP threshold of 0.05 mg/L throughout the 2022 season. Each sampling event yielded low SRP concentrations below the lab detection limit of 0.002 mg/L throughout the water column at Upper Greenwood Lake.

Chlorophyll *a* concentrations declined as the season progressed in both the surface and deep-waters. The peak seasonal concentration of 10 µg/L was measured in the deep-water during May, declining to the seasonal minimum of 2.4 µg/L in October. Conversely, TSS concentrations increased from 1 mg/L to 10 mg/L as the season progressed, ultimately remaining low and not of concern.

Overall, nitrate-N concentrations within the lake remained low throughout the season, with a peak concentration of 0.09 mg/L in the deep water in May to a minimum concentration of 0.02 mg/L in the surface water in July. Ammonia-N concentrations remained low in the surface water during the 2022 season, reaching a maximum measure of 0.05 mg/L in May. Deep-water concentrations were slightly elevated in comparison during this first sampling event, yielding a concentrations of 0.14 mg/L.

Plankton and macrophytes

The May event yielded a very dense phytoplankton community with a bloom of *Dinobryon* and an abundance of *Pseudanabaena*. Densities declined overall by the July sampling event. A total of 11 genera were noted during this event, most of which were listed as present or rare. Moderate densities of *Pediastrum* were also observed during this time. Peak species richness of 13 identified genera were observed during the October event. Moderate densities of *Melosira* and *Microcystis* were observed, while the remaining genera were listed as present or rare. The poorest zooplankton richness was observed during the May event, with 6 genera identified. Co-dominance was exerted by the rotifers *Conochilus* and *Asplanchna*. Conversely, peak richness was observed in July and remained a healthy diverse community. Dominance was shared by *Bosmina* and *Conochilus* at that time. Densities declined overall, with the dominant copepods and rotifers listed as common.

Overall, little vegetation was visually observed during the 2022 sampling period. Brittle naiad was identified in the shallow areas of the boat launch cove during a stream sampling event.

VAN NOSTRAND LAKE

In-situ water quality

Two sampling stations were monitored at Van Nostrand Lake during the 2022 season, including a Dam and Mid-Lake station. Sampling events took place on 16 May, 25 July and 3 October 2022. Temperatures were slightly higher at the Mid-Lake sampling station in comparison to the Dam station. Surface temperatures ranged from a minimum temperature of 12.52 °C at the Dam in October to a peak temperature of 27.25 °C at the Mid-Lake station in July. A thermal gradient was established during the first sampling event, declining from surface temperatures of 21.30 °C or greater to temperatures of around 17.20 °C at 1.5 m. The thermal gradient persisted through the July event, before breaking down during the October event, with consistent temperatures throughout the water column.

DO concentrations were highly variable within Van Nostrand Lake, with surface DO ranging from 2.18 mg/L at the Mid-Lake station in October to 8.49 mg/L at the Mid-Lake station in May. DO remained ample throughout the water column at both sampling stations during the first sampling event. DO declined sharply by the July event, with both stations yielding surface concentrations less than 3.0 mg/L. Anoxia was established at 1.0 m at both stations at this time. By the October event, DO was reestablished at the Dam station, with concentrations greater than 7.60 mg/L throughout the water column. Low DO persisted at the Mid-Lake station during this event with concentrations around 2.0 mg/L noted from surface to sediment.

Clarity remained adequate at Van Nostrand during each sampling event, ranging from 1.4 m to 2.0 m. Clarity was observed to the sediments at both sampling stations during the May and October events. pH declined as the season progressed at this waterbody, with a seasonally low surface measure of 5.07 noted in October to a peak value of 7.65 noted in May. pH fell below the optimal NJDEP range of 6.5 – 8.5 at the Mid-Lake station during July and both stations during October.

Table 251. 2022 In-Situ Monitoring for Van Nostrand Lake

***In-Situ* Monitoring for Van Nostrand Lake 2022**

Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
5/16/2022	Van Nostrand - Dam	2.0	2.0+	0.0	21.30	21.45	7.94	93.25	7.65
				0.5	20.94	21.68	7.44	86.45	7.45
				1.0	18.90	20.77	8.79	99.74	7.46
				1.5	17.22	21.35	8.13	87.88	7.22
5/16/2022	Van Nostrand - Mid-Lake	1.9	1.9+	0.0	21.99	20.68	8.49	100.44	7.37
				0.5	21.22	20.41	8.72	102.93	7.30
				1.0	18.99	20.41	9.23	103.78	7.27
				1.5	17.26	20.94	7.81	79.32	6.98
7/25/2022	Van Nostrand - Dam	1.9	1.4	0.0	26.78	19.97	2.82	36.79	6.79
				0.5	27.15	20.31	1.67	21.59	6.44
				1.0	25.73	32.29	0.04	0.46	6.13
				1.5	24.40	37.37	0.01	0.10	5.99
7/25/2022	Van Nostrand - Mid-Lake	1.7	1.5	0.0	27.25	18.56	2.28	29.66	5.94
				1.0	26.10	22.44	0.20	2.50	5.80
				1.5	24.87	36.07	0.06	0.59	5.70
10/3/2022	Van Nostrand - Dam	1.7	1.7+	0.0	12.52	18.70	7.72	74.17	5.07
				0.5	12.58	18.67	7.61	72.96	5.17
				1.0	12.57	18.57	7.65	73.44	5.20
				1.5	12.55	18.56	7.70	74.11	5.27
10/3/2022	Van Nostrand - Mid-lake	1.5	1.5+	0.0	13.13	18.89	2.18	20.82	5.23
				0.5	13.03	18.92	2.09	20.23	4.86
				1.0	13.05	18.70	2.09	20.26	4.87

Discrete water quality

Van Nostrand Lake exhibited low phosphorus concentrations during the 2022 season, with TP concentrations of either 0.01 mg/L or 0.02 mg/L noted throughout the water column during each event. SRP concentrations were also low, yielding concentrations below the lab detection limit of 0.002 mg/L during each sampling event at all sampling depths. While depressed DO was observed during multiple sampling events, it did not appear to affect the nutrient load within the waterbody.

Chlorophyll *a* concentrations at this waterbody were some of the lowest noted within this study, ranging from a minimum concentration of 0.3 µg/L to a maximum of 4.6 µg/L. The majority of sampling events yielded especially low TSS concentrations, only increasing to 10 mg/L in the deep water during the July event.

Nitrate-N concentrations increased slowly throughout the season, with surface measures between 0.02 mg/L in May to 0.08 in October. A wider range was observed within the deeper water, reaching a maximum concentration of 0.15 mg/L in July. Ammonia-N concentrations were highly variable across sampling events. Minimum concentrations at both sampling depths were noted during the July event, both yielding concentrations below the lab detection limit of 0.01 mg/L. While surface concentrations were low during the May sampling event (0.03 mg/L), a spike to 0.37 mg/L was observed in the deep water during that time.

Plankton and macrophytes

Community composition during the May sampling event was poor at this waterbody, only yielding a total of 4 identified genera. Moderate densities of *Chlorella* were observed at this time alongside low densities of *Tabellaria*, *Chrysosphaerella* and *Pseudanabaena*. By the July sampling event, richness increased to 11 identified genera. *Chrsyosphaerella* exhibited dominance during this event along with a mixture of diatoms, chrysophytes, green algae, cyanobacteria and euglenoids. Densities declined by the final sampling event, with moderate densities of *Dinobryon,* and low densities of the remaining 7 genera. The May zooplankton sample was characterized by elevated densities, with co-dominance shared by *Keratella* and *Conochilus*. A slight shift was observed by July, with *Conochilus* sharing dominance with *Microcyclops*. Peak seasonal richness of 13 genera was noted during this event. A mixture of cladocerans, copepods and rotifers were noted throughout the season at this waterbody.

Overall, Van Nostrand Lake was characterized as relatively shallow, with at least 70% coverage with vegetation throughout the growing season. Dominant plants include watershield, white water lily and common bladderwort. In addition to these plants, ribbon leaf pondweed (*Potamogeton epidhydrus*) was also identified.

WONDER LAKE

In-situ water quality

Two sampling stations were analyzed at Wonder Lake during the 2022 season, including a Dam and Mid-Lake station. Sampling events took place on 20 June, 26 July and 5 October 2022. Overall, surface temperatures ranged from 11.27 °C at the Dam station in October to 25.52 °C at the Mid-Lake station in August. Due to the shallow nature of the Dam station, the water column remained well-mixed thermally throughout the season. Temperatures at the Mid-Lake station declined slightly during the May and October sampling events. A thermal gradient was established during the July sampling event, with temperatures dropping sharply at 1.5 m.

DO was highly variable across station and sampling event at this waterbody, with surface concentrations ranging from 0.67 mg/L at the Mid-Lake station in July to 8.40 mg/L at the Mid-Lake station in October. The May sampling event was characterized by a low DO concentration of 1.89 mg/L at the Dam station, increasing to 5.47 mg/L at the Mid-Lake station. DO declined with depth at both sampling stations and became anoxic at the Dam. By July, the entirety of the water column at the Mid-Lake station was anoxic. While surface measures at the Dam station were slightly higher, DO declined sharply at 0.5 m to below 1.0 mg/L. Ample DO was noted throughout the water column during the October event. Secchi depths at the Dam station were consistently to the bottom of the lake. The Mid-Lake station yielded clarity between 1.2 m in July and 1.9 m in October. Surface pH ranged from a minimum or 6.69 during June to a maximum of 7.15 during July.

Table 252. 2022 In-Situ Monitoring for Wonder Lake

In-Situ Monitoring for Wonder Lake 2022									
Date	Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
		Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
6/20/2022	Wonder Lake - Dam	0.9	0.9+	0.0	19.51	251.16	1.89	20.38	6.69
				0.5	18.67	245.44	0.92	8.84	6.58
6/20/2022	Wonder Lake - Mid-lake	1.7	1.3	0.0	20.63	316.47	5.47	60.89	6.82
				0.5	20.03	316.16	5.52	60.86	6.79
				1.0	19.61	319.52	4.30	47.97	6.69
				1.5	19.50	320.44	2.34	25.79	6.63
7/26/2022	Wonder Lake - Dam	0.8	0.8+	0.0	23.98	293.01	3.29	33.52	7.15
				0.5	23.94	288.17	0.96	9.14	6.80
7/26/2022	Wonder Lake - Mid-Lake	1.7	1.2	0.0	25.52	349.53	0.67	8.19	6.78
				0.5	25.35	352.97	0.52	2.22	6.69
				1.0	24.29	372.68	0.12	1.16	6.49
				1.5	21.67	539.84	0.00	0.00	6.57
10/5/2022	Wonder Lake - Dam	0.5	0.5+	0.0	11.27	237.58	7.56	71.16	6.95
				0.4	11.22	240.30	7.61	70.58	6.87
10/5/2022	Wonder Lake - Mid-lake	2.0	1.9	0.0	11.76	300.17	8.40	78.85	7.11
				0.5	11.31	303.78	7.20	66.95	7.02
				1.0	11.09	308.44	7.05	65.79	6.96
				1.5	10.94	308.63	6.71	62.40	6.88

Discrete water quality

Surface TP concentrations remained well below the NJDEP recommended threshold throughout the 2022 season, ranging from a minimum below the lab detection limit of 0.01 mg/L in October to a maximum of 0.02 mg/L in July. The deep station yielded slightly higher concentrations than its surface counterpart during each event, ranging from 0.01 mg/L to 0.04 mg/L. SRP concentrations were consistently low in the surface and deep waters during the 2022 season, with concentrations ranging from below the lab detection limit of 0.002 mg/L up to 0.002 mg/L.

Chlorophyll *a* measures were extremely low during both the June and October sampling events, remaining below 3 µg/L in the surface and deep samples. A slightly higher measure of 7.8 µg/L was observed in the surface water during the July event, while the deep-water sample spiked to 25 µg/L. Surface TSS concentrations ranged between 1 mg/L during the June event to 7 mg/L in the July event. Overall, deep-water TSS remained low in the first and final event but spiked to a peak concentration of 15 mg/L in July.

Surface nitrate-N concentrations were relatively consistent throughout the 2022 sampling period, yielding concentrations of either 0.05 mg/L or 0.06 mg/L. Both the June and October sampling events indicate a well-mixed waterbody, yielding 0.06 mg/L at both the surface and deep sampling depths. Nitrate-N concentrations increased in July to 0.11 mg/L in the deep waters.

The June sampling event was characterized by especially low ammonia-N concentrations in the surface and deep (0.005 mg/L) samples. Surface concentrations persisted through the July event, while an increase to 0.02 mg/L was observed in the deep sample. Peak ammonia-N concentrations were noted during the October sampling event, yielding a measure of 0.04 mg/L in the surface and 0.16 mg/L in the deep sample.

Plankton and macrophytes

The June sampling event was characterized by a relatively low-density phytoplankton community. Moderate densities of *Dinobryon* were noted, while the remaining 6 genera were listed as either rare or present. Densities increased overall by the July event, with dominance exerted by *Chroomonas* and moderate densities of *Lyngbya* and *Ceratium*. Peak seasonal richness of 12 genera was observed during the October event. Moderate densities of *Trachelomonas* and *Chlorella* were noted during this event, while low densities of the remaining identified genera were observed. The zooplankton community within Wonder Lake yielded lower richness throughout the season, with only 4 or 6 genera observed during each event. A mixture of copepods, cladocerans and rotifers were noted during each event.

Wonder Lake was macrophyte dominated throughout the 2022 season, with approximately 95% coverage. While a dense community was observed, diversity remained high, forgoing a monoculture. Overall, the plant identified within the lake included white water lily, watershield, *Elodea* (*Elodea canadensis*), coontail, big leaf pondweed (*Potamogeton amplifolius*), leafy pondweed, curlyleaf pondweed, bladderwort, *Chara sp. and* mermaidweed *(Proserpinaca palustris)*.

5.0 BASELINE WATERSHED-BASED WATER QUALITY DATA (INLET STREAMS)

5.0 METHODS

Water samples were collected in streams entering each Lake (when present) during base-flows in order to assess the nutrient load contributed by these streams during periods when no additional runoff is occurring. Base flows typically reflect groundwater influence as well. These sampling events occurred twice a year on days where no significant rainfall had occurred in the previous 48 hours. Each stream was sampled once per event during spring and late summer/fall of 2021. In areas where the streams were not directly accessible to sample by hand (tall bridges, difficult access, etc.), an extendable rod with a bottle attached was used to aid in sample collection. Following collection, all samples were delivered to the laboratory Environmental Compliance Monitoring in Hillsborough Township, NJ for analysis. Samples were analyzed for the following parameters:

- Total Phosphorus (TP)
- Soluble Reactive Phosphorus (SRP)
- Total Nitrogen (TN)
- Total Suspended Solids (TSS)

Inlet streams also received a single measurement per event for *In situ* data using the same protocols as those used for lake sampling.

Additionally, Farm Crest Acres Pond, Lindy's Lake, Mt. Spring Lake, Shady Lake, and Van Nostrand Lake did not feature any true inlets that flow during baseflow and were not sampled for this portion of the study. Princeton Hydro was not granted permission to sample Carpi Lake. Maps displaying sampling locations for the baseline sampling are provided in Appendix I.

Comparisons were made between obtained values and concentrations derived from modeled data. Concentrations based on modeled data were calculated using the modeled stream flow, nitrogen, phosphorus, and sediment rates for the months of May and October in the subwatershed sampled.

5.1 RESULTS

The following water quality results are compared with the New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B), where applicable. All surface water classifications for the streams discussed in this section are identified in N.J.A.C. 7:9B.

ALGONQUIN WATERS

The Algonquin Waters stream was sampled on 20 May and 22 October 2022. This stream (tributary of Posts Brook) is classified as a FW2-NT stream. Temperatures were relatively consistent during both sampling events, with measures between 14.23 °C and 14.54 °C. Dissolved oxygen (DO) concentrations were highly variable during the May and October events, yielding concentrations of 7.12 mg/L and 1.29 mg/L, respectively. Measures fell below the NJDEP threshold of 4.0 mg/L for FW2-NT waters during this time. pH for this stream was relatively comparable during both events, with measures between 6.36 and 6.81. pH fell just below the optimal threshold of 6.5 – 8.5 during the May sampling event.

TP concentrations were variable across sampling events, with the 20 May event yielding a concentration of 0.03 mg/L and the 22 October event yielding concentrations of 0.14 mg/L. The first sampling event fell below the NJDEP Non-Tidal Stream threshold of 0.10 mg/L; however, the October event contravened this measure. SRP concentrations remained relatively consistent, with measures between 0.026 mg/L and 0.028 mg/L. TSS concentrations remained well below the NJDEP threshold of 40 mg/L for FW2-NT streams during both sampling events. A maximum concentration of 18 mg/L was measured at this inlet. Nitrate-N concentrations ranged between 0.12 mg/L during October and 0.25 mg/L during the May sampling event.

Measured nitrogen concentrations were lower than those calculated from modeled values. This may suggest that processes exist in the inlet subwatershed that serve to reduce nitrogen transferred downstream, and these are not accounted for in the model. Measured total phosphorus concentrations were also lower than values obtained from modeled results, however the May concentrations were more similar to each other than the corresponding nitrogen concentrations. Concentrations of total suspended solids measured in the field were higher than sediment concentrations derived from the model, suggesting higher rates of erosion in the inlet subwatershed may be occurring than were accounted for in the model.

BUBBLING SPRINGS POND

The Bubbling Springs Pond inlet was sampled on 20 May and 20 October 2022. This stream (Belchers Creek tributary) is classified as a FW2-NT stream. Temperatures remained cool, with a minimum temperature of 13.19 °C during the October event and a maximum temperature of 20.77° C during May. Ample DO was measured during both sampling events at this inlet, yielding concentrations of 8.41 mg/L and 9.41 mg/L. pH was well within the optimal range of 6.5 to 8.5 during the 2022 season.

TP concentrations were consistently below the NJDEP Non-Tidal Stream threshold of 0.10 mg/L during the 2021 season, with concentrations of 0.04 mg/L in May and 0.01 mg/L in October. Non-detectable (<0.002 mg/L) SRP concentrations were measured during both sampling events. TSS concentrations also fell below their respective thresholds, with concentrations between < 2 mg/L and 14 mg/L. Nitrate-N concentrations were elevated in comparison to most of the other waterbodies within this sampling program, with concentrations between 0.95 mg/L and 1.01 mg/L; these are extremely elevated concentrations. This may be due to the stream's origin as an upwelling of groundwater above the swimming lake. Such surface springs often naturally yield relatively high nitrate-N concentrations.

Nitrogen concentrations obtained in the field were somewhat similar to those derived from modeled results, particularly during the month of October. Total phosphorus concentrations obtained in the field were similar to results derived from modeled concentrations during the month of May, while field concentrations were much lower than those modeled for October. Field TSS concentrations obtained in May were much higher than those derived from modeled sediment results, while October's field concentrations were considerably lower than modeled sediment concentrations.

CARPI LAKE

Access to this stream site was not granted prior to the May or October sampling events, and therefore could not be sampled for this project.

FARM CREST ACRES POND

A flowing inlet was not observed at Farm Crest Acres Pond and therefore could not be analyzed.

FOREST HILL LAKE

The Forest Hill Lake inlet was sampled on 3 May and 22 October 2022. This stream (tributary of Pequannock River) is classified as a FW2-TP stream. Temperatures during the May and October sampling events fell below the NJDEP threshold of 22.00 °C for FW2-TP waters, with temperatures of 14.97 °C and 16.95 °C, respectively. Similarly, DO concentrations were ample throughout the season, with concentrations remaining above the NJDEP threshold of 7.0 mg/L during both events. pH was well within the optimal range of 6.5 to 8.5 designated for this stream.TP concentrations were well below the NJDEP threshold for Non-Tidal Streams of 0.10 mg/L during the 2021 season, with concentrations of 0.04 mg/L and 0.05 mg/L. SRP concentrations were consistently low, yielding either non-detectable measures (ND<0.002 mg/L) or 0.002 mg/L. TSS concentrations fell below the 25 mg/L threshold for this stream, with non-detectable concentrations (ND<2 mg/L) noted in May and 18 mg/L noted in October. Nitrate-N concentrations were highest during the May sampling event, with measures of 0.22 mg/L, declining to 0.07 mg/L by the October event.

Measured nitrogen concentrations in the Forest Hill Lake inlet were lower than concentrations derived from modeled values for both the October and May events. The measured concentration of phosphorus from the May event was similar to the concentration derived from modeled phosphorus results, however the modeled concentration for October was considerably higher than the field value for this month. Field TSS values were higher than model-based sediment results for both months.

GORDON LAKE

The Gordon Lake inlet was sampled on 3 May and 20 October 2022. This stream (tributary of Post Brook) is classified as a FW2-NT stream. Temperatures measured during the 2022 season ranged from 13.46 °C in May to 15.01 °C in October. DO was ample during both sampling events, remaining well above the 4.0 mg/L threshold set for FW2-NT streams. Relatively neutral pH was observed during both sampling events, with measures between 7.13 and 7.53. These values fell within the optimal range of 6.5 to 8.5 for this stream.

Both the May and October sampling events yielded TP concentrations of 0.02 mg/L, remaining well below the NJDEP threshold of 0.10 mg/L for Non-Tidal Streams. SRP concentrations were similarly low, with measures of 0.002 mg/L or less noted during each event. TSS concentrations were consistently low during the 2021 season, yielding 5 mg/L during both events. Like many of the other parameters, nitrate-N concentrations remained relatively consistent during each sampling event, with concentrations of 0.22 mg/L and 0.21 mg/L noted in May and October, respectively.

Measured nitrogen concentrations were lower than those derived from the modeled results for both May and October. The measured phosphorus concentration obtained in May was similar to that derived from modeled results for this month, however the October field result is considerably lower than modeled results. TSS concentrations obtained in the field were higher than modeled sediment concentrations for both months.

HIGH CREST LAKE

The High Crest Lake inlet was sampled on 3 May and 22 October 2022. This stream (tributary of the Pequannock River) is classified as a FW2-TP stream. Temperatures within this inlet were below the 22.00 °C threshold for FW2-TP waters, with a minimum temperature of 12.45 °C in May, increasing to 15.15 °C in October. DO concentrations remained above the 7.0 mg/L threshold during both the May and October events, yielding concentrations of 8.99 mg/L and 7.57 mg/L, respectively. pH was consistent throughout both sampling events, with a neutral pH between 7.08 and 7.10 noted. These values fell within the optimal pH range.

TP concentrations were low during both sampling events, remaining at or below 0.02 mg/L. These concentrations were well below the NJDEP threshold during the 2021 season. SRP concentrations were non-detectable (ND<0.002 mg/L) throughout the season. TSS concentrations ranged from non-detectable concentrations (ND<2 mg/L) during the May event to 9 mg/L during the October event. These remained below the 25 mg/L threshold set by NJDEP for FW2-TP streams. Nitrate-N concentrations were relatively consistent at High Crest Lake's inlet, with measures ranging from 0.11 mg/L in October to 0.17 mg/L in May.

Nitrogen concentrations obtained in the field were lower than modeled results for both months, while phosphorus field-based results were similar to those obtained via modeled results. The May event yielded a field-based TSS concentration that was somewhat similar to the modeled sediment concentration, while the October field TSS concentration was notably lower than modeled sediment concentrations.

JOHNS LAKE

The Johns Lake inlet was sampled on 3 May and 22 October 2022. This stream (tributary of the Pequannock River) is classified as a FW2-TP stream. Temperatures were consistent from the May and October events, with temperatures remaining around 15.40 °C; thus, remaining below the 22.00 °C maximum threshold. The May sampling event yielded a DO concentration of 8.39 mg/L, before declining to 6.14 mg/L by the October event. The DO concentration during the latter sampling event fell below the 7.00 mg/L threshold set by NJDEP for FW2-TP waters. pH values remained well within the optimal range of 6.5 – 8.5 during both sampling events.

TP concentrations were low overall, ranging from 0.02 mg/L in October to 0.03 mg/L in May. Each sampling event fell below the recommended maximum threshold of 0.10 mg/L for Non-Tidal Streams. SRP concentrations were also low, ranging between 0.002 mg/L and 0.004 mg/L. TSS concentrations fell below the 25 mg/L maximum threshold during both sampling events during the 2021 season, with measures of non-detectable concentrations (ND<2 mg/L) in May and 8 mg/L in October. Nitrate-N concentrations were elevated compared to most of the other waterbodies sampled for this plan. Concentrations of 1.11 mg/L were noted during the May event, before increasing to 2.70 mg/L in October.

The total nitrogen concentration obtained in the field during the month of May was lower than that derived from modeled results, while the October field concentration was higher than that derived from the model. May's field concentration of phosphorus was very similar to that obtained from the model, while the October concentration was much lower than the modeled result. Field-based TSS concentrations from both May and October were higher than the sediment concentrations derived from the model, with the larger difference occurring in October.

KITCHELL LAKE

The Kitchell Lake inlet was sampled on 3 May and 20 October 2022. This stream (West Brook tributary) is classified as a FW2-TP, C1 stream. Temperatures in the Kitchell Lake inlet remained below the 22.00 °C NJDEP threshold during both 2022 sampling events. Temperatures varied slightly, from a low of 13.27 °C during May up to 14.05 °C during October. DO was also adequate during both the May and October events, with measures of 9.94 mg/L and 8.84 mg/L, respectively. DO concentrations remained above the 7.00 mg/L minimum threshold during both sampling events. pH remained within the optimal range of 6.5 – 8.5 during both sampling events.

TP concentrations remained below the NJDEP threshold of 0.10 mg/L for Non-Tidal Streams throughout the 2021 sampling season, with both events yielding concentrations of 0.02 mg/L. SRP concentrations were especially low during the May event, yielding 0.002 mg/L, before increasing to 0.015 mg/L in October. TSS concentrations were well below the 25 mg/L threshold for this stream, with maximum concentrations of 2 mg/L observed. Nitrate-N concentrations at the Kitchell Lake inlet were highest during the May sampling, at a concentration of 0.26 mg/L. Nitrate-N concentrations declined greatly by October, yielding measures of 0.05 mg/L.

Nitrogen concentrations obtained in the field were lower than modeled results during both the May and October events, suggesting that the nutrient may be sequestered upstream more efficiently than the model predicted. The May concentration of phosphorus obtained in the field was similar to the result derived from the model, however the October field concentration was much lower than the modeled value. Field results for TSS were much lower than the model-derived sediment results for both May and October.

LINDY'S LAKE

A flowing inlet was not observed at Lindy's Lake and therefore could not be analyzed.

LAKE LOOKOVER

The Lake Lookover inlet was sampled on 20 May and 20 October 2022. This stream (Longhouse Brook) is classified as a FW2-NT stream. Temperatures within this inlet were higher than the other waterbodies, with a minimum temperature of 16.03 °C in October and a maximum temperature of 22.57 °C in May. DO concentrations remained above the minimum threshold of 4.00 mg/L during both sampling events, declining to a minimum of 7.99 mg/L in May. pH fell within the optimal range of 6.5 – 8.5 throughout the 2022 season.

TP concentrations fell below the NJDEP threshold of 0.10 mg/L for Non-Tidal Streams, with measures of 0.02 mg/L noted during both the May and October events. In addition, SRP concentrations were observed in non-detectable concentrations (ND<0.002 mg/L). TSS concentrations were extremely low during both sampling events, with maximum concentrations of 2 mg/L. Similar to the other analyzed nutrients, nitrate-N concentrations were low, with a maximum concentration of 0.07 mg/L in May, declining to 0.01 mg/L in October.

Nitrogen concentrations obtained in the field were lower than model-derived results for both May and October, while field-based phosphorus concentrations were higher than modeled results for both months. TSS concentrations obtained in the field were also higher than sediment concentrations derived from the model.

LOWER MOUNT GLEN LAKE

The Lower Mount Glen Lake inlet was sampled on 3 May and 20 October 2022. This stream (West Brook tributary) is classified as a FW2-TP, C1 stream. Stream temperatures ranged between 14.71 °C in October and 16.05 °C in May. While some variation was observed, temperatures remained below the 22.00 °C threshold for this stream classification. Ample DO was noted during both sampling events, consistently above the 7.00 mg/L minimum threshold. Similarly, pH remained within the optimal range of 6.5 – 8.5, with measures between 7.12 and 7.64.

TP concentrations within this stream were low overall during both sampling events, yielding a maximum of 0.02 mg/L during the May sampling event. TP concentrations fell below the NJDEP maximum threshold of 0.10 mg/L for Non-Tidal Streams during the 2021 season. SRP concentrations increased slightly as the season progressed, with measures of 0.002 mg/L in May and 0.004 mg/L in October. TSS concentrations fell well below the 25 mg/L threshold, reaching maximums of 3 mg/L. Nitrate-N concentrations were variable, declining from 0.44 mg/L in May to 0.20 mg/L in October.

Similarly, to Lake Lookover, nitrogen concentrations obtained from the field were lower than modeled concentrations for both May and October. Phosphorus concentrations were similarly measured to be lower than the modeled results. Modeled sediment concentrations generally closely aligned to TSS concentrations obtained in the field for both months.

UPPER MOUNT GLEN LAKE

The Upper Mount Glen Lake inlet was sampled on 3 May and 20 October 2022. This stream (West Brook tributary) is classified as a FW2-TP, C1 stream. A slight increase in temperature from 12.96 °C in May to 14.32 °C in October was observed at this stream. Temperatures fell well below maximum temperature threshold for FW2-TP, C1 waters during the 2022 season. The stream was well-oxygenated throughout the sampling period, with concentrations ranging from 8.33 mg/L to 9.10 mg/L. DO concentrations remained above minimum thresholds of 7.00 mg/L throughout the season. Neutral pH was observed during both the May and October events, falling between 7.02 and 7.12. These values fell within the optimal pH range for this stream classification.

TP concentrations were especially low during the May sampling event, yielding a measure of 0.02 mg/L. An increase in phosphorus was observed by the October event, spiking to 0.09 mg/L. While an increase was observed, TP concentrations noted in this stream did not contravene the 0.10 mg/L NJDEP threshold for Non-Tidal Streams. SRP concentrations were also variable, increasing from a minimum of 0.004 mg/L in May to 0.062 mg/L in October. TSS concentrations yielded consistent values of 2 mg/L during both sampling events. Nitrate-N concentrations were highest during the May event with 0.48 mg/L. A decline to 0.13 mg/L was observed by the October sampling event.

Both the nitrogen and phosphorus results obtained in the field for both months were lower than the modeled results. The TSS concentration obtained during the May event aligned somewhat closely with the modeled sediment concentration, however the measured concentration of TSS was much lower than the modeled sediment concentration in October.

MT. LAUREL LAKE

The Mt. Laurel Lake inlet was sampled on 20 May and 20 October 2022. This inlet (Longhouse Brook) is classified as a FW2-NT stream. Stream temperatures experienced a wide range, with a minimum temperature of 13.10 °C in October to a maximum temperature of 20.51 °C in May. Ample DO was noted throughout the season, with concentrations well above NJDEP standards, ranging from 8.50 mg/L to 9.68 mg/L. pH during both sampling events fell within the optimal range of 6.5 and 8.5.

TP concentrations were low overall, peaking at 0.02 mg/L during the May event, and remaining well below NJDEP standards. SRP concentrations were also low during both sampling events, increasing from non-detectable concentrations (ND<0.002 mg/L) in May to 0.002 mg/L in October. TSS concentrations fell well below the NJDEP standard of 40 mg/L during each sampling event, with maximum concentrations of 2 mg/L noted. Nitrate-N concentrations were consistent from May to October, increasing from 0.38 mg/L to 0.41 mg/L, respectively.

Nitrogen concentrations measured in the field were somewhat similar to those derived from modeled results for both May and October. The phosphorus concentration obtained from field samples in May closely aligned with the modeled result, however the field concentration obtained in October was notably lower than the modeled result. Measured TSS concentrations were somewhat similar to sediment concentrations derived from the model for both months, although the two results are closer to one another in May.

MOUNTAIN SPRINGS LAKE

A flowing inlet was not observed at Mountain Springs Lake and therefore could not be analyzed.

PINECLIFF LAKE

The Pinecliff Lake inlet was sampled on 20 May and 20 October 2022. This inlet stream (Belchers Creek) is classified as a FW2-NT stream. Temperatures remained relatively cool, with a maximum temperature of 19.94°C in May and a minimum temperature of 13.66°C in October. DO was consistently elevated compared to the NJDEP standard of 4.0 mg/L, reaching a maximum concentration of 9.76 mg/L. Similar to the majority of the other waterbodies sampled, pH fell within the optimal range during both sampling events.

TP concentrations ranged from 0.03 mg/L in October to 0.05 mg/L in May, remaining below the 0.10 mg/L threshold for Non-Tidal Streams. SRP made up a larger portion of TP than some of the other waterbodies, with measures ranging from 0.017 mg/L to 0.020 mg/L. TSS concentrations were low, falling well below NJDEP standards. Nitrate concentrations remained consistent during both sampling events, with concentrations of 0.92 mg/L and 0.97 mg/L.

Nitrogen concentrations obtained from field samples were higher than those derived from modeled results for both May and October. The May phosphorus concentration measured from field samples was higher than the model-derived result, while the October results more closely aligned with one another. The measured TSS concentration in May was somewhat similar to the modeled sediment concentration, however the October field concentration of TSS was lower than the sediment concentration estimated via the modeled results.

POST BROOK FARMS LAKE

The Post Brook Farms Lake inlet was sampled on 20 May and 22 October 2022. This inlet was comprised of a small, unclassified intermittent stream. Temperatures were consistent at this stream throughout both sampling events, ranging from 14.14°C to 14.92°C. Ample DO was observed, with concentrations between 8.68 mg/L and 8.97 mg/L. pH remained well within the optimal range of 6.5 – 8.5.

TP concentrations fell below the NJDEP maximum threshold of 0.10 mg/L during both sampling events, with concentrations of 0.05 mg/L (May) and 0.07 mg/L (October) noted. SRP concentrations comprised a large portion of the TP in the lake, with concentrations between 0.047 mg/L and 0.049 mg/L; these are extremely elevated SRP concentrations. TSS concentrations ranged from 7 mg/L to 13 mg/L, remaining below NJDEP standards. Nitrate-N concentrations were the highest of any of the sampled waterbodies during both monitoring events. Peak concentrations of 4.63 mg/L were noted during May, declining to 3.70 mg/L by October. As this stream was very shallow, high nutrient values may be the result of contamination of the sample with sediment and/or organic matter inadvertently collected with the sample.

Nitrogen concentrations measured from field samples generally aligned with concentrations derived from modeled results for both May and October. Phosphorus concentrations obtained in the field were lower than modeled results for both months. The TSS concentration obtained in the field for the May event closely aligned with the sediment concentration derived from modeled results for the month of May, however the measured TSS results were notably higher than the modeled sediment concentration in October.

SHADY LAKE

An inlet was identified feeding into Shady Lake; however, the flow was extremely low. Due to these low flows, the stream could not be sampled properly for *in-situ* and discrete measures.

UPPER GREENWOOD LAKE

The Upper Greenwood Lake inlet was sampled on 20 May and 20 October 2022. This inlet stream (Sawmill Pond Brook) is classified as a FW2-NT stream. Stream temperature ranged between 13.47 °C during the October event to 18.04 °C during May. DO was adequate at this waterbody, with concentrations between 6.89 mg/L and 7.62 mg/L. Measures were above the NJDEP threshold of 4.0 mg/L during both sampling events. pH remained within the optimal range during both sampling events, with values between 6.76 and 7.28.

TP concentrations within this inlet were low overall, ranging from 0.02 mg/L to 0.04 mg/L, and staying below the maximum threshold of 0.10 mg/L for Non-Tidal Streams. SRP concentrations varied from a minimum concentration of 0.004 mg/L in May to a maximum concentration of 0.011 mg/L in October. TSS measures were well below recommended thresholds throughout the season, yielding concentrations of either 2 mg/L or less. Nitrate-N concentrations remained low during both sampling events, with peak concentrations of 0.07 mg/L.

Nitrogen concentrations obtained from field samples were notably lower than those obtained from modeling results for both the months of May and October. The field concentrations of phosphorus, however, closely aligned with modeled results for both months. Modeled sediment and field-based TSS concentrations were somewhat closely aligned with one another for both months, with the May event yielding more closely aligningresults.

VAN NOSTRAND LAKE

Access to this stream site was not granted prior to the May or October sampling events, and therefore could not be analyzed for this project. Furthermore, examination of maps and aerial images indicate that this lake does not receive any surface inflow.

WONDER LAKE

The Wonder Lake inlet was sampled on 3 May and 22 October 2022. This inlet stream (Matthews Brook) is classified as a FW2-TP, C1 stream. Stream temperatures varied little throughout the season, increasing from 14.47 °C in May to 15.12° C in October. Temperatures remained below the 22.00 °C maximum threshold for this stream classification. DO remained just above the recommended 7.0 mg/L standard during the May sampling, with a concentration of 7.05 mg/L. DO fell below this standard by the October event, with a concentration of 5.62 mg/L. pH remained within the optimal range with values between 6.95 and 6.97.

Nutrient concentrations were low overall within this stream. TP concentrations were well below the maximum threshold of 0.10 mg/L for Non-Tidal Streams, with peak concentrations of 0.03 mg/L noted. SRP concentrations remained consistent during both sampling events, yielding a measure of 0.004 mg/L. TSS concentrations remained below the 25 mg/L maximum threshold throughout the season. Nitrate-N concentrations were low during both sampling events, declining from 0.10 mg/L in May to 0.03 mg/L in October.

Nitrogen concentrations measured in the field were notably lower than those derived from modeled results for both May and October. Phosphorus concentrations from the field and modeled results closely aligned with one another for the May event, however the October event yielded a lower field concentration than that of the model-derived results. The May TSS concentration was notably higher than the sediment concentration derived from the model, however the field TSS concentration obtained in October was more closely aligned with the sediment concentration estimated by the model.

6.0 TROPHIC STATE MODELING

6.0 METHODS

Utilizing data collected in the field or obtained through the lake and watershed modeling methods outlined in Section 3.0, multiple predictive models were used in order to estimate the status of each lake as it pertains to the amount of nutrients and the resulting biological activity that occurs within. Some of these models also may predict concentrations of phosphorus or chlorophyll *a* within the water column itself at certain times of the year.

Once estimated annual hydrologic and phosphorus loads are established for a waterbody, they can be used in conjunction with the estimated volume of the lake to determine an estimated concentration of phosphorus. The results of these models can be compared against in-lake total phosphorus values obtained in the field in order to validate the results of hydraulic and pollutant modeling. If the resulting predicted phosphorus concentrations are lower than what is typically obtained in the field, other variables may be present within the watershed and/or waterbody that were not accounted for in the model. If modeled phosphorus concentrations are similar to those collected in the field, the model(s) can be used to predict changes in overall phosphorus concentrations as a result of predicted phosphorus reductions resulting from in-lake or watershed-based management implementations.

Many of these models were run twice, for both only the watershed-based phosphorus load and for the total combined load. Details regarding each of the models are as follows:

Carlson's Trophic State Index (TSI)

Trophic state as it applies to lakes refers to the amount of nutrients in a lake and the primary productivity (growth of photosynthetic organisms) that results. This is the base of a food web in a lake from which consumers (higher organisms such as macroinvertebrates and fish) feed in order to maintain their own populations within the lake. Low levels of primary productivity in a lake result in an oligotrophic state. This usually occurs in glacial kettle ponds and lakes and is characterized by low amounts of plants and algae, very high water clarities, and a fisheries consisting of salmonids and/or other cold-water fish. Conversely, high levels of primary productivity in a lake result in a eutrophic state. Many of the small lakes and ponds in New Jersey (with some exceptions) are typically eutrophic, featuring relatively high nutrient loads, lower water clarities, and a higher propensity for algae blooms. Mesotrophic lakes refer to those with primary productivity levels between oligotrophy and eutrophy. Eutrophication describes increasing system productivity over time. This can include natural eutrophication at geological time scales and includes sediment infilling and increasing nutrient concentrations due to natural accretions of these materials, although at slow rates and with low loads. Cultural eutrophication is an accelerated eutrophication caused by excess nutrient loads entering the waterbody as a product of anthropogenic activities in the watershed. Cultural eutrophication is a much greater concern and results in greater impairment of waterbodies. This is particularly true in areas where waterbodies are artificial, that is they are created entirely or expanded via excavation or impoundment, and most of the waterbodies in this study have been significantly altered in area and volume. Eutrophication can be assessed in part through trophic state models which describe the productivity of a lake system.

The Carlson's Trophic State Index (TSI) assesses the trophic state of lakes by calculating index values based on phosphorus and chlorophyll a concentrations and Secchi depths that relate to each other on a similar scale (Carlson, 1977). The higher these numbers are, the more representative they are of eutrophic conditions.

Carlson's trophic state index (TSI) was calculated for each in-lake sampling event using surface concentrations of TP, Chlorophyll *a,* and Secchi depths collected during water quality monitoring events throughout the season. The TSI for total phosphorus is calculated as follows:

$$TTTTT = 14.42 llll^{TTTT} + 4.15$$

Where *TSI* = Trophic State Index result for phosphorus and *TP* = total phosphorus concentration in µg/L.

The TSI for chlorophyll *a* is calculated as follows:

$$TTTTT = 9.81 llll^{CChll} + 30.6$$

Where *TSI* = Trophic State Index Result for chlorophyll *a* and *Chl* = Chlorophyll *a* concentration in µg/L.

Lastly, the TSI for water clarity as Secchi depth is as follows:

$$TTTTTT = 60 - 14.41 llll^{SSSS}$$

Where *TSI* = Trophic State Index Result for Secchi depth and *SD* = Secchi depth in meters. It is important to note that this index is somewhat reversed from the others. While higher phosphorus or chlorophyll equates to higher index values and thus higher trophic state, higher clarity is indicative or reduced productivity and yields a lower value; the reverse is also true and lower clarity equates to higher index values.

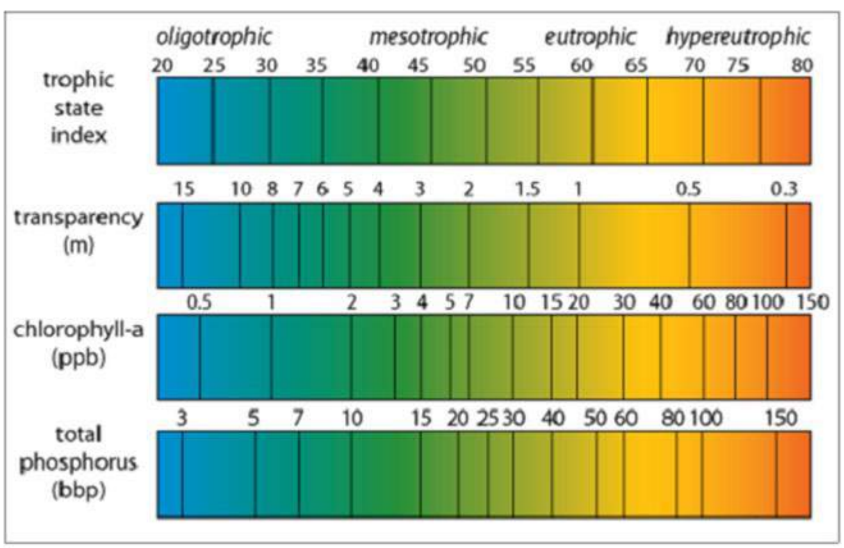


Figure 101. Ranges of trophic states for the three components of Carlson's TSI.

The resulting TSI values represent the trophic state of the waterbody along a trophic spectrum or continuum, although the three primary classifications (eutrophic, mesotrophic, or oligotrophic) are still widely used by limnologists. Each of the individual index values is supposed to yield the same value. This is built on the assumption that phosphorus is the sole control on algal density, algal density is accurately represented by chlorophyll concentrations, and that algal density is the primary determinant of Secchi clarity. In many cases, these three TSI values will differ notably from one another within a single event (e.g., chlorophyll *a* concentrations may be very high but relatively high Secchi depths may still be measured) indicating that some of the model assumptions are not met. An analysis of these residuals (differences) between the results of a TSI analysis can be suggestive of other conditions affecting the waterbody's trophic state and yield additional information about the ecology of the studied system. The differences between the chlorophyll-based TSI and the Secchi-based TSI and between the Chlorophyll-based TSI and the Phosphorus-based TSI can be plotted as either several dates in a year or for several years. As demonstrated in Figure 102 by Carlson and Havens (2005), the location of events in one of the "quadrats" on the graph, relative to the axes, may suggest differences in conditions during those particular events.

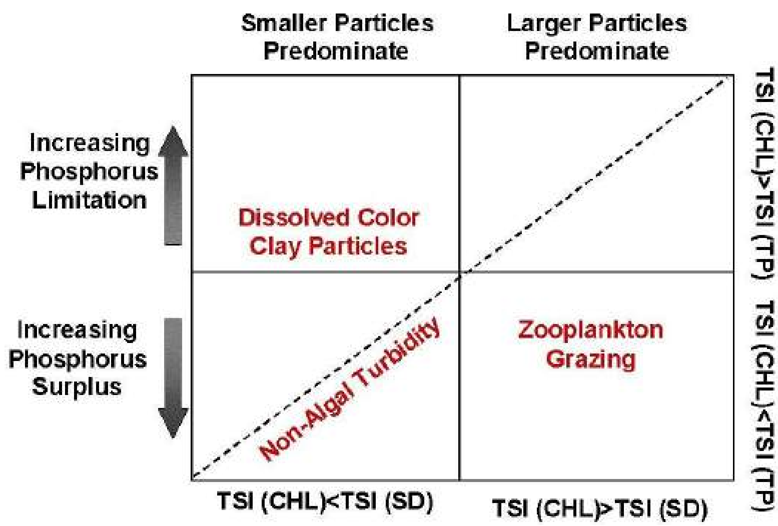


Figure 102. Carlson and Havens (2005) display possible interpretations for differences in trophic state indices when plotted on an axis.

Kirchner and Dillon's Phosphorus Retention

This metric by Kirchner and Dillon (1975) utilizes the incoming hydraulic load from the watershed, as well as the total area of the waterbody, to estimate what percentage of incoming phosphorus will stay within the waterbody rather than be flushed from the system. The equation is as follows:

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

Where R = the phosphorus retention coefficient and qs = the areal water load, calculated as the total annual hydrologic input divided by the total surface area of the waterbody.

Dillon and Rigler's Spring Phosphorus Prediction

The result of Kirchner and Dillon's phosphorus retention equation above can be directly used, as well as the estimated total annual load of phosphorus, the waterbody's hydraulic retention time, and average depth, can be used to predict total phosphorus concentrations in the water column at the beginning of the growing season (Dillon and Rigler, 1975). The equation is as follows:

$$[\mathrm{TP}] = \mathrm{LT}(1 - \mathrm{R})/ZZ_{mmmmmmm}$$

Where [TP] = annual mean phosphorus concentration (mg/L), L = areal phosphorus loading ($g/m^2/yr$), R = phosphorus retention, T = water retention time in years, and Z_{mean} = average depth.

Walker's Spring Phosphorus Prediction

Other models for the prediction of spring phosphorus, as well as for predicting the overall trophic state of a waterbody, are Walker's 1977 equations, which are described below:

$$PP_{qq} = \frac{LLTT}{ZZ} * \left(\frac{1}{1 + 0.8247\,{}^{0.454}}\right)$$

Where P_s = estimated spring phosphorus load, *L* = areal phosphorus load, *T* = hydraulic retention time, and Z = mean depth.

Walker's trophic state equation uses a different equation to generate spring phosphorus loads, before plotting the Log_{10} of the estimated spring phosphorus on a graph in order to determine the trophic state probability of the lake. The equation for determining the spring phosphorus load for this purpose is as follows:

$$XX = LL(qqqq(1 + 0.824 * TT^{0.454}))^{-0.815}$$

Where *X* = spring phosphorus, *L* = areal phosphorus, *T* = hydraulic retention time, and *qs* = areal water load. The log_{10} of the result of this is plotted on the graph below in order to assess the chances of the waterbody being classifiable as one of the three main trophic states.

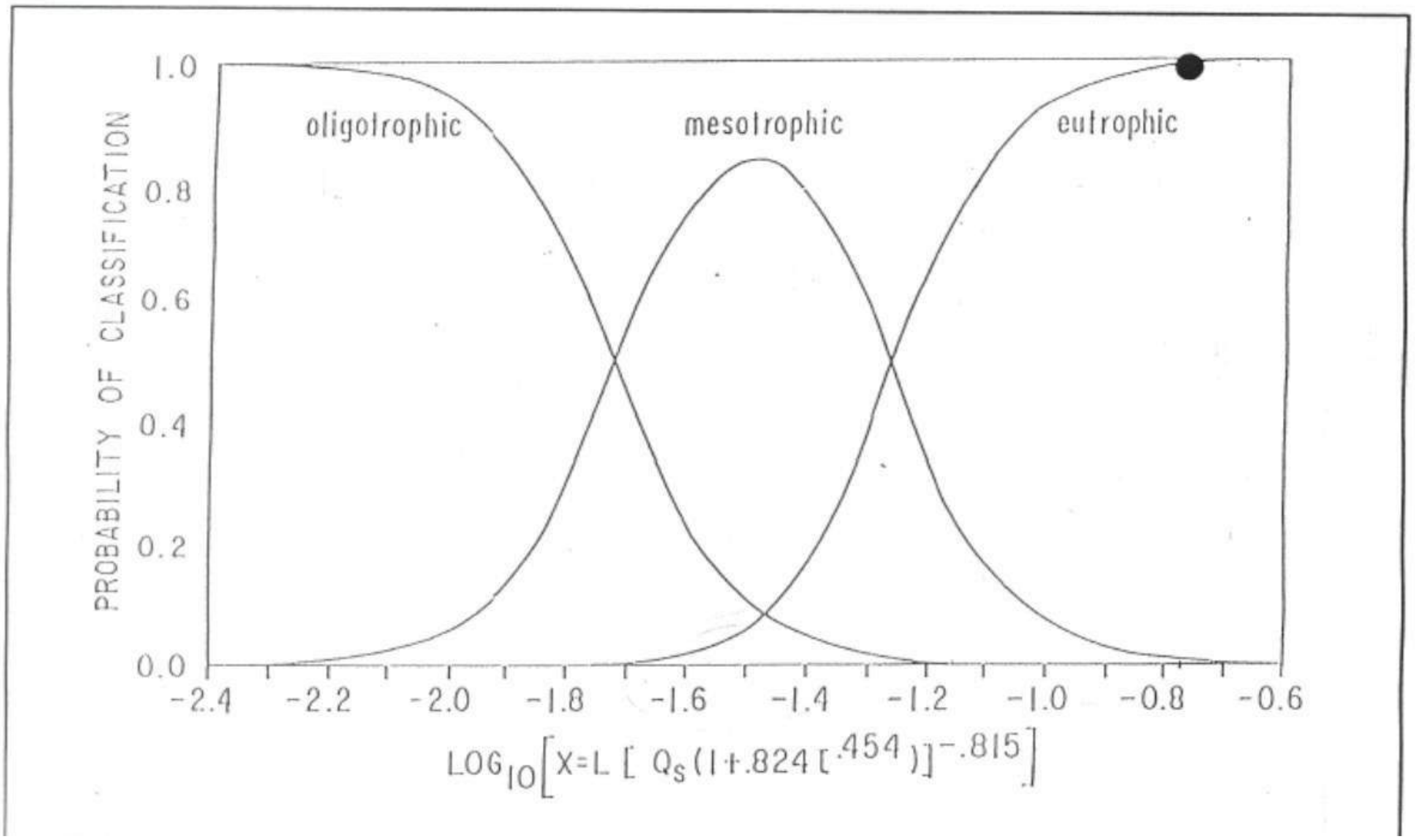


Figure 103. Walker (1977) displays how to interpret the log$_{10}$ of spring phosphorus concentrations in order to assess the trophic state of a waterbody.

Carlson's Predicted Average Chlorophyll

Using the predicted phosphorus loads from Walker's initial equation above, Carlson (1977) developed an equation for estimating the average midsummer chlorophyll *a*. The equation for doing so is as follows:

$$Chl. = e^{((1.449 * LN(P_s)) - 2.442)}$$

Where *Chl.* = estimated summer average chlorophyll *a* concentrations and P_s.

Vollenweider's Predicted Phosphorus

Vollenweider's equation (1976) uses the incoming total phosphorus and hydraulic load, as well as the lake's mean depth and hydraulic residence time, to calculate an estimated phosphorus concentration. The equation for this metric is as follows:

$$P = \frac{L}{10 + \frac{Z_{mean}}{t}}$$

Where *P* = the predicted phosphorus concentration, *L* = the incoming phosphorus load, z_{mean} = the average depth, and *t* = the hydraulic residence time.

Reckhow's Predicted Phosphorus

Lastly, this model by Reckhow (1988) utilizes a nutrient trapping parameter to estimate phosphorus concentrations. The equation is as follows:

$$P = \frac{P_{in}}{(1 + kT_w)}$$

Where *P* = the predicted phosphorus load, P_{in} = the total incoming phosphorus load divided by the total hydraulic load, T_w = the retention time, and *k* = the nutrient trapping parameter. The equation for determining *k* is as follows:

$$k = 3\left(P_{in}^{0.53}\right) * T_w^{-0.75} * z_{mean}^{0.58}$$

Where *k* = the nutrient trapping parameter, P_{in} = the total incoming phosphorus load divided by the total hydraulic load, T_w = the retention time, and z_{mean} = the average depth.

It is important to note that many of these models are designed to consider only the external phosphorus load. They were run for the purposes of this study for both the external load and for the total phosphorus load including the external watershed load and internal phosphorus loading.

6.1 RESULTS

ALGONQUIN WATERS

Surface concentrations of total phosphorus collected in Algonquin Waters during the 2022 season were relatively low, yielding a mid-summer phosphorus-based TSI of 37.35, suggesting late-oligotrophic conditions. Chlorophyll *a* concentrations were also relatively low, yielding a mid-summer Chl. *a*-based TSI of 43.95, suggestive of mesotrophic conditions. Secchi depths typically were moderate, and the Secchi-based TSI for the middle of the summer was calculated to be approximately 50.01, suggesting early-eutrophic conditions.

Residuals of TSI values for each sampling date are plotted below in Figure 104. The points representing the June and August events are located in the upper-left quadrat; this suggests that chlorophyll was limited by phosphorus concentrations at these times and water clarity was impacted either by small-celled algae or by suspended clay particles or other non-algal particulates in the water column. Given the low total suspended solids concentrations obtained during every sampling event, it is more likely that this was a product of smaller-celled algae. This is further suggested by the high presence of the diatom *Synedra* and the cyanobacteria *Dolichospermum* and *Microcystis* in plankton samples. While *Dolichospermum* and *Microcystis* can form dense "clumps" in the water column, this was not observed to occur in 2022. The point representing the October event is located in the upper-right quadrat, suggesting that algae was limited by phosphorus availability and overall larger algal particulates in the water column. Particulates were observable in the field during this event, however these were not particularly large.

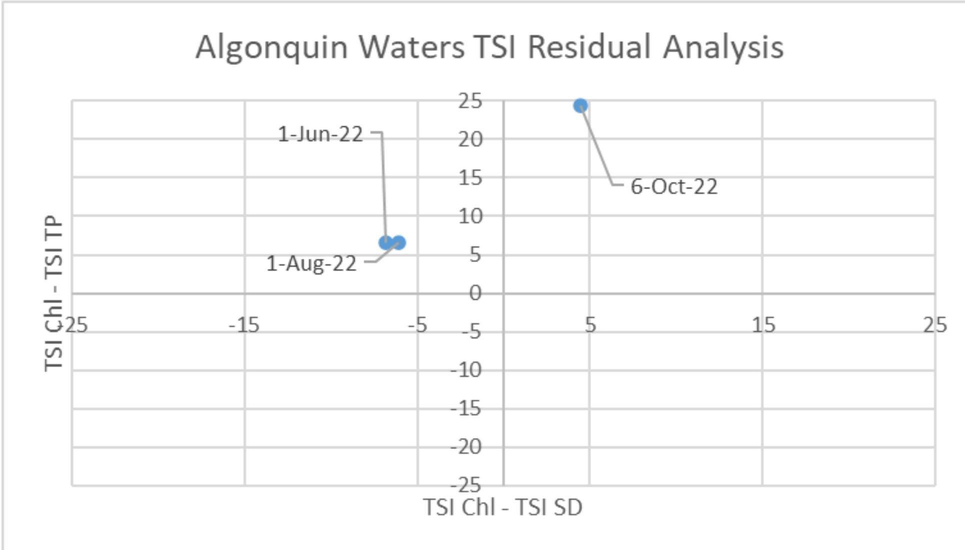


Figure 104. Residuals from TSI values obtained over the course of the 2022 growing season in Algonquin Waters.

When assessed with Kirchner and Dillon's phosphorus retention model, Algonquin Waters yielded an R value of 0.56, suggesting that a little over half of the phosphorus that enters the waterbody is retained on an annual basis and not flushed from the waterbody. When this value is entered into the Dillon-Rigler predictive phosphorus model, Algonquin Waters is predicted to have a spring phosphorus concentration of approximately 0.03 mg/L. This is a slight overestimation when compared to the total phosphorus concentration of 0.01 mg/L obtained at the lake's surface during the June event. The Walker model yielded a closer value of approximately 0.03 mg/L or 0.04 mg/L if the internal phosphorus load is accounted for. According to Walker's trophic state analysis, Algonquin Waters has approximately a 20% likelihood of being mesotrophic and an 80% likelihood of being eutrophic. This is a slight departure from the Carlson's TSI values, which suggested the lake is generally mesotrophic. Carlson's estimated summertime chlorophyll *a* model predicted a chlorophyll concentration of approximately 10.0 µg/L, an overestimation of the actual concentration obtained during the August event of 3.9 µg/L. Vollenweider's predicted phosphorus model yield an estimated phosphorus concentration of approximately 0.03 mg/L (0.04 mg/L when the internal load is accounted for), while Reckhow's predicted phosphorus model yielded a similar estimated value of approximately 0.03 mg/L (0.04 mg/L when internal loads are accounted for). The models generally yield somewhat overestimated results, suggesting that the watershed-based pollutant model may slightly overestimate incoming phosphorus loads.

BUBBLING SPRINGS POND

During the 2022 sampling season, Bubbling Springs Pond yielded relatively low surface total phosphorus concentrations, with the mid-summer phosphorus-based TSI calculated to be 47.35, characteristic of mesotrophy. Chlorophyll *a* concentrations were also relatively low, with the mid-summer Chl. *a*-based TSI value calculated to be 41.38, also characteristic of mesotrophy. Secchi depths were relatively high during the spring and autumn events, reaching the bottom of the water column, while the summer water clarity was somewhat lower, yielding a Secchi-based TSI value of 57.37, characteristic of a eutrophic water body.

TSI value residuals are plotted below in Figure 105. All three of the points representing the three sampling events are located in the lower-left quadrat. This suggests that phosphorus did not fully explain chlorophyll *a* concentrations, suggesting that phosphorus may not have been the limiting nutrient for algae growth. This also can result from an algae community consisting mostly of smaller-cells organisms or instances where reduced water clarity is the product of non-algal particulates in the water column. While the pond yielded higher TSS results during the mid-summer sampling event, this likely does not entirely explain the reduced clarity. Plankton samples showed the pond to have a somewhat consistently abundant population of the dinoflagellate *Ceratium*. While this genus is relatively large compared to other algae taxa, it does not often form "clumps".

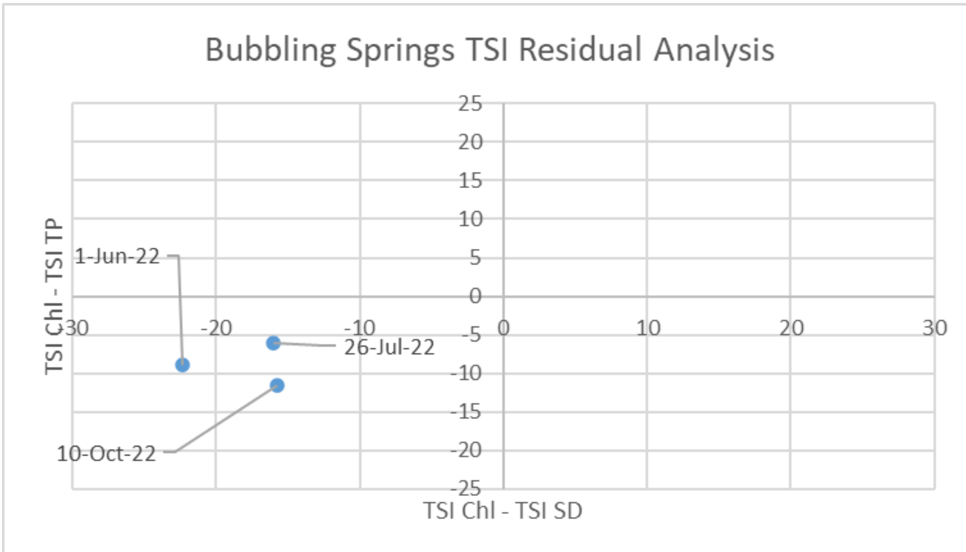


Figure 105. Residuals from TSI values obtained over the course of the 2022 growing season in Bubbling Springs Pond.

When assessed with Kirchner and Dillon's phosphorus retention model, Bubbling Springs Pond yields an *R*-value of approximately 0.51, suggesting that the lake retains approximately half of the phosphorus it receives from the watershed, with the rest flushing from the system. When this value is used in the Dillon-Rigler spring phosphorus prediction model, Bubbling Springs Pond is predicted to yield a spring-time phosphorus concentration of approximately 0.02 mg/L, or 0.03 mg/L if the internal load is considered. These are slight overestimations compared to the surface total phosphorus concentration of 0.01 mg/L obtained during the early June event. Walker's predicted spring phosphorus model yielded similar results of 0.02 mg/L or 0.03 mg/L if the internal load is included. The results of Walker's trophic state analysis suggest that the pond has an approximately 80% likelihood of being eutrophic and a 20% likelihood of being mesotrophic. These results suggest a eutrophic state more than the results of Carlson's TSI, which suggest a mesotrophic-to-eutrophic state. Carlson's predicted summertime chlorophyll model yielded an estimated concentration of approximately 14.0 µg/L if using the results of the Reckhow model and 10.4 µg/L if using the results of the Walker model. Both of these are large overestimations, as the actual concentration obtained during the mid-summer sampling event was 3.0 µg/L. Vollenweider's model predicted a phosphorus concentration of approximately 0.03 mg/L when using both the external load only and when factoring for the internal load. As mentioned above, this is an overestimation of the results collected in the field (a mid-summer surface phosphorus concentration of 0.02 mg/L). Reckhow's model predicted similar results of 0.03 mg/L or 0.04 mg/L of phosphorus when accounting for the internal load. Many of these models produced slight overestimations, while Carlson's estimated summertime chlorophyll model resulted in much higher overestimations when compared to field concentrations. It should be noted that Bubbling Springs Pond was observed to contain some aquatic plant life and a moderate amount of filamentous algae, and these may have served to sequester some of the phosphorus towards the bottom of the water column, possibly explaining the field concentrations that were lower than model estimates.

FARM CREST ACRES POND

Surface total phosphorus concentrations collected in Farm Crest Acres Pond were consistently low throughout the season, resulting in a phosphorus-based TSI value of 37.35, characteristic of an oligotrophic-to-mesotrophic waterbody. Surface chlorophyll *a* concentrations were also relatively low, with the mid-summer concentration yielding a chl. *a*-based TSI value of 44.20, characteristic of a Mesotrophic waterbody. The Secchi depth obtained during the mid-summer event was relatively moderate and yielded a Secchi-based TSI value of 51.53, which is suggestive of eutrophic conditions.

Farm Crest Acres Pond's TSI residuals are plotted below in Figure 106. The points representing the May and August events are located in the upper-left quadrant, suggesting that phosphorus was limiting algae growth at this time and that Secchi depths may had been partially due to smaller algal particulates being dominant in the water column. Plankton tow results generally support this hypothesis. The point representing the October event is located in the lower-left quadrat, suggesting that algae growth was less limited by phosphorus than in other points in the year.

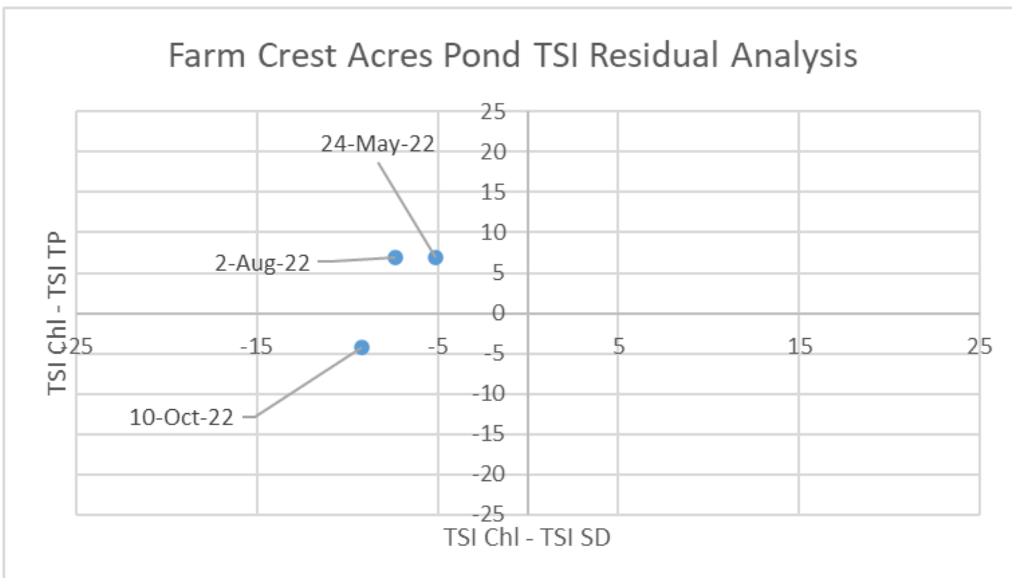


Figure 106. Residuals from TSI values obtained over the course of the 2022 growing season in Farm Crest Acres Pond

When assessed with Kirchner and Dillon's phosphorus retention model, Farm Crest Acres Pond was calculated to have a retention value of approximately 0.73, suggesting that the waterbody retains approximately three-quarters of all incoming phosphorus in a year. When this value is used in the Dillon-Rigler predicted phosphorus model, Farm Crest Acres Pond was estimated to have a springtime phosphorus concentration of approximately 0.03 mg/L, or 0.04 mg/L if internal loading is considered. Both of these predicted concentrations are higher than the surface phosphorus concentration of 0.01 mg/L measured from the May event's water sample. Walker's Springtime predictive phosphorus model yielded concentrations of approximately 0.05 mg/L or 0.08 mg/L if internal loads are considered. Walker's trophic state assessment predicted that the pond has an approximately 90% likelihood of being eutrophic and a 10% likelihood of being mesotrophic. These results suggest that the pond has a higher likelihood of being eutrophic than Carlson's TSI analysis suggests. Carlson's predicted chlorophyll *a* model predicted a summertime chlorophyll *a* concentration of approximately 24.3 μg/L when using the results of the Reckhow model and 46.4 μg/L when using the results of the Walker model, both of which are large overestimations when compared with the August surface chlorophyll *a*. concentration collected in the field (4.0 μg/L). Vollenweider's predicted phosphorus model predicted an overestimation of approximately 0.02 mg/L of phosphorus (0.04 mg/L when internal loads are used), while Reckhow's model yielded a prediction of approximately 0.05 mg/L, or 0.06 mg/L when internal loads are considered. These models generally overestimated phosphorus and chlorophyll concentrations when compared to those obtained in the field. This suggests that the watershed-based model may be overestimating annual phosphorus loads entering Farm Crest Acres Pond.

FOREST HILL LAKE

The July sampling event conducted at Forest Hill Lake yielded the highest surface phosphorus concentration of the year, resulting in a mid-summer phosphorus-based TSI value of approximately 57.3, characteristic of eutrophic conditions. The July chlorophyll *a* concentration was lower than those collected during the spring and autumn events, yielding a chl. *a*-based TSI value of approximately 50.5, characteristic of eutrophic conditions. The Secchi depth measured during the July event was reduced compared to those collected during the spring or autumn events, yielding a Secchi-based TSI value of approximately 60.0, characteristic of eutrophic conditions.

Residuals from Forest Hill Lake's 2022 TSI values are plotted below in Figure 107. The point representing the May sampling event, while in the upper right quadrat, is relatively close to the figure's origin, as TSIs for this event were relatively similar, indicating that phosphorus largely controlled chlorophyll *a* and algae growth, and algae growth was the major factor determining water clarity. The point representing the July event is located in the lower-left quadrat, suggesting that algae growth at this time was not entirely limited by phosphorus, and water clarity was either influenced by non-algal particulates in the water column, or that the algae community was dominated by smaller-celled organisms. Given the low concentration of surface TSS obtained from this event, it is more likely that this is a product of smaller-celled algae. The point representing the October event is located in the upper- left quadrat. Because this point is close to the y-axis, however, it may be inferred that water clarity was largely a product of algae growth during this event. The location above the x-axis suggests that phosphorus was the limiting nutrient controlling algae growth during this event.

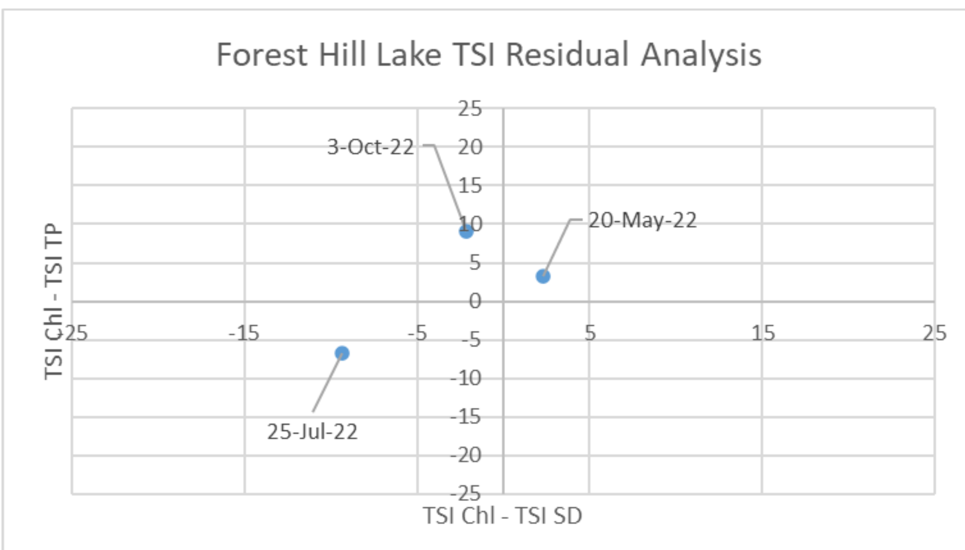


Figure 107. Residuals from TSI values obtained over the course of the 2022 growing season in Forest Hill Lake.

Analysis using the Kirchner-Dillon phosphorus retention model yielded a retention value of approximately 0.56, suggesting that Forest Hill Lake retains approximately half of the phosphorus that enters over the course of an average year. When this coefficient is used as part of the Dillon-Rigler predictive phosphorus model, Forest Hill Lake is estimated to have a springtime phosphorus concentration of approximately 0.02 mg/L, or 0.03 mg/L if the internal phosphorus load is accounted for. The value obtained using only external loading is only a slight underestimation of the surface total phosphorus concentration of 0.03 mg/L obtained during the May event, while the estimation calculated using the total load is more accurate. Analysis with Walker's predicted phosphorus model yields an estimated Springtime phosphorus concentration of approximately 0.03 mg/L. The Walker trophic state model estimated that Forest Hill Lake has an approximately 80% likelihood of being eutrophic and a 20% likelihood of being mesotrophic. This largely aligns with the results obtained by Carlson's TSI, which mostly provided values indicative of eutrophic conditions. Carlson's predicted summer chlorophyll model yielded a concentration of approximately 10.61 µg/L when using the results of the Kirchner-Dillon model for external loads only and 13.9 µg/L when using the same model for both external and internal loads. These are overestimations when compared to the chl. *a* concentration of 7.7 µg/L obtained in the field during the summer event. Interestingly, however, both the May event and October event yielded concentrations of 14.0 µg/L, which is more similar to the results of the model when both internal and external loading are considered. Vollenweider's predicted phosphorus concentration yielded an estimated phosphorus concentration of approximately 0.02 mg/L when only the external load is used and 0.03 mg/L when both external and internal loading are accounted for. The Reckhow predicted phosphorus model yielded an estimated concentration of approximately 0.03 mg/L for both external loads only and when internal loads are also accounted for. Phosphorus estimates calculated through these models were largely similar to those obtained in the field, supporting the accuracy of the hydrologic and pollutant loading model.

GORDON LAKE

Total phosphorus concentrations obtained in the field from lower Gordon Lake peaked during the August event, yielding a phosphorus-based TSI value for this event of 57.34, characteristic of a eutrophic system. The chlorophyll *a* concentration obtained during the August event was relatively high at over 20 µg/L, translating to a chl. *a*-based TSI value of 60.92, also characteristic of a eutrophic system. The lake featured somewhat low Secchi depths during this event as well, yielding a Secchi-based TSI value of 61.52, characteristic of a eutrophic system.

TSI residual values for data collected from Gordon Lake are plotted below in Figure 108. Points representing the May and August events are relatively close to the origin of the figure, suggesting that chlorophyll *a* concentrations and algae growth during these dates is largely controlled by phosphorus concentrations, while water clarity during these dates was largely a product of algae growth. The October event is located in the upper right quadrat, suggesting that algae growth was strongly limited by phosphorus during this date. As the point is relatively close to the y-axis, it may be inferred that water clarity was largely a product of algae growth during this date.

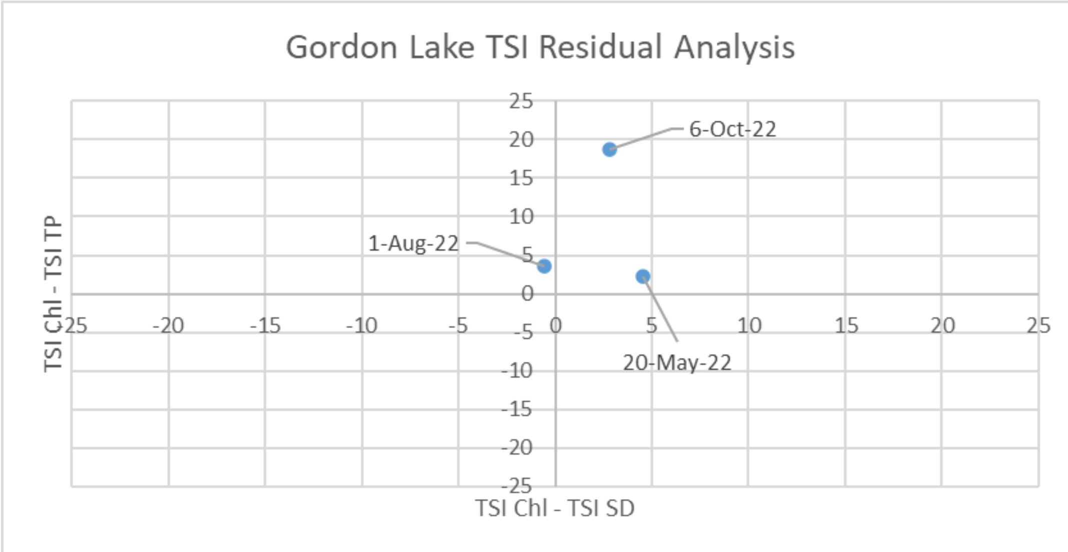


Figure 108. Residuals from TSI values obtained over the course of the 2022 growing season in Gordon Lake

When assessed with Kirchner and Dillon's phosphorus retention model, Gordon Lake received a retention coefficient of approximately 0.45, suggesting that the lake retains approximately half of the phosphorus it receives over the course of an average year. When this coefficient is used in the Dillon-Rigler predictive phosphorus model, the lake is estimated to feature a springtime phosphorus concentration of approximately 0.04 mg/L, or 0.05 mg/L when internal loads are also accounted for. This is an overestimation of the in-field concentration of 0.02 mg/L obtained during the spring event. Similarly, the Walker model also predicted a springtime phosphorus load of approximately 0.04 mg/L. When assessed with Walker's trophic state model, Gordon Lake is estimated to have an 80% likelihood of being eutrophic and a 20% likelihood of being Mesotrophic, largely aligning with the results of the Carlson's trophic state index. When the results of the Walker model with only external loads included are used, the Carlson predictive summer chlorophyll model yields an estimated summer chlorophyll concentration of approximately 19.5 µg/L. Using the results of the Walker model when both external and internal loads are used, the predicted concentration is 20.8 µg/L. The latter result aligns more closely with the concentration of 22.0 µg/L collected during the summer field event. When assessed with the Vollenweider model, Gordon Lake was estimated to feature a phosphorus concentration of 0.06 mg/L, while the Reckhow model yielded a lower estimate of approximately 0.01 mg/L. With the exception of the Reckhow model, most of the predictive springtime phosphorus models yielded results notably higher than the result obtained from field sampling. One of these over-estimated concentrations, however, yielded a more accurate predicted chlorophyll *a* concentration when used in Carlson's predicted summertime chlorophyll model. As noted with other lakes in this study, Gordon Lake may sequester a portion of phosphorus in aquatic plants or macroalgae. While the lower lake was not observed by Princeton Hydro to contain a particularly high density of aquatic plants, upper Gordon Lake was observed to feature very dense growth of macrophytes throughout its basin. It may be inferred that the upper lake serves as a wetland buffer and sequesters nutrients prior to water entering Lower Gordon Lake.

HIGH CREST LAKE

Surface phosphorus concentrations obtained during the summer sampling event at High Crest Lake were lower than those obtained during the spring or autumn events and resulted in a phosphorus-based TSI of 37.35, characteristic of late-oligotrophic-to-mesotrophic systems. Chlorophyll *a* concentrations were similarly lower than spring and autumn concentrations during this event, yielding a chl. *a*-based TSI of approximately 37.88, also characteristic of a late-oligotrophic system. The Secchi depth obtained during the summer event was the highest of the year, resulting in a Secchi-based TSI of approximately 44.17, suggestive of mesotrophic conditions. It should be noted that, while the summer TSI values were reflective of an oligotrophic or mesotrophic system, TSIs calculated from the spring and autumn events were more suggestive of a mesotrophic or eutrophic system.

TSI residuals for High Crest Lake are plotted in Figure 109. The point representing the May event is relatively close to the figure's origin, suggesting that algae growth and chlorophyll concentrations were largely a factor of phosphorus concentrations and water clarity was largely a product of algae growth. The point representing the July event is located along the x-axis to the left of the y-axis. The location on the X-axis suggests that chlorophyll *a* concentrations could be largely attributed to total phosphorus concentrations. As the point is left of the y-axis, it may be inferred that the water column was dominated by smaller algal cells or that visibility was more influenced by non-algal suspended solids. The somewhat elevated TSS concentration obtained during this date at the surface of the water column lends evidence for the latter hypothesis. The point representing the October event is located in the upper-right quadrat, suggesting that algae growth was phosphorus-limited and the water column was dominated by larger particulates.

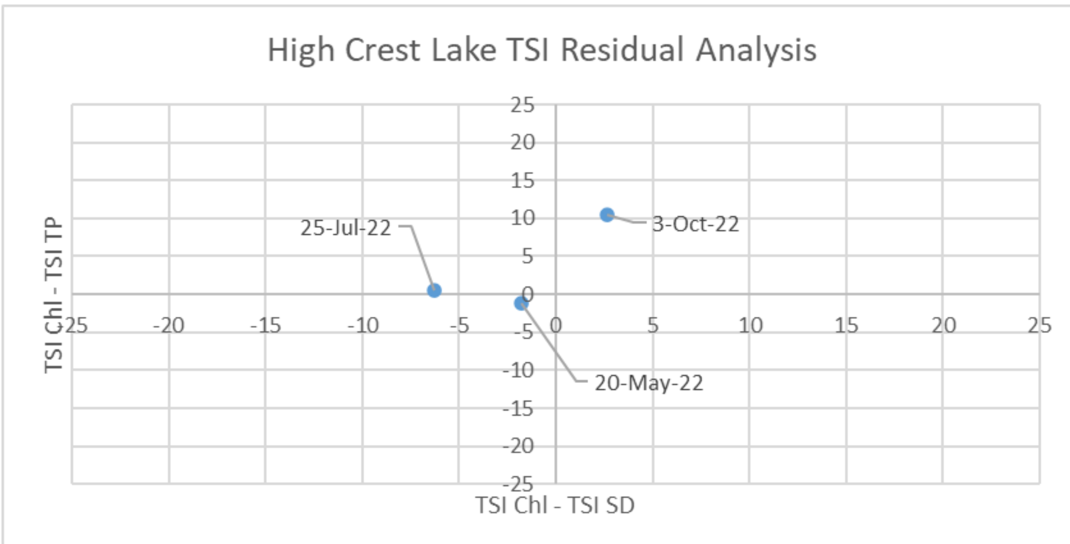


Figure 109. Residuals from TSI values obtained over the course of the 2022 growing season in High Crest Lake.

When assessed using the Kirchner-Dillon phosphorus retention model, High Crest Lake received a phosphorus retention coefficient of approximately 0.68, suggesting that the lake retains approximately two-thirds of the phosphorus that enters over the course of an average year. When this result is entered into the Dillon-Rigler predicted phosphorus model, the lake is estimated to feature a springtime phosphorus concentration of 0.03 mg/L, or 0.04 mg/L if the internal load is also considered. This is a slight overestimation when compared to the phosphorus concentration of 0.02 mg/L obtained during the spring sampling event. The Walker predictive phosphorus model yielded higher estimated springtime phosphorus concentrations of approximately 0.05 mg/L, or 0.07 mg/L if internal loads are included in the analysis. The results of Walker's trophic state analysis suggest that High Crest Lake has a 95% likelihood of being eutrophic and a 5% likelihood of being mesotrophic. This model suggests that High Crest Lake trends towards eutrophy more than the summer Carlson's TSI results do. When using the external load-based predicted phosphorus load from the Vollenweider model, Carlson's predicted summer chlorophyll model estimated a concentration of approximately 12.8 µg/L; when the result of the Vollenweider model involving the internal loading results is used, a higher concentration of 19.1 µg/L was predicted. These are large overestimations when compared to the surface concentration of 2.1 µg/L obtained during the summer event, however the deep sample from this event yielded a concentration of 53.0 µg/L, which the Carlson model aligns more with when using the output from the Walker model run using internal and external loads. The Vollenweider model itself predicted phosphorus model yielded a predicted springtime phosphorus concentration of approximately 0.03 mg/L (0.04 mg/L when internal loads were included), while the Reckhow model yielded a predicted concentration of 0.04 µg/L (0.05 mg/L when internal loads were included. When comparing the results with surface concentrations obtained in the field, many of the above models overestimate spring phosphorus. The models align more, however, with deep water concentrations of phosphorus. This suggests that the internal phosphorus load may be a larger source of the lake's total load than was modeled. Alternatively, the lake may at times experience deep-water blooms of cyanobacteria. This is most evidenced during the summer, when the deep sample yielded a chlorophyll *a* concentration of 53.0 µg/L.

JOHNS LAKE

Johns Lake's highest detected surface concentration of total phosphorus collected in 2022 occurred during the summer event, yielding a phosphorous-based TSI of approximately 57.3, a value consistent with eutrophic systems. The summer event similarly yielded the highest chlorophyll *a* concentration of the season, resulting in a chl. *a*-based TSI value of 52.6, also consistent with eutrophic systems. The summer Secchi depth at Johns Lake was low-to-moderate for a north New Jersey waterbody and resulted in a Secchi-based TSI of 58.6, representative of eutrophic conditions.

Figure 110 below displays the plotted TSI residuals from Johns Lake. All points are located to the left of the y-axis, suggesting that the plankton population may have been dominated by smaller-celled organisms or that clarity was in part influenced by non-algal turbidity. The point representing the May sampling event is located in the lower-left quadrat, suggesting that algae growth and chlorophyll was not entirely limited by phosphorus concentrations and may have been influenced by other factors. While the point representing the July event is located below the x-axis, also suggesting a phosphorus surplus, the point is close enough to the x-axis that it may be inferred that algae growth and chlorophyll concentrations were largely explained by phosphorus concentrations. This was likely also taking place during the October event, which is similarly close to the x-axis.

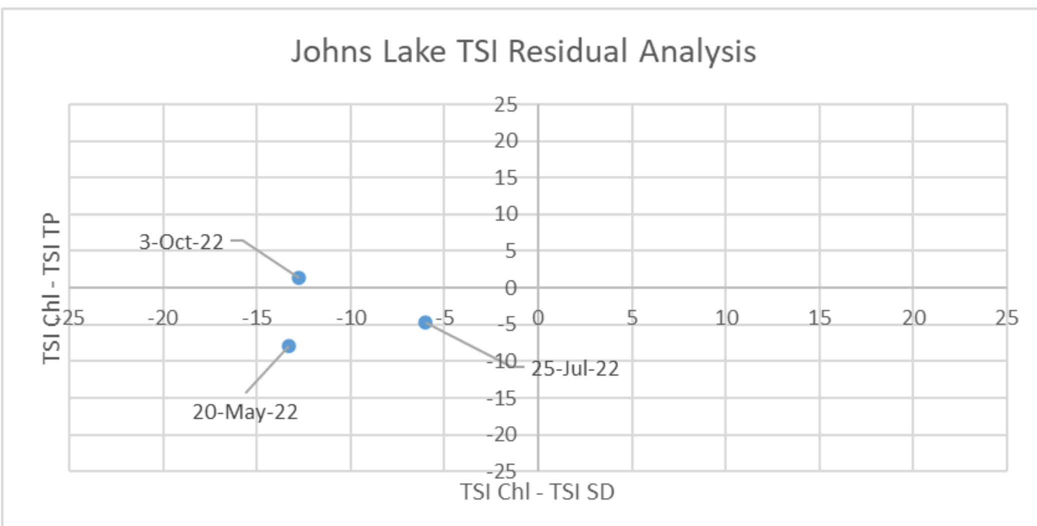


Figure 110. Residuals from TSI values obtained over the course of the 2022 growing season in Johns Lake.

When assessed with the Kirchner-Dillon model, Johns Lake yielded a phosphorus retention coefficient of approximately 0.76, suggesting that the waterbody retains approximately three-quarters of incoming phosphorus over the course of a year. When this is used for the Dillon-Rigler model for springtime phosphorus prediction, a phosphorus concentration of approximately 0.01 mg/L is estimated. This is an underestimate from the 0.03 mg/L obtained in the field during the May event. Walker's spring phosphorus prediction model yielded a more closely aligning phosphorus concentration of approximately 0.03 mg/L. Walker's trophic state model estimates that Johns Lake has a 60% likelihood of being eutrophic and a 40% chance of being mesotrophic. Carlson's summertime chlorophyll *a* predictive model estimates that Johns Lake will have a summer chlorophyll *a* concentration of approximately 10.35 µg/L when using the results of the Walker Model with external loads only, and a concentration of approximately 10.92 µg/L when using the results of the same model with internal loads included. Both results are close to the in-field summer concentration of 9.4 µg/L. Vollenweider's predictive phosphorus model estimated a springtime phosphorus concentration of approximately 0.01 mg/L, while Reckhow's model estimated approximately 0.05 mg/L. With the exception of the Walker model, the predicted phosphorus concentrations were somewhat overestimated, suggesting that the hydrologic and pollutant load modeling either overestimated the amount of incoming phosphorus to the lake or did not take into account factors that may be serving to reduce this load. As mentioned with some of the other lakes in this study, Johns Lake was observed to exhibit aquatic plant growth over most of the waterbody's area; these plants may serve to sequester some incoming phosphorus, reducing the concentration present in the water itself.

KITCHELL LAKE

Similarly to Johns Lake, Kitchell Lake's highest surface phosphorus concentration was detected in the summer sample, and resulted in a phosphorus-based TSI of approximately 57.34, consistent with eutrophic conditions. The lake's summer chlorophyll *a* concentrations were somewhat elevated, resulting in a chl. *a*-based TSI value of 60.9, which is also indicative of a eutrophic system. The summer Secchi depth was measured to be less than a meter, resulting in a Secchi-based TSI value of approximately 61.52, consistent with eutrophic conditions.

Figure 111 below displays the TSI residuals for all three events at Kitchell Lake. The point representing the May event is located in the lower-left quadrat, suggesting that algae growth and chlorophyll *a* was limited by a factor other than phosphorus concentrations. It also suggests that the plankton community at this time was dominated by smaller-celled organisms. This is further suggested by the large numbers of the smaller-celled green algae genus *Gloeocystis* in the plankton sample collected during this event. The point representing the August event is located near the origin of the figure, suggesting that algae growth and chlorophyll *a* concentrations were an effect of phosphorus concentrations, while clarity was an effect of algae densities. The point representing the October event is located in the upper-right quadrat, suggesting that algae growth was strongly phosphorus-limited. As the point is located close to the y-axis, it may be inferred that water clarity on this date was largely a product of algal turbidity.

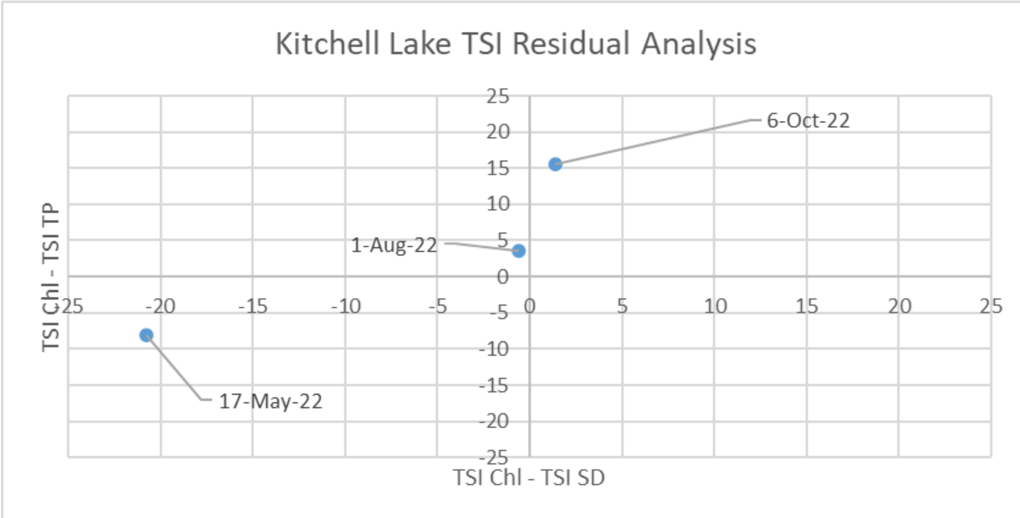


Figure 111. Residuals from TSI values obtained over the course of the 2022 growing season in Kitchell Lake.

When assessed with the Kirchner-Dillon phosphorus retention model, Kitchell Lake received a retention coefficient of approximately 0.53, suggesting that the lake retains approximately half of the phosphorus that enters over the course of an average year. When used in the Dillon-Rigler predictive phosphorus model, Kitchell Lake was estimated to feature a springtime phosphorus concentration of 0.01 mg/L or 0.02 mg/L if the internal load is accounted for. This aligns with the surface phosphorus concentration of 0.02 mg/L collected during the spring sampling event. The Walker predictive phosphorus model yielded a prediction of 0.02 mg/L, or 0.03 mg/L if the internal load is included in the analysis. The results of Walker's trophic state analysis suggest that Kitchell Lake has a 10% likelihood of being a mesotrophic system and a 90% likelihood of being a eutrophic system, largely aligning with the results of Carlson's TSI. When using the phosphorus concentration predicted by the Reckhow model using only external phosphorus loads, Carlson's predicted summer chlorophyll *a* model yielded a concentration of 10.5 µg/L; when using the results of the same model with internal loads included, the lake is predicted to have a chlorophyll *a* concentration of approximately 13.1 µg/L. Both of these results are underestimations when compared with the surface chlorophyll *a* concentration of 22.0 µg/L obtained in the field during the summer event. The Vollenweider predictive phosphorus model yielded a springtime phosphorus estimate of approximately 0.02 mg/L (0.03 mg/L when internal loads are also considered), while the Reckhow model yielded a phosphorus concentration of approximately 0.03 mg/L. Most of the predictive models yielded spring phosphorus concentrations that aligned with the surface phosphorus concentration obtained in Kitchell Lake during the spring event, however the summer chlorophyll *a* predictions were notably lower than what was obtained in the field. It should be noted that the lake appeared to have been drawn down several feet between the summer and fall seasons. Modeling of the lake's volume and flushing rate was performed with the assumption that the lake remains at full water height, and the reduced quantity of water may have further concentrated algae growth.

LINDY'S LAKE

Lindy's Lake yielded overall low surface phosphorus concentrations during the 2022 field season, with the summer concentration resulting in a phosphorus-based TSI of 47.35, characteristic of a mesotrophic system. Surface chlorophyll *a* concentrations were also somewhat low, resulting in a chl. *a*-based TSI of 49.41, characteristic of a mesotrophic-to-eutrophic system. The summer event yielded the lowest water clarity of the season, and the Secchi-based TSI was calculated to be 57.37, which is indicative of a eutrophic system.

TSI residuals are plotted below in Figure 112. All three events are represented by points located in the upper-left quadrat, however the point representing the May event is located close to the figure's origin, indicating that algae growth and chlorophyll *a* concentrations were largely a product of phosphorus concentrations and that water clarity was largely a product of algae growth and chlorophyll *a* concentrations. The point representing the August sampling event is located further to the left of the y-axis, suggesting that the algae population was dominated by smaller-celled organisms during this event or was possibly influenced by non-algae particulates. The plankton tow results indicate that many genera of plankton were common in the water column during this event, with several of them being relatively small-celled. It should be noted that the lake is treated with blue dye, which may also impact water clarity. Because this event's point is located close to the x-axis, it may be inferred that algae growth was largely a product of phosphorus concentrations. The point representing the October sampling event is located relatively close to the y-axis, suggesting that water clarity was largely a product of algae growth and chlorophyll *a* concentrations. The point's location above the x-axis suggests that algae growth and chlorophyll *a* concentrations were somewhat strongly phosphorus limited.

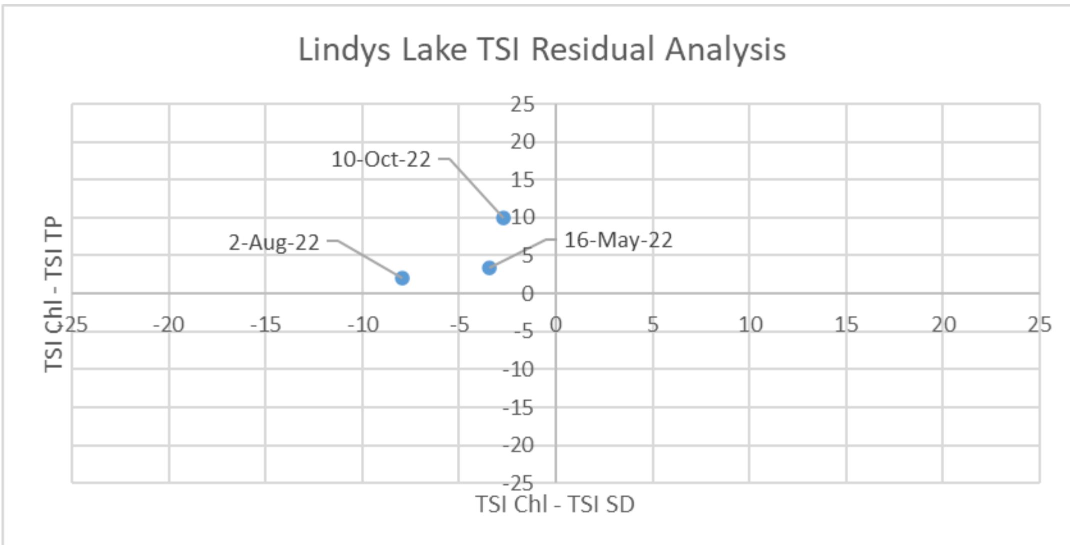


Figure 112. Residuals from TSI values obtained over the course of the 2022 growing season in Lindy's Lake.

When assessed with the Kirchner-Dillon model, Lindy's Lake was assessed to have a phosphorus retention coefficient of approximately 0.79, suggesting that the lake retains over three-quarters of its incoming phosphorus load. The Dillon-Rigler model estimated a very high springtime phosphorus concentration of 0.15 mg/L, or 0.18 mg/L if the internal load is included in the analysis. This is a high overestimation when compared to the surface sample of 0.02 mg/L obtained during the spring event. Walker's predictive spring phosphorus model yielded even higher estimates at 0.39 mg/L, or 0.46 mg/L if including the internal load. When assessed with Walker's trophic state model, the lake is estimated to have a nearly 100% likelihood of being eutrophic. While Carlson's TSI yielded some results consistent with eutrophic waterbodies, these results also suggested that mesotrophic conditions may occur at times. Carlson's estimated summer chlorophyll *a* model yielded a result of 87.20 µg/L when the results of the Reckhow model were used, and a result of 487.47 µg/L when the result of the Walker equation is used. The Vollenweider model predicted a springtime phosphorus concentration of 0.13 mg/L, while the Reckhow model predicted a concentration of 0.12 mg/L. Most of the trophic models overestimated both surface springtime phosphorus concentrations and surface summer chlorophyll *a* concentrations. This suggests that the hydrologic and nutrient loading model may have overestimated the annual phosphorus load entering

Lindy's Lake. It should be noted that this model does not account for any management actions that may already be in place to decrease annual nutrient loads. Alternatively, much of Lindy's Lake's phosphorus load may be located towards the bottom of the water column, either as phosphorus that entered the water column via internal loading or as benthic algae that is not often represented in surface chl. *a* samples. While septic system influence was modeled to be the largest single source of phosphorus to Lindy's Lake, the modeled internal load is still high enough to lend evidence to the former hypothesis. Additionally, benthic algae were collected via anchor in the northern portion of the lake during sampling events, lending evidence towards the latter hypothesis.

LAKE LOOKOVER

Lake Lookover yielded low concentrations of surface phosphorus throughout the 2022 season, resulting in a phosphorus-based TSI of 37.35 for all sampling dates; this is consistent with late-oligotrophic-to-mesotrophic conditions. Chlorophyll *a* concentrations were also relatively low throughout the season, with the highest obtained in the summer. This concentration yielded a chl. *a*-based TSI of 42.31, consistent with mesotrophic conditions. The lake featured a somewhat reduced Secchi depth during the summer event, yielding a Secchi-based TSI of 57.37, which is suggestive of eutrophic conditions.

TSI residuals are plotted below in Figure 113. All three events are represented by points located close to the x-axis, suggesting that surface chlorophyll *a*. concentrations were largely a product of total phosphorus throughout the season. The points representing all three events are also to the left of the y-axis, suggesting that the system was dominated by smaller-celled algae or that Secchi depth was influenced by non-algal turbidity. Plankton tow data suggests that this may had been the case at some points in the year. It should also be noted that Lake Lookover is a largely macrophyte-dominated system; as such, much of the phosphorus and associated primary production is likely occurring in these macrophytes towards the bottom of the water column and are not easily detected by discrete water quality samples.

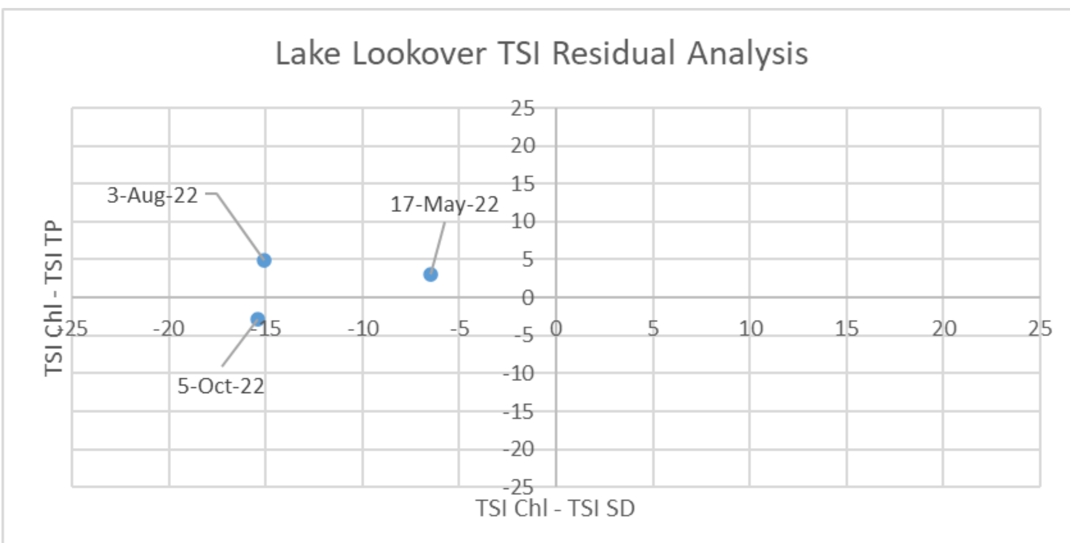


Figure 113. Residuals from TSI values obtained over the course of the 2022 growing season in Lake Lookover.

When assessed with the Kirchner-Dillon model, Lake Lookover received a phosphorus retention coefficient of 0.45, suggesting that the lake retains approximately half of the phosphorus that enters over the course of an average year. This value was used as part of the Dillon-Rigler predictive phosphorus model, which yielded a predicted springtime phosphorus concentration of 0.01 mg/L. This estimation strongly aligns with the concentration of 0.01 mg/L obtained from field samples during the Spring event. Similar results were obtained when using the Walker predictive phosphorus model. When assessed with Walker's trophic state model, Lake Lookover is estimated to have an approximately 10% likelihood of being eutrophic, a 80% likelihood of being mesotrophic, and a 10% likelihood of being oligotrophic. Carlson's predictive summer chlorophyll model yielded a predicted summer chlorophyll *a* concentration of 2.6 μg/L when the result of the Walker model is used with only the external loads used, as well as a concentration of 3.3 μg/L when the same model is used with internal loads included in the analysis. The latter prediction is very closely aligned to the in-field concentration of 3.3 μg/L obtained during the summer event. The Vollenweider model yielded a predicted spring phosphorus concentration of 0.01 mg/L, or 0.02 mg/L when the internal load is accounted for, while the Reckhow model yielded a predicted concentration of 0.02 mg/L. These models generally align with the concentrations obtained in the field at Lake Lookover, suggesting that the hydrologic and nutrient loading watershed model was largely accurate. As noted above, however, it is likely that Lake Lookover sequesters a large portion of its phosphorus load in macrophytes, suggesting more phosphorus may enter the lake than the nutrient model suggests.

LOWER MOUNT GLEN LAKE

Surface concentrations of total phosphorus were relatively low throughout the 2022 season in Lower Mount Glen Lake, with the summer concentration yielding a phosphorus-based TSI of 47.35, indicative of mesotrophic conditions. The lake's summer chlorophyll *a* concentration was somewhat elevated, yielding a chl. *a*-based TSI of 58.39, indicative of eutrophic conditions. Secchi depths were at their lowest during the summer event, yielding a Secchi-based TSI of 56.22, also indicative of eutrophic conditions.

TSI residuals are plotted below in Figure 114. The point representing the May event is located in the lower-left quadrat, suggesting that algae growth was not limited by phosphorus but by another factor such as water temperatures. Secchi depths during this date were also lower than chlorophyll *a* concentrations might usually suggest, indicating that the water column may have been dominated by smaller-celled algae taxa at this time. The plankton tow was dominated by dinoflagellates during this date; while these organisms are larger in size, they may occur in dense enough concentrations to reduce Secchi depth at some points of the season. The August event is represented by a point in the upper-right quadrat, although the point is close to the y-axis, suggesting that water clarity was largely a function of algae growth and chlorophyll *a* concentrations. The point's location above the x-axis suggests that phosphorus concentrations were strongly limiting algae growth. The point representing the October sampling event is relatively close to the figure's origin, suggesting that algae growth and chlorophyll *a* concentrations were largely attributable to phosphorus concentrations, and this algae growth was a large factor affecting water clarity.

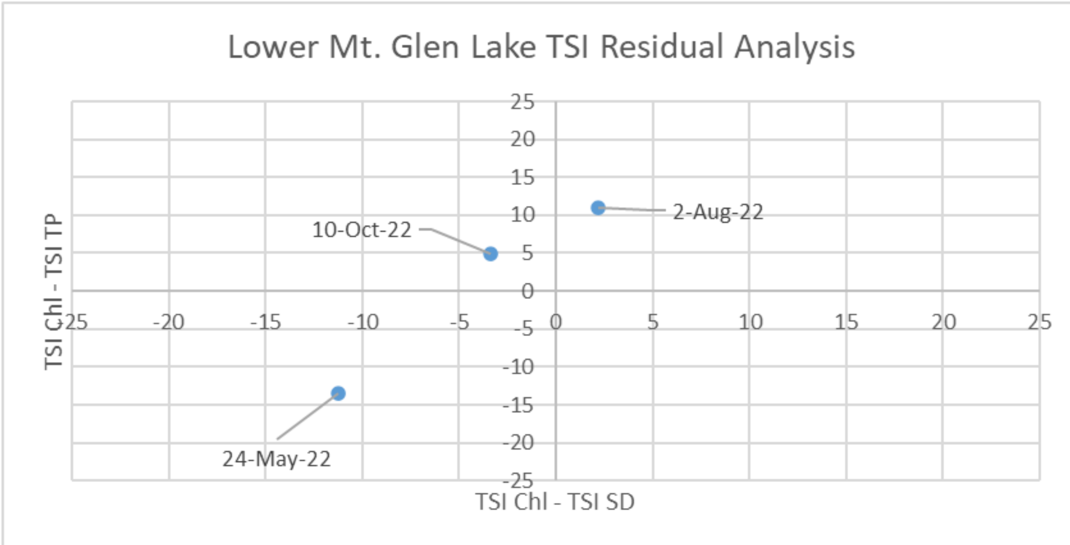


Figure 114. Residuals from TSI values obtained over the course of the 2022 growing season in Lower Mount Glen Lake.

When assessed using the Kirchner-Dillon model, Lower Mount Glen Lake yielded a phosphorus retention coefficient of 0.47, suggesting that approximately half of the phosphorus that enters the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, Lower Mount Glen Lake is estimated to feature a springtime phosphorus concentration of approximately 0.06 mg/L or 0.07 mg/L if internal loads are considered. This is an overestimation when compared with the surface sample phosphorus concentration of 0.02 mg/L obtained during the spring event. The Walker model yielded a similar predicted pring phosphorus load of 0.06 mg/L. When assessed with Walker's trophic state model, Lower Mount Glen Lake is estimated to have a nearly 100% likelihood of being eutrophic. This result points to eutrophic conditions more than the Carlson TSI, which indicated that mesotrophic conditions may be present during the early and late season. When assessed with Carlson's predictive chlorophyll model using the results of the Walker model, the lake is estimated to feature a summer chlorophyll *a* concentration of approximately 32.1 µg/L or 35.9 µg/L if internal loads are included in the analysis. These are high overestimations when compared to the concentration of 17 µg/L obtained during the summer sampling event. The Vollenweider model yielded a predicted springtime phosphorus concentration of approximately 0.08 mg/L, while the Reckhow model yielded an elevated concentration of 0.11 mg/L, or 0.12 mg/L if internal loads are included. While overestimates, the result of the Reckhow model aligns the closest with the deep phosphorus concentration of 0.10 mg/L collected during the summer event, suggesting that internal loading may produce a more significant percentage of the lake's annual phosphorus load than originally modeled. The other overestimations by trophic models suggest that the annual watershed-based phosphorus load predicted by the hydrologic and nutrient loading model may also be an overestimation. It should be noted that this model does not take into account any management actions that may have already been implemented to reduce the watershed-based nutrient load.

UPPER MOUNT GLEN LAKE

Upper Mount Glen Lake yielded a relatively elevated total phosphorus concentration from the summer sampling event, resulting in a phosphorus-based TSI of 69.04, a value representative of eutrophic conditions. Chlorophyll *a* concentrations were also high during the summer, yielding a chl. *a*-based TSI of 68.58, also representative of a eutrophic system. The summer event also yielded a low Secchi depth, yielding a Secchi-based TSI value of 68.99, a value consistent with eutrophic conditions.

TSI residuals are plotted below in Figure 115. The point representing the Spring water quality sampling event is located in the bottom-left quadrat, suggesting that at this time, chlorophyll *a* production was not limited by phosphorus concentrations, but by other factors. Additionally, the Secchi depth was lower than the concentration of chlorophyll *a* obtained during this date would normally suggest. This may be in part due to the lake's shallow depth limiting potential Secchi depth and possibly due to plants or benthic algae obscuring the Secchi disk towards the bottom of the water column. The point representing the summer event is located close to the figure's origin, suggesting that algae growth and chlorophyll *a* production was largely a product of phosphorus concentrations and that water clarity was a function of algae growth. The point representing the autumn sampling event is located in the upper-left quadrat, close to the x-axis, suggesting that algae and chlorophyll production was largely a product of phosphorus concentrations and that water clarity was not entirely due to algae production.

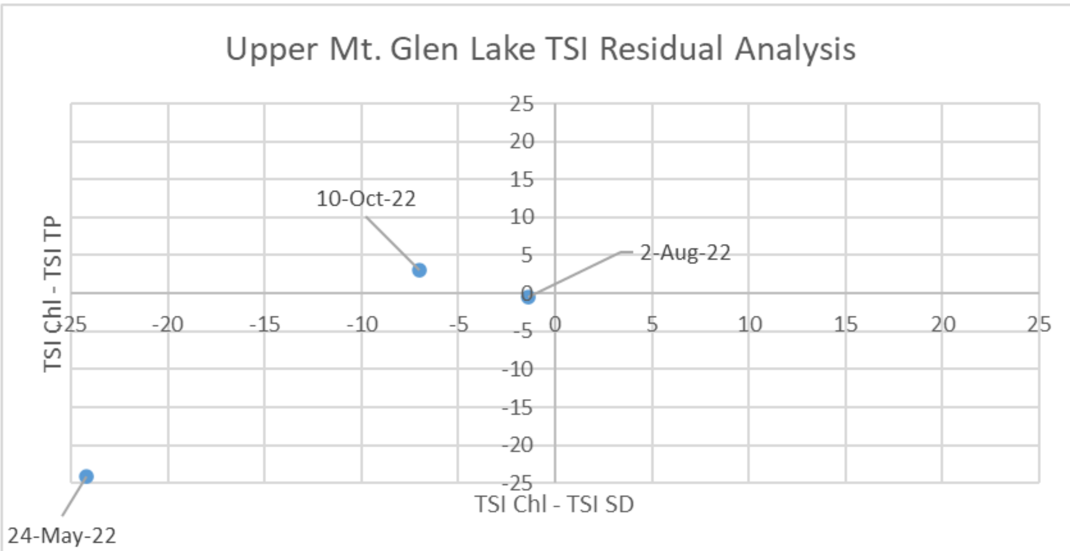


Figure 115. Residuals from TSI values obtained over the course of the 2022 growing season in Upper Mount Glen Lake.

When assessed using the Kirchner-Dillon model, Upper Mount Glen Lake yielded a phosphorus retention coefficient of 0.45, suggesting that approximately half of the phosphorus that enters the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, Upper Mount Glen Lake is estimated to feature a springtime phosphorus concentration of approximately 0.11 mg/L. This is an overestimation when compared with the surface sample phosphorus concentration of 0.04 mg/L obtained during the spring event. The Walker model yielded a similar predicted spring phosphorus load of 0.10 mg/L. When assessed with Walker's trophic state model, Upper Mount Glen Lake is estimated to have a nearly 100% likelihood of being eutrophic, aligning with the results of Carlson's trophic state index. Assessing Upper Mount Glen Lake with Carlson's predictive chlorophyll model yields a summer chlorophyll *a* concentration of approximately 70.0 µg/L if the result from the Walker model (external load only) is used, and 71.8 µg/L if the result from the Walker model that includes internal loads is used. These are high overestimations when compared to the concentration of 48 µg/L obtained during the summer sampling event. The Vollenweider model yielded a predicted springtime phosphorus concentration of approximately 0.14 mg/L, while the Reckhow model yielded a concentration of 0.13 mg/L (0.14 mg/L if the internal load is considered). As with some of the other lakes in this study, the overestimations of phosphorus and chlorophyll may be in part a function of macrophyte growth that was observed to occur in Upper Mount Glen Lake; this plant growth may sequester phosphorus and reduce the amounts of phosphorus and chlorophyll *a* in the water itself.

MT. LAUREL LAKE

Surface concentrations of total phosphorus in Mt. Laurel Lake were overall low, with the summer concentration yielding a phosphorus-based TSI of 37.35, suggestive of oligotrophic-to-mesotrophic conditions. Summer chlorophyll *a* concentrations were also somewhat low and yielded a chl. *a*-based TSI of 47.85, a value consistent with mesotrophic conditions. The summer Secchi depth in the northern basin was 1.8 meters, yielding a Secchi-based TSI of 51.53, a value consistent with eutrophic conditions.

TSI residuals are plotted below in Figure 116. The point representing the spring water quality sampling event is located in the bottom-left quadrat, suggesting that at this time, chlorophyll *a* production was not limited by phosphorus concentrations, but by other factors. Additionally, the Secchi depth was lower than the concentration of chlorophyll *a* obtained during this date would normally suggest. The point representing the summer event is located close to the y-axis, suggesting that water clarity can largely be explained as a function of algae growth and chlorophyll *a* production. The point's location above the x-axis suggests that algae growth was strongly limited by total phosphorus concentrations at this point during the year. The point representing the October sampling event is also located in the upper-left quadrat, suggesting that algae growth was phosphorus limited and that water clarity was not entirely a function of algae growth.

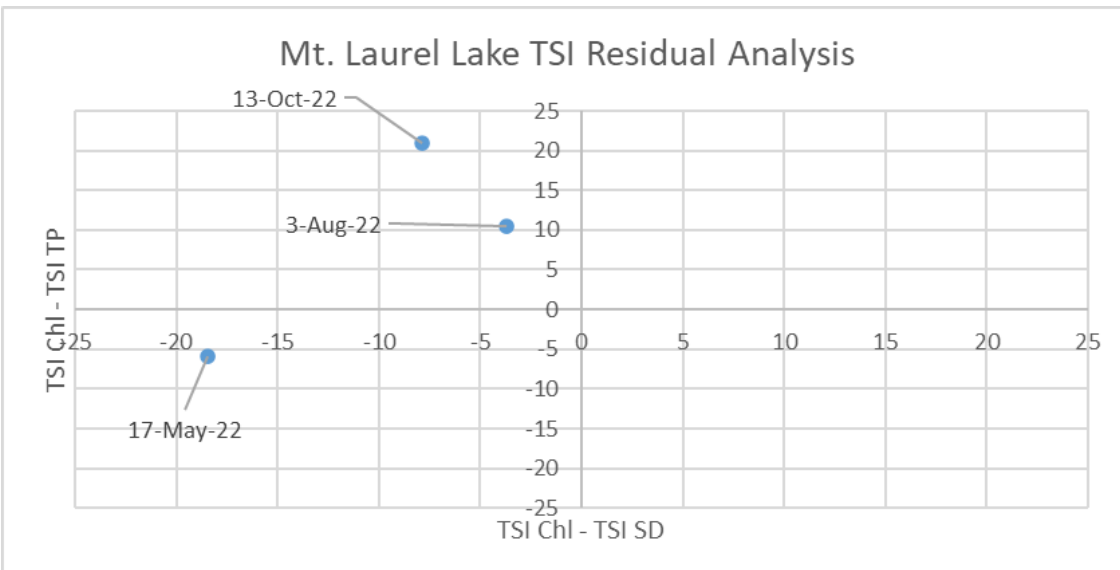


Figure 116. Residuals from TSI values obtained over the course of the 2022 growing season in Mt. Laurel Lake.

When assessed with the Kirchner-Dillon model, Mt. Laurel Lake yielded a phosphorus retention coefficient of 0.49, suggesting that approximately half of the phosphorus that enters the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, Mt. Laurel Lake is estimated to feature a springtime phosphorus concentration of approximately 0.02 mg/L. This is somewhat aligned with the surface phosphorus concentration of 0.01 mg/L obtained during spring sampling events. The Walker model yielded a similar estimated springtime phosphorus concentration of 0.02 mg/L. When assessed with Walker's trophic state model, Mt. Laurel Lake is estimated to have an approximately 40% likelihood of being a mesotrophic system and a 60% likelihood of being a eutrophic system. Carlson's predictive chlorophyll model yielded a predicted summer chlorophyll *a* concentration of 6.6 µg/L when the result of the Walker model with only external loads is used and a concentration of 7.9 µg/L when the result of the Walker model using both external and internal loads is used.

These are slight overestimations of the actual value of 5.8 µg/L. The Vollenweider model yielded a predicted Spring phosphorus concentration of 0.02 mg/L (0.03 mg/L when internal loads are used), while the Reckhow model yielded a predicted concentration of 0.03 mg/L. The above models generally produced slight overestimations when compared with field values. As noted with some of the other lakes in this study, however, there may be a percentage of incoming phosphorus that is sequestered in aquatic macrophytes, and this phosphorus and resulting chlorophyll *a* will not typically be captured by discrete water quality samples. Mt. Laurel Lake is largely dominated by macrophytes, particularly towards the southern end by the Longhouse Creek inlet; this area may act as a wetland to sequester nutrients and "settle" incoming sediment before incoming water continues to the main body of the lake.

MOUNTAIN SPRINGS LAKE

While the summer sampling event at Mountain Springs Lake yielded the lake's highest phosphorus concentration of the year, this was relatively low, yielding a phosphorus-based TSI of 47.35, a value consistent with mesotrophic systems. Surface chlorophyll *a* concentrations during the summer event were the lowest of the season, yielding a chl. *a*-based TSI of 42.01, also consistent with mesotrophic systems. The Secchi depth was at its lowest during the summer event, yielding a Secchi-based TSI of 53.23, consistent with eutrophic systems.

TSI residuals are plotted below in Figure 117. The point representing the spring sampling event is located above the x-axis and close to the y-axis, suggesting that phosphorus was limiting algae growth at this time and that water clarity was largely a function of algae growth. The point representing the summer event is located in the lower-left quadrat, suggesting that there was a slight phosphorus surplus at this time with algae growth being more largely impacted by other factors and that water clarity was lower than would be expected for the chlorophyll *a* concentration obtained from the surface. This may be attributed to the plankton community being dominated by smaller-celled organisms at this time. The point representing the autumn event is located above the x-axis and close to the y-axis. Similarly, to the spring event, this suggests that algae growth in the lake was largely limited by phosphorus concentrations, and that water clarity was largely a function of algae growth.

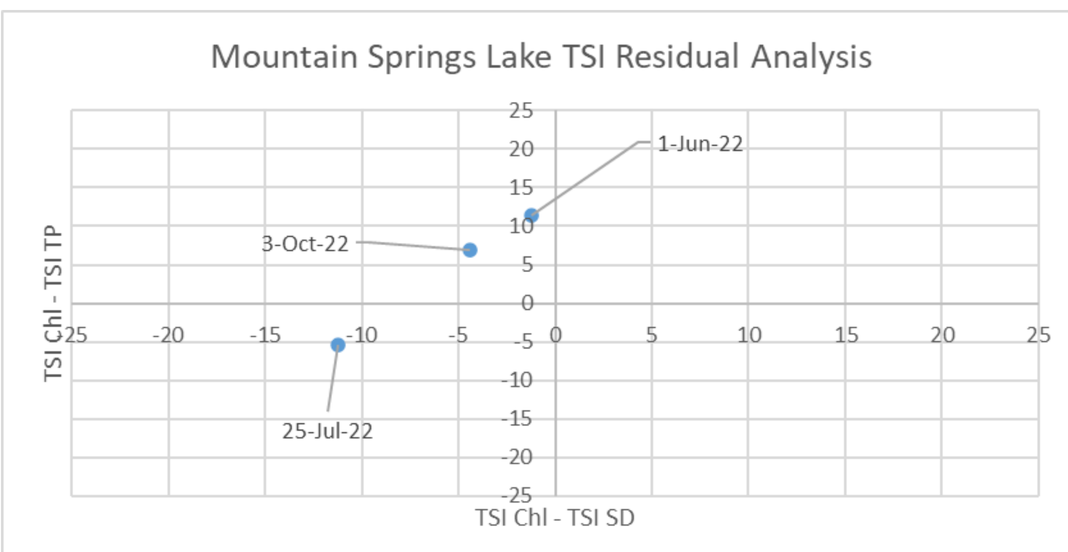


Figure 117. Residuals from TSI values obtained over the course of the 2022 growing season in Mountain Springs Lake.

When assessed with the Kirchner-Dillon model, Mountain Springs Lake yielded a phosphorus retention coefficient of 0.53, suggesting that approximately half of the phosphorus that enters the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, Mountain Springs Lake is estimated to feature a springtime phosphorus concentration of approximately 0.02 mg/L, only slightly above the actual surface spring event concentration of 0.01 mg/L. The Walker predictive phosphorus model yielded similar results, at 0.02 mg/L or 0.03 mg/L if the internal load is considered. Walker's trophic state model estimates that the lake has an approximately 20% likelihood of being a mesotrophic system and an 80% likelihood of being a eutrophic system. Carlson's predictive summer chlorophyll *a* model yielded predicted concentrations of 12.85 µg/L if the result of the Reckhow model is used and 8.15 µg/L if the result of the Walker model is used. These are both overestimations when compared to the actual surface summer concentration of 3.2 µg/L. The Vollenweider model yielded an estimated springtime phosphorus concentration of 0.02 mg/L, while the Reckhow model yield a predicted concentration of 0.03 mg/L. The overestimated values obtained by the trophic models suggests that the watershed-based hydrologic and nutrient loading model may be overestimating the amount of phosphorus entering the lake on an average year.

PINECLIFF LAKE

Pinecliff Lake featured elevated surface total phosphorus concentrations during the summer, yielding a phosphorus-based TSI 60.56, a value consistent with eutrophic conditions. The summer sampling event yielded the lake's highest surface chlorophyll *a* concentration of the year, yielding a chl. *a*-based TSI of 69.17, also suggesting eutrophic conditions. Relatively low Secchi depths were measured during the summer event; these yielded a Secchi-based TSI of 69.99, indicative of eutrophic conditions.

TSI residuals are plotted below in Figure 118. The point representing the spring sampling event is located in the bottom-left quadrat, suggesting that algae growth was not limited by phosphorus but by another factor, possibly temperature. It also suggests that the algae community may have consisted largely of smaller-celled organisms. The point representing the summer event is located above the x-axis and close to the y-axis, suggesting that, during this time, algae growth was limited by phosphorus concentrations and water clarity was largely a product of algae growth. The point representing the October event is close to the figure's origin, suggesting that algae growth and chlorophyll *a* production was largely a factor of phosphorus concentrations and that water clarity was impacted mostly by algae densities.

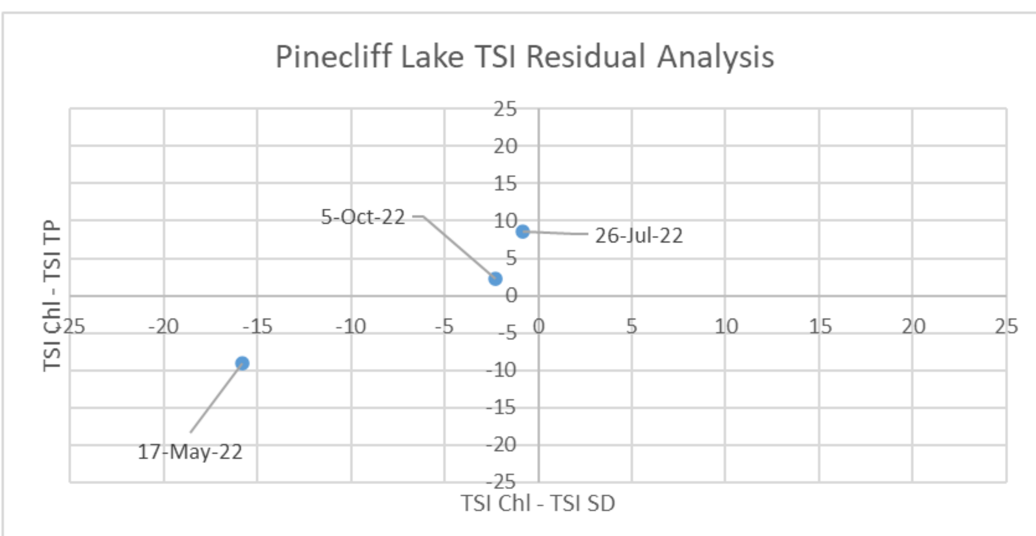


Figure 118. Residuals from TSI values obtained over the course of the 2022 growing season in Pinecliff Lake.

When assessed with the Kirchner-Dillon model, Pinecliff Lake yielded a phosphorus retention coefficient of 0.52, suggesting that approximately half of the phosphorus that enters the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, Pinecliff Lake is estimated to feature a springtime phosphorus concentration of approximately 0.02 mg/L, aligning with the actual surface spring phosphorus concentration of 0.02 mg/L. The Walker predictive phosphorus model yielded similar results at 0.02 mg/L. Walker's trophic state model estimates that the lake has an approximately 5% likelihood of being an oligotrophic system, a 35% chance of being a eutrophic system, and a 60% likelihood of being a mesotrophic system. The results of this model point more towards mesotrophy than did Carlson's TSI, which yielded values more consistent with eutrophication. Carlson's predictive chlorophyll *a* model predicted a summertime chlorophyll *a* concentration of 5.44 µg/L if the result of the Walker model with only the external load considered is used and a concentration of 7.21 µg/L if the result of the Walker model with both loads considered is used. Both of these estimates are much lower than the actual concentration of 51.0 µg/L obtained during the summer sampling event. The Vollenweider predictive phosphorus model predicted a springtime phosphorus concentration of approximately 0.02 mg/L, while the Reckhow model also predicted a concentration of 0.02 mg/L, or 0.03 mg/L if the internal load was also used in the analysis. While the results of the predictive springtime phosphorus models are largely accurate to the actual phosphorus sample result from the Spring sampling event, chlorophyll *a* predictions are very low compared to what was obtained from surface samples during the summer event.

POST BROOK FARMS LAKE

Post Brook Farms Lake featured a low-to-moderate surface total phosphorus concentration during the summer event, yielding a phosphorus-based TSI of 57.34, a value consistent with eutrophic conditions. The summer event yielded the highest surface chlorophyll *a* concentration, yielding a chl. *a*-based TSI of 62.18, also consistent with eutrophic conditions. Secchi depths during the summer event were low-to-moderate for a northern New Jersey lake, yielding a Secchi-based TSI of 57.37, a value associated with eutrophic conditions.

TSI residuals are plotted below in Figure 119. The point representing the spring sampling event is located in the bottom-left quadrat, suggesting that algae growth was not limited by phosphorus but by another factor, possibly temperature. It also suggests that the algae community may have consisted largely of smaller-celled organisms. The point representing both the summer and autumn events are located near the figure's origin, suggesting that algae growth and chlorophyll *a* production was largely attributable to phosphorus concentrations and that water clarities were largely a product of algae growth.

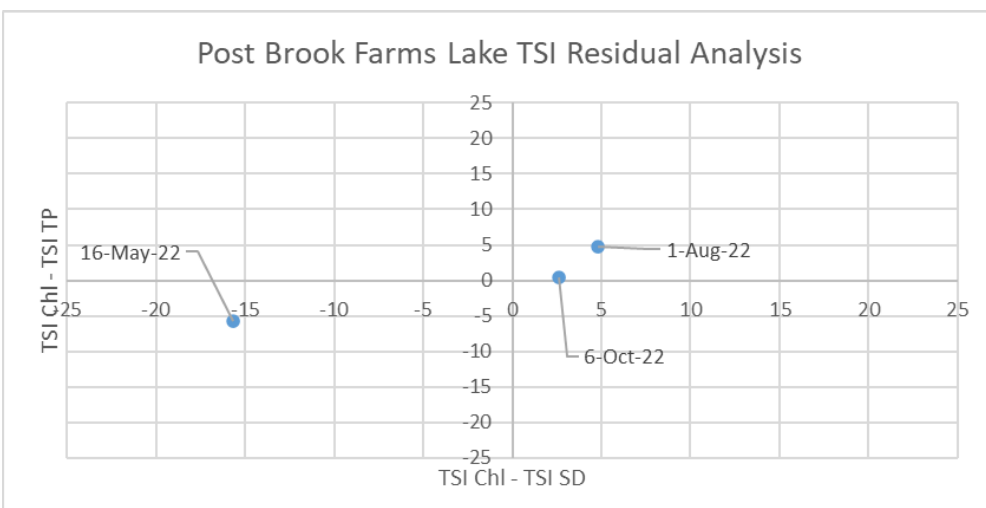


Figure 119. Residuals from TSI values obtained over the course of the 2022 growing season in Post Brook Farms Lake.

When assessed with the Kirchner-Dillon model, Post Brook Farms Lake yielded a phosphorus retention coefficient of 0.68, suggesting that approximately two-thirds of the phosphorus entering the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, Post Brook Farms Lake is estimated to feature a springtime phosphorus concentration of approximately 0.06 mg/L, or 0.08 mg/L if internal loading is also accounted for. This is an overestimation when compared with the surface concentration of 0.02 mg/L obtained in the field. Walker's predictive phosphorus model yielded higher spring phosphorus predictions at 0.10 mg/L or 0.13 mg/L when internal loading is included in the model. Walker's trophic state model estimates that the lake has a nearly 100% likelihood of being eutrophic. This largely aligns with the results of the Carlson's TSI. Carlson's predictive chlorophyll model predicted a summertime chlorophyll *a* concentration of 33.3 µg/L when the Vollenweider model's result utilizing the external load only is used and a concentration of 46.3 µg/L when the result of the same model using both external and internal loads is used. These are overestimations when compared to the surface chlorophyll *a* concentration of 25.0 µg/L collected during the summer sampling event, however they are underestimations when compared with the deep chlorophyll *a.* concentration of 66.0 µg/L obtained during this date. Vollenweider's model itself yielded a predicted spring phosphorus concentration of 0.06 mg/L or 0.08 mg/L if internal loads are used in the analysis, while Reckhow's model yielded a concentration of 0.09 mg/L, or 0.10 mg/L when considering internal loads. The general overestimations produced by each model suggests that the watershed-based hydrologic and pollutant loading model may be over estimating the amount of phosphorus entering Post Brook Farm Lake over the course of an average year. The higher concentrations of deep chlorophyll *a.*¸ however, suggest that a majority of the lake's algae production may be occurring towards the bottom of the water column rather than the surface. The overall shallow depth of the waterbody and the water clarity measured in the field seem to suggest that primary production could occur at any point throughout the water column throughout most of the lake.

SHADY LAKE

Shady Lake featured a featured a low-to-moderate surface total phosphorus concentration during the summer event, yielding a phosphorus-based TSI of 57.34, a value consistent with eutrophic conditions. The summer event yielded a moderate chlorophyll *a* concentration, yielding a chl. *a*-based TSI of 55.76, also consistent with eutrophic conditions. Secchi depths during the summer event were low-to-moderate for a northern New Jersey lake, yielding a Secchi-based TSI of 56.22, a value associated with eutrophic conditions.

TSI residuals are plotted below in Figure 120. The point representing the spring sampling event is located in the bottom-left quadrat, suggesting that algae growth was not limited by phosphorus but by another factor, possibly temperature. It also suggests that the algae community may have consisted largely of smaller-celled organisms. The point representing the summer event is located near the figure's origin, suggesting that algae growth and chlorophyll *a* production was largely attributable to phosphorus concentrations and that water clarities were largely a product of algae growth at this time of the year. The point representing the autumn sampling event is located close to the y-axis and above the x-axis. This suggests that algae growth was limited by phosphorus concentrations at this time and water clarity was largely a product of algae growth.

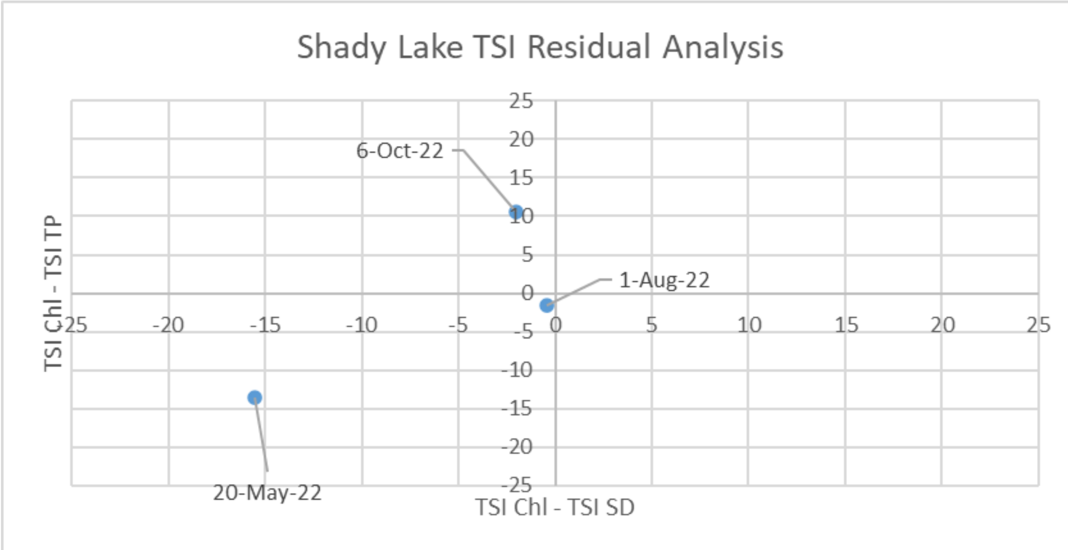


Figure 120. Residuals from TSI values obtained over the course of the 2022 growing season in Shady Lake.

When assessed with the Kirchner-Dillon model, Shady Lake yielded a phosphorus retention coefficient of 0.65, suggesting that approximately two-thirds of the phosphorus entering the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, Shady Lake is estimated to feature a springtime phosphorus concentration of approximately 0.07 mg/L, or 0.08 mg/L if internal loading is also accounted for. This is an overestimation when compared with the surface concentration of 0.03 mg/L obtained in the field. Walker's predictive phosphorus model yielded higher spring phosphorus predictions at 0.10 mg/L or 0.11 mg/L when internal loading is included in the model. Walker's trophic state model estimates that the lake has a nearly 100% likelihood of being eutrophic. This largely aligns with the results of the Carlson's TSI. Carlson's predictive chlorophyll model predicted a summertime chlorophyll *a* concentration of 69.2 µg/L when the Reckhow model result is used and a concentration of 73.8 µg/L when the result of the Walker model is used. These are overestimations when compared to the surface chlorophyll *a* concentration of 13.0 µg/L collected during the summer sampling event. Vollenweider's model yielded a predicted spring phosphorus concentration of 0.07 mg/L, while Reckhow's model yielded a concentration of 0.10 mg/L. The general overestimations produced by each model suggests that the watershed-based hydrologic and pollutant loading model may be over estimating the amount of phosphorus entering Shady Lake over the course of an average year. Aquatic macrophytes were observed to be common in the lake, however, and these may serve to sequester a significant portion of incoming phosphorus, resulting in lower surface concentrations of phosphorus and chlorophyll *a*.

UPPER GREENWOOD LAKE

Surface total phosphorus concentrations in Upper Greenwood Lake were relatively low over the course of the 2022 season, with the summer concentration yielding a phosphorus-based TSI of 47.35. This value is typically consistent with mesotrophic systems. Summer chlorophyll *a* concentrations obtained from the top of the water column were also relatively low, yielding a chl. *a*-based TSI of 43.17, also consistent with mesotrophic conditions. Water clarities during the summer event were moderate, yielding a Secchi-based TSI of 49.31, suggestive of a mesotrophic-to-eutrophic system.

TSI residuals are plotted below in Figure 121. All sampling events are represented by points located close to the x-axis, suggesting that algae densities and chlorophyll *a* production was largely a product of phosphorus concentrations. The point representing the May event is also located close to the y-axis, suggesting that water clarity was largely impacted by algae growth. The points representing the summer and autumn events are located to the left of the y-axis, suggesting that the plankton community was dominated by smaller celled organisms. It should be noted that the Secchi depth collected during the autumn event was equal to the total depth of the sampling station, suggesting that the Secchi-based TSI for this date may in fact be lower and would place the point representing this date closer to the figure's origin.

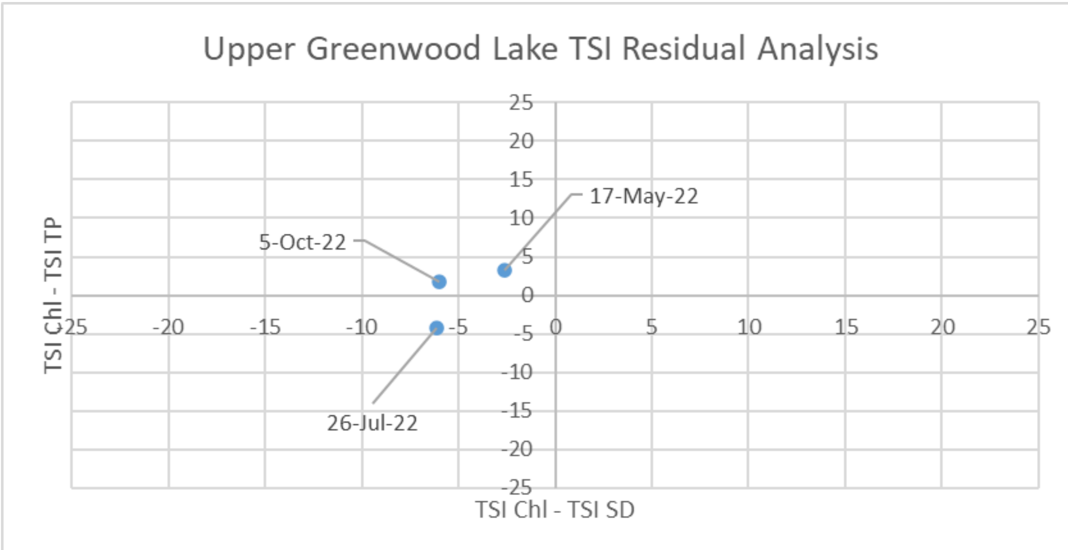


Figure 121. Residuals from TSI values obtained over the course of the 2022 growing season in Upper Greenwood Lake.

When assessed with the Kirchner-Dillon model, Upper Greenwood Lake yielded a phosphorus retention coefficient of 0.65, suggesting that approximately two-thirds of the phosphorus entering the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, the lake is estimated to feature a springtime phosphorus concentration of approximately 0.02 mg/L, or 0.03 mg/L if internal loading is also accounted for, aligning with the surface total phosphorus concentration of 0.02 mg/L obtained during the spring sampling event. Walker's predictive phosphorus model yielded higher spring phosphorus predictions at 0.04 mg/L or 0.05 mg/L when internal loading is included in the model. Walker's trophic state model estimates that the lake has an approximately 25% likelihood of being mesotrophic and a 75% likelihood of being eutrophic. This diverges slightly from the results of Carlson's TSI, which yielded values more representative of a mesotrophic waterbody. Carlson's predictive chlorophyll model predicted a summertime chlorophyll *a* concentration of 8.87 µg/L when the Dillon Rigler model result is used and a concentration of 8.57 µg/L when the result of the Vollenweider model is used. These are overestimations when compared to the surface chlorophyll *a* concentration of 3.6 µg/L collected during the summer sampling event. Vollenweider's model yielded a predicted spring phosphorus concentration of 0.02 mg/L, while Reckhow's model yielded a concentration of 0.04 mg/L. While some of the models predicted springtime phosphorus concentrations fairly accurately, Carlson's predicted summertime chlorophyll *a* model yielded overestimations. While aquatic macrophytes were not observed during most of the 2022 surveys, Princeton Hydro staff have observed notable macrophyte densities in the lake in previous years, and these may serve to sequester a portion of the lake's phosphorus load, resulting in lower concentrations of surface water phosphorus and chlorophyll *a*.

VAN NOSTRAND LAKE

Van Nostrand Lake yielded relatively low surface concentrations of total phosphorus over the course of the 2022 season, with the summer concentration yielding a phosphorus-based TSI of 37.35. This value is indicative of an oligotrophic system. Chlorophyll *a* concentrations were also relatively low, with the summer concentration yielding a chl. *a*-based TSI of 43.17, a value consistent with mesotrophic conditions. Secchi depths during the Summer sampling event were moderate, yielding a Secchi-based TSI of 55.15, suggestive of eutrophic conditions.

TSI residuals are plotted below in Figure 122. The point representing the spring sampling event is located in the bottom-left quadrat, suggesting that algae growth was influenced less by phosphorus concentrations and more likely influenced by another factor such as water temperature. The Secchi-based TSI is higher for this event than might be expected based on the chlorophyll *a*-based TSI, suggesting that the algae community at this time may have been dominated by smaller-celled taxa. The points representing the summer and autumn sampling events are both located in the upper-left quadrat, suggesting that algae growth and chlorophyll *a* production were limited by phosphorus concentrations and were largely represented by smaller-celled organisms.

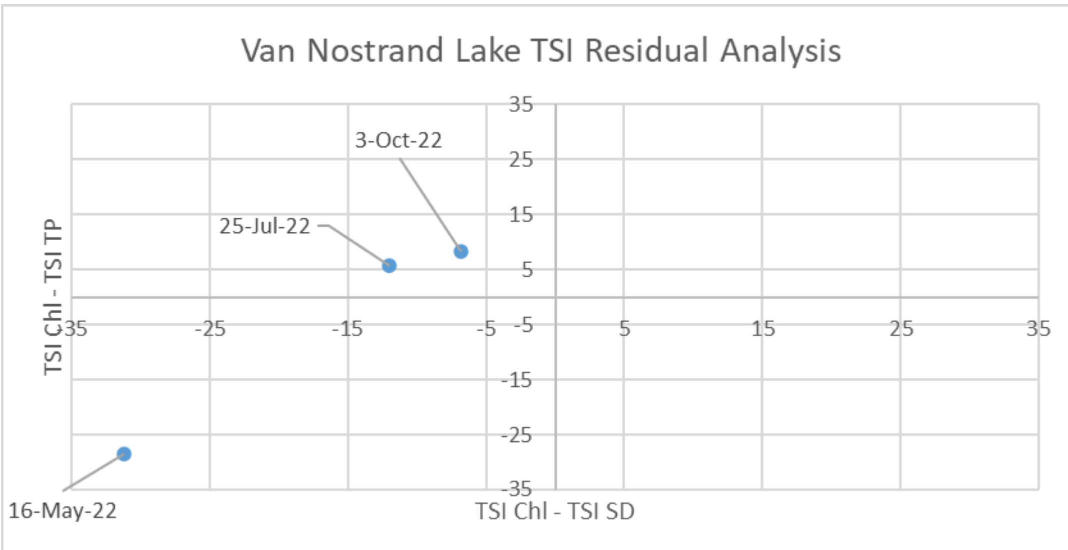


Figure 122. Residuals from TSI values obtained over the course of the 2022 growing season in Van Nostrand Lake.

When assessed with the Kirchner-Dillon model, Van Nostrand Lake yielded a phosphorus retention coefficient of approximately 0.77, suggesting that approximately three-quarters of the phosphorus entering the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, the lake is estimated to feature a low springtime phosphorus concentration of approximately 0.002 mg/L, or 0.01 mg/L if internal loading is also accounted for, a slight underestimation when compared with the surface total phosphorus concentration of 0.02 mg/L obtained during the spring sampling event. Walker's predictive phosphorus model yielded higher spring phosphorus predictions at 0.005 mg/L or 0.02 mg/L when internal loading is included in the model. When using only external phosphorus loading estimates, Walker's trophic state model estimates that the lake has an approximately 5% likelihood of being mesotrophic and a 95% likelihood of being oligotrophic. When external and internal loads are accounted for, the model estimates that the lake has an approximately 10% likelihood of being oligotrophic, a 10% likelihood of being eutrophic, and an 80% likelihood of being mesotrophic. Carlson's TSI yielded a relatively wide range of summer TSIs and the result of Walker's trophic state model is relatively similar. Carlson's predictive summer chlorophyll model yielded a summer chlorophyll *a* concentration of 0.2 µg/L when the result of the Vollenweider model including only the external load is used. The model yielded a predicted summer chlorophyll *a* concentration of 2.1 µg/L when the result of the Vollenweider model including the internal phosphorus load was used. Using the Vollenweider input, the model only slightly underestimates the actual surface chlorophyll *a* concentration of 3.6 µg/L collected during the summer event. When assessed with the Vollenweider model itself, Van Nostrand Lake is estimated to have a springtime phosphorus concentration of approximately 0.002 mg/L, or 0.01 mg/L if the internal load is accounted for, while the Reckhow model yielded results of 0.008 mg/L or 0.03 mg/L if the internal load is accounted for. While Van Nostrand Lake was modeled to not feature increased internal loading as a result of anoxia, internal loading was modeled to contribute more to the lake's total annual phosphorus load than external loading contributes. Because of this, it is not surprising that the trophic models yielded more accurate results when accounting for the internal load.

WONDER LAKE

The surface total phosphorus concentrations obtained in Wonder Lake during the summer event was relatively low, yielding a phosphorus-based TSI of 47.35, characteristic of a mesotrophic waterbody. The summer surface chlorophyll *a* concentration was relatively moderate and yielded a chl. *a*-based TSI of 50.75, characteristic of eutrophic conditions. The summer water clarity in Wonder Lake was low-to-moderate, yielding a Secchi-based TSI of 57.37, also characteristic of eutrophic conditions.

TSI residuals are plotted below in Figure 123. The points representing the spring and summer sampling events are located in the left of the y-axis but close to the x-axis, suggesting that algae growth was generally expected given the phosphorus concentrations obtained, however with a much higher Secchi-based TSI value than the chlorophyll *a* YSI value would usually suggest. This may indicate that the algae community consisted largely of smaller-celled organisms. The October event is represented by a point located in the upper-left quadrat, suggesting that algae growth and chlorophyll *a* production was limited by phosphorus and that water clarity may have been affected by a domination of the plankton assemblage by smaller-celled organisms.

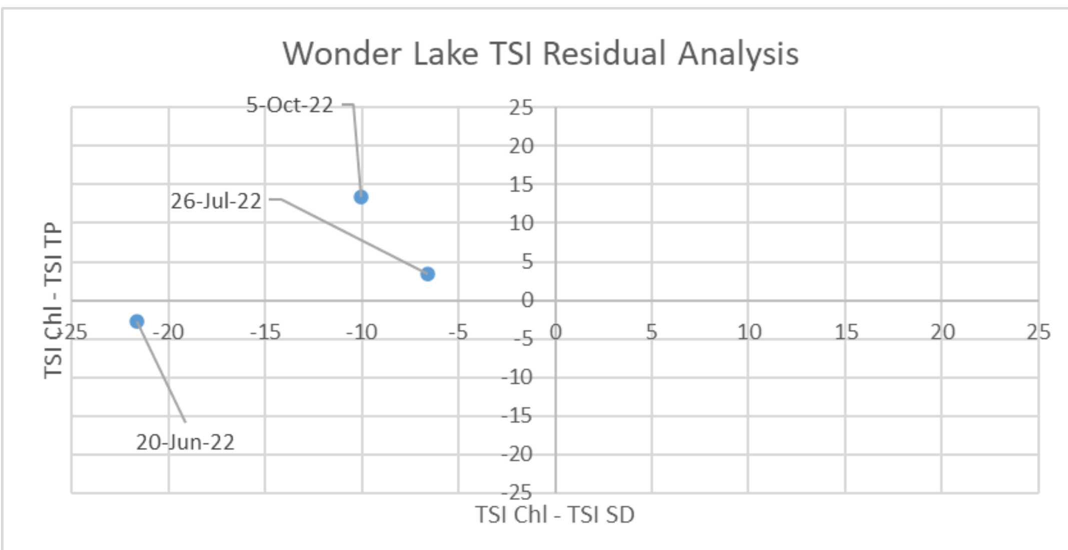


Figure 123. Residuals from TSI values obtained over the course of the 2022 growing season in Van Nostrand Lake.

When assessed with the Kirchner-Dillon model, Wonder Lake yielded a phosphorus retention coefficient of 0.64, suggesting that approximately two-thirds of the phosphorus entering the waterbody is retained and utilized by primary producers. When this value is used in the Dillon-Rigler model, the lake is estimated to feature a springtime phosphorus concentration of approximately 0.01 mg/L, or 0.02 mg/L if internal loading is also accounted for, largely aligning with the 0.01 mg/L obtained at the surface of the water column during the spring sampling event. Walker's predictive phosphorus model yielded slightly higher spring phosphorus predictions at 0.02 mg/L or 0.03 mg/L when internal loading is included in the model. When both external and internal loads are accounted for, the Walker trophic state model estimates that the lake has an approximately 40% likelihood of being eutrophic and a 60% likelihood of being mesotrophic. Carlson's predictive summer chlorophyll model yielded a summer chlorophyll *a* concentration of approximately 7.4 µg/L when the result of the Vollenweider model using both external and internal phosphorus loads is used. When using the result of the Dillon-Rigler model using both external loads and internal loads, the model predicts a concentration of approximately 7.6 µg/L. These both generally align with the surface chlorophyll *a* concentration of 7.8 µg/L obtained during the summer event. The Vollenweider model itself yielded an estimated spring phosphorus concentration of 0.01 mg/L, or 0.02 mg/L if the internal load is factored into the model, while the Reckhow model yielded predicted concentrations of 0.02 mg/L or 0.03 mg/L if internal loads are accounted for. Wonder Lake's annual internal phosphorus load is estimated to be similar to that originating in the lake's watershed, and as such the models yield more accurate recommendations when the internal phosphorus load is included.

7.0 IN-LAKE CONCLUSIONS AND RECOMMENDATIONS

Given the variety of waterbodies in West Milford Township (in regards to size, volume, watersheds, and other factors), it is not surprising that the issues that affect each waterbody vary. Many of the waterbodies with larger watersheds (such as Upper Greenwood Lake and Pinecliff Lake) featured more modeled incoming nutrients through this avenue than from internal loading, whereas waterbodies with lower inflow (such as Van Nostrand Lake) tend to feature a proportionally higher internal load. Princeton Hydro therefore will provide recommendations in the balance of this report for management measures that can be taken in each lake and its watershed. A more detailed and comprehensive description of some of the watershed-based recommendations is provided in Section 8.

Because the Township of West Milford is focused on watershed-based solutions, recommendations will be broken into watershed-based and In-lake solutions. In-lake recommendations are provided for the benefit of each waterbody's community; however, should a community wish to move forward with any of the in-lake recommendations, the community must do so without contribution from the township. Additionally, general recommendations that can apply to all of the lakes studied are provided at the end of the section.

ALGONQUIN WATERS

Algonquin Waters is a moderately-sized lake (relative to others in the township) with a largely forested watershed. A majority of the lake's annual phosphorus load is modeled to originate from septic systems within the watershed. Total phosphorus concentrations collected in the field in Algonquin Waters were relatively low. Based on observations made by Princeton Hydro scientists, the lake did not feature apparent problematic plant or algae growths, although an elevated deep chlorophyll *a* concentration was obtained during the August sampling event. While not observed at bloom-like densities, cyanobacteria were relatively common in samples from all sampling events.

Based on these findings, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Due to Algonquin Waters' largely forested watershed, Princeton Hydro does not have specific recommendations for watershed management work within the watershed. It is recommended that smaller-scale practices are performed by individual property owners in the watershed; these will be explained in greater detail at the end of the following section.

IN-LAKE RECOMMENDATIONS

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. Algonquin Waters may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

EutroSORB F® Bags – While the subwatershed largely consists of wetlands and forested land, Algonquin Waters' main inlet stream is modeled to yield a notable percentage of the lake's watershed-based phosphorus load. This may be mitigated with the use of the SePro product EutroSORB F®, a compound designed to remove SRP from flowing water. These products can be installed in streams to remove phosphorus prior to entry into a lake. It should be noted however that EutroSORB F® bags need to be periodically changed to achieve continued proper removal rates. Additionally, installation of bags into the stream may require permits through the NJDEP.

BUBBLING SPRINGS POND

Bubbling Springs Pond is a smaller waterbody with a relatively high flushing rate, receiving a majority of its nutrients from the watershed rather than from internal loading. The waterbody is managed mainly for fishing, while the upper lake is managed for swimming.

Based on these findings, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

During watershed-based field assessments, part of the gravel access road south of the swimming pond at Bubbling Springs was observed to be flooded and eroded. Princeton Hydro recommends that a more in-depth hydrological assessment be conducted in this area in order to determine the source and frequency of this flooding. Additionally, Princeton Hydro recommends the creation of a bioretention system located down-gradient from the catch-basins located near between the two Bubbling Springs waterbodies. Both of these recommendations will be discussed in greater detail in the following section.

IN-LAKE RECOMMENDATIONS

Floating Wetland Islands – Bubbling Springs Pond may benefit from the installation of floating wetland islands (FWIs). FWIs uptake nutrients that would be otherwise used by undesirable plants and algae. Additionally, these structures have the added benefit of providing fish habitat and shading out some aquatic vegetation. They are planted with wetland species including aesthetically pleasing flowering plants. In particular, the area around the pond's inlet may be a candidate location for FWIs, as islands in this area should not obstruct use of the pond by anglers and can intercept nutrients entering the waterbody from the inlet. Alternatively, the islands could be placed in an area visible from the nearby pavilion and accompanying educational signage can be added onshore as a public education installation, if desired.

Biochar and EutroSORB® – A newer technology that Princeton Hydro has conducted work with recently is biochar, a plant-based charcoal product that can be loaded into porous bags and other structures for the use of filtering phosphorus and other pollutants out of the water. Bags of biochar can be installed in the pond under buoys. As described above, EutroSORB® bags can also be installed in the inlet stream and used to remove SRP from incoming water.

Bathymetric Survey – As mentioned previously, modeling of the internal load and trophic state for Bubbling Springs Pond were in part conducted using rough estimates of depth and volume. A bathymetric survey, or mapping of the lake bottom, could provide more detailed information used for refining these models. This information is also useful in the installation of an aeration system. Such a survey can also be used to measure the volume of sediment in the bottom of the lake. This will be necessary if dredging is eventually planned for this waterbody.

CARPI LAKE

Limited information is available regarding Carpi Lake, as Princeton Hydro was not granted access to the waterbody. As such, recommendations for improvements are limited. The watershed is largely forested with small amounts of urbanized land-use, and most phosphorus entering the waterbody is modeled to originate from septic systems.

Based on these findings, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the creation of a rain garden along the western edge of a nearby restaurant's parking lot. More information is provided in the following section.

FARM CREST ACRES POND

Farm Crest Acres Pond is a relatively small waterbody which features a small, largely urbanized watershed. External phosphorus loads are estimated to largely originate from septic systems within the watershed, and there is estimated to be a degree of increased internal loading that occurs within the lake itself.

Based on these findings, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the planting of an aquatic riparian buffer along the southwest shoreline of the lake along Doremus road and along the northern shoreline, as well as the expansion of a ditch located near the intersection of Doremus Road, Cresthill Drive, and Greenhole Drive into a bioswale and a rain garden or bioretention area to treat sheet flow coming from the road at this intersection. Further information regarding these recommendations is provided in the following section.

IN-LAKE RECOMMENDATIONS

Aeration – Farm Crest Acres Pond may benefit from the installation of an aeration system in order to keep the water column relatively well-mixed during the summer months. This would in turn likely reduce bottom anoxia and associated increased internal phosphorus loading. This would be particularly effective if diffusers can be located adjacent to the dam, where the lake is deepest and features bottom anoxia. Prior to the installation of an aeration system, however, a bathymetric study and further water quality sampling are advised.

Bathymetric Survey – A mapping of Farm Crest Acres Pond's water and sediment depths may assist in refining the models located in the sections above and in assisting with installations of aeration systems and other management equipment, if desired.

Biochar – As with some of the other lakes in this study, Farm Crest Acres Pond may benefit from the addition of biochar. These would be installed in the form of buoys with biochar bags suspended underneath. These could be placed in multiple areas of the lake to absorb some of the nutrients introduced to the water column through internal loading or from the watershed. Areas of known concentrated stormwater input are also preferred, so incoming nutrients can be intercepted. These bags would likely be installed in spring at the start of the growing season and replaced approximately halfway through the growing season.

Floating Wetland Islands – Another option for the removal of nutrients from the water column in Farm Crest Acres Pond is the installation of floating wetland islands. These will serve to remove nutrients from the water column through uptake by planted vegetation and the beneficial biofilm that grows over time on the planting matrix. These can be placed in any of multiple locations throughout the lake, however the shallower northern portion of the waterbody may be preferred.

FOREST HILL LAKE

Forest Hill Lake is a small-to-moderately-sized lake with a largely forested watershed and a high flushing rate for its size and depth. External loads are modeled to largely originate from farm animals and septic systems within the watershed, although the lake also features a notable external load. The lake features sparse-to-moderate aquatic plant growth in shallower areas and featured a notable presence of cyanobacteria during the warmer portions of the growing season.

Based on these results, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the installation of porous pavement to portions of the parking lots located near the southeastern shoreline of Forest Hill Lake. Further information regarding this potential project is provided in the following report section.

IN-LAKE RECOMMENDATIONS

Assessment of Aeration System – As mentioned above, Forest Hill Lake was observed to feature an aeration system, however the water column near the lake's dam was measured to be thermally stratified and featured anoxia during the peak of the summer. It is recommended that the aeration system in place be examined in order to diagnose potential problems and/or to determine if the system needs to be updated or if additional diffusers are needed.

Bathymetric Survey – A mapping of Forest Hill Lake's water and sediment depths may assist in refining the models located in the sections above and in assisting with installations of aeration systems and other management equipment, if desired. The element of a bathymetry pertaining to sediment depth and volume would also be particularly useful in assessing the apparent sedimentation of the shallower northern portion of the lake and would be required prior to a dredging operation.

Zooplankton and Fisheries Assessment – In 2022, Forest Hill Lake was observed to feature relatively low abundances of large-bodied, herbivorous zooplankton such as those in the genus *Daphnia.* These zooplankton genera exert grazing pressure on green algae populations, and decreases in their numbers can result in increased green algae growth. These larger zooplankton are also important food items for the earlier life-stages of several fish species, and a drop in zooplankton populations can result in decreases in the populations of some fish species. Large, herbivorous zooplankton populations can be negatively effected by an abundance of smaller, planktivorous fish, such as alewife (*Alosa pseudoharengus*). This can be assessed by a quantitative zooplankton study and a fish survey. A fish survey will also provide information to the Forest Hill Lake community to assist in making management decisions regarding fisheries management.

GORDON LAKES

Lower Gordan Lake is a small-to-moderately sized lake with a relatively large watershed. The watershed includes Upper Gordon Lake, which was observed by field scientists to feature a high coverage of aquatic plants. This upper waterbody may sequester incoming nutrients from this portion of the watershed prior to them entering Lower Gordon Lake. The lower lake's phosphorus load is modeled to largely consist of phosphorus entering the lake via septic system influence. Lower Gordan Lake was observed to feature a cyanobacteria scum during the October sampling event.

Based these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the installation of a bioretention system in the commercial lot upstream of Upper Gordon, as well as installing porous pavement on parts of this lot. It is also recommended that the small stream entering the northern end of Upper Gordan Lake be improved with bank stabilization and a riparian buffer. A riparian shoreline buffer should also be installed along the shoreline near this inlet. Lastly, it is recommended that individual property owners in the areas surrounding Lower Gordon Lake practice stormwater management techniques on their lots. These recommendations are discussed in greater detail in the following report section.

IN-LAKE RECOMMENDATIONS

Vegetation Management (Upper Lake) – While not monitored in 2022, Upper Gordan Lake was observed to feature very dense populations of aquatic plants, which regularly cover the water's surface over significant areas of the lake. While aquatic vegetation is beneficial when growing in smaller populations for fish habitat, sediment settling, and nutrient uptake, large populations can lead to imbalances in the fishery, water flow issues, and dissolved oxygen crashes at the end of the season when the vegetation decomposes. The Gordan Lakes community may wish to treat these plants with herbicides or manage them with physical/mechanical removal.

Dredging (Upper Lake) - Dredging is the removal of sediments that have accumulated on the bottom of a waterbody. In Upper Gordon Lake, this would be particularly effective if utilized on the shallow, southern portion of the waterbody. Dredging a waterbody can have a variety of positive effects, including the physical removal of a large amount of nutrients and a potentially large reduction in aquatic vegetation. Spatterdock and white water lily in particular are usually best controlled by removal of the entire root structure, and dredging may aid with this. However, prior to dredging operations various local and state-level permits will need to be obtained. Additionally, the Gordon Lakes community will need to conduct a dredging feasibility study, in which any additional topographic information is collected in order to generate the signed and sealed engineering drawings required for the permit. This also includes detailed chemical tests of sediment samples in order to assess for containments and physical qualities, as these will in part determine where and how dredge spoils can be disposed of. Dredging can be a very expensive operation, but the positive impacts to the lake would likely be immediately noticeable in years following operations.

Bathymetric Survey – As with many other lakes in the study, a recent bathymetric survey was not found to be available for either of the two Gordan Lakes. An updated bathymetric survey can provide important information allowing for a more accurate calculation of water volume and average depth. Additionally, this survey can be used to obtain accurate estimates of sediment volume, which will be necessary if the community wishes to eventually dredge one or both of the lakes.

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. Lower Gordan Lake may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

HIGH CREST LAKE

High Crest Lake is a relatively moderate-to-large sized waterbody with a largely forested watershed, although a notable amount of urbanized land is present immediately along most of the lake's shoreline. While a majority of High Crest Lake's annual phosphorus load is modeled to originate from septic systems in the watershed, the lake is also modeled to feature a notable internal phosphorus load. Cyanobacteria were observable near the surface of the water column, particularly during the October sampling event.

Based on these observations, Princeton Hydro Recommends the following:

WATERSHED-BASED RECOMMENDATIONS

As will be discussed further in the following report section, Princeton Hydro recommends stormwater management techniques be implemented in several areas around the lake. Recommendations for the Apshawa preserve's parking lot north of the lake include the installation of vegetated filter strips, the conversion of an adjacent gully to a bioswale, the establishment of a riparian buffer along the inlet stream, and the installation of a gravel stabilization grid. It is recommended that a vegetated shoreline buffer be established along the northern inlet cove in order to intercept nutrients and sediment flowing towards the lake from High Crest Drive. The catch basins in this area should also be regularly cleared to prevent potential flooding, or larger manufactured treatment devices (MTDs) can be installed in the existing system.

The Apshawa Elementary School has the potential for multiple projects, including the installation of a porous pavement system in place of the asphalt sidewalk along the front of the school as well as in parts of the pavement near the school's entrance. A green roof retrofit on the building's roof is also recommended, as is the installation of a bioretention system and bioswales near the heads of parking stalls and other areas of the school's driveway.

Improvements to the lake's picnic area are also recommended, including the re-installation of pavers under picnic tables with a permeable stone base, the fitting of the shed with a rain gutter system, and the establishment of areas on the grass hill with higher-infiltrating soil.

Lastly, a vegetated buffer is recommended for the area along the shoulder of Highcrest Drive south of the lake's beach.

IN-LAKE RECOMMENDATIONS

Aeration – High Crest Lake may benefit from the installation of an aeration system in order to keep the water column relatively well-mixed during the summer months. This would in turn likely reduce bottom anoxia and associated increased internal phosphorus loading. This would be particularly effective if diffusers can be located in the deep southern area of the lake, where bottom anoxia was measured in 2022. Prior to the installation of an aeration system, however, a bathymetric study and further water quality sampling are advised.

Bathymetric Survey – As with many other lakes in the study, a recent bathymetric survey was not found to be available for High Crest Lake. An updated bathymetric survey can provide important information allowing for a more accurate calculation of water volume and average depth. Additionally, this survey can be used to obtain accurate estimates of sediment volume, which will be necessary if the community wishes to eventually dredge one or both of the lakes.

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. High Crest Lake may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

JOHNS LAKE

Johns Lake is a small, shallow waterbody with a large watershed relative to its size. A majority of the lake's incoming phosphorus load is modeled to originate from septic systems in the watershed, although as most of these are present in Forest Hill Lake's watershed, that waterbody may sequester a portion of this phosphorus before the water continues downstream to Johns Lake. The lake is estimated to have a very small internal phosphorus load. While the lake was not observed to have any problems with cyanobacteria, aquatic plants grew to moderate-to-dense abundance throughout the waterbody, with curlyleaf pondweed and brittle naiad being dominant species.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

As will be described in greater detail in the following section, Princeton Hydro recommends the installation of a vegetative buffer along the southern shoreline of the lake, as well as a further assessment and potential vegetation of a stormwater gully that was identified at the northwest end of the lake.

IN-LAKE RECOMMENDATIONS

Bathymetric Survey – Johns Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. It is also advisable to conduct a bathymetry prior to the installation of an aeration system in order to better assess potential locations for diffusers.

Biochar – As with some of the other lakes in this study, Johns Lake may benefit from the addition of biochar. These would be installed in the form of buoys with biochar bags suspended underneath. These could be placed in multiple areas of the lake to absorb some of the nutrients introduced to the water column through internal loading or from the watershed. Areas of known concentrated stormwater input are also preferred, so incoming nutrients can be intercepted. These bags would likely be installed in spring at the start of the growing season and replaced approximately halfway through the growing season.

Floating Wetland Islands –Johns Lake may also benefit from the installation of floating wetland islands. These structures serve to absorb some nutrients from the water column before they can be used by algae and would be best placed in the shallower northern end of the waterbody. They also can provide habitat for fish and other aquatic animals.

Vegetation Management – Johns Lake was observed to feature moderate-to-dense populations of aquatic plants throughout the waterbody. While aquatic vegetation is beneficial when growing in smaller populations for fish habitat, sediment settling, and nutrient uptake, large populations can lead to imbalances in the fishery, water flow issues, and dissolved oxygen crashes at the end of the season when the vegetation decomposes. While these plants can be treated with herbicides, the lake's small size may make mechanical removal a cost-effective management option. Physical removal of plants has an added benefit of removing nutrients from the waterbody.

KITCHELL LAKE

Kitchell Lake is a moderately sized waterbody with a largely forested watershed. The waterbody has a relatively high flushing rate as well as an aeration system, and as a result was not observed to have problems with anoxia at the bottom of the water column. Most of the lake's annual phosphorus load is modeled to originate from septic systems in the watershed. The lake features relatively low water clarity and featured a localized cyanobacteria scum during the October sampling event.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the establishment of a riparian buffer along the small pond and stream entering the northern end of Kitchell Lake. It is also recommended that the stream entering the northeastern end of the lake receive planting of riparian vegetation, as well as the stabilization of the streambank upstream of the road and the removal of the concrete apron located along this stream. As with some of the previously discussed lakes, individual stormwater management practices should also be implemented by property owners in the lake's watershed. These recommendations are explained in greater detail in the following report section.

IN-LAKE RECOMMENDATIONS

Bathymetric Survey – Kitchell Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. It is also advisable to conduct a bathymetry prior to the installation of an aeration system in order to better assess potential locations for diffusers.

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. Kitchell Lake may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

LINDY'S LAKE

Lindy's Lake is a moderate-to-large lake with the deepest total depth of any of the lakes in the study. The lake's watershed is relatively small for its size, with a majority of the land-use being classified as urban. Lindy's Lake was not observed to feature any inlets, and it is hypothesized that the lake is largely fed by subsurface springs. Phosphorus contributed by septic systems dominates the annual load, however the lake also has a notable internal load. A large portion of the water column was measured to be anoxic during the May and August events. Despite the lake featuring notable phosphorus loads, cyanobacteria were not common in plankton samples from any of the three sampling events.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the installation of curbs and porous pavement at the installation of Woodside Street and Otterhole Road, as well as the replacement of the asphalt apron adjacent to the lake's beach with vegetated or porous pavement. Practices by individual property owners to reduce and treat stormwater on their properties are also recommended. These recommendations will be discussed further in the following report section.

IN-LAKE RECOMMENDATIONS

Aeration – Lindy's Lake may benefit from the installation of an aeration system in order to keep the water column relatively well-mixed during the summer months. This would in turn likely reduce bottom anoxia and associated increased internal phosphorus loading. This would be particularly effective if diffusers can be located in the deep southern area of the lake, where bottom anoxia was measured in 2022. Prior to the installation of an aeration system, however, a bathymetric study and further water quality sampling are advised.

Bathymetric Survey – Lindy's Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. It is also advisable to conduct a bathymetry prior to the installation of an aeration system in order to better assess potential locations for diffusers.

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. Lindy's Lake may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

LAKE LOOKOVER

Lake Lookover is a relatively small lake with a large watershed relative to its size. As with other lakes in this study, Lake Lookover is modeled to receive a large portion of its annual phosphorus load from septic systems within the watershed. The lake's internal load is relatively low. While cyanobacteria and other algae growth were not observed to be large problems in Lake Lookover, the lake features moderate plant growth.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the installation of vegetated conveyance systems on both sides of the Bearfort Waters dam immediately upstream of Lake Lookover, as well as the conversion of Brookfield Road from gravel to pavement. Additionally, a vegetated buffer should be installed between the southern shoreline of Lake Lookover and the northern side of Brookfield Road.

The beach parking lot located along the eastern edge of the lake would benefit from the installation of porous or vegetated paving along the back edge of the lot, as well as from an enhancement of the riparian buffer on both sides of the parking lot. These recommendations will be further discussed in the following report section.

IN-LAKE RECOMMENDATIONS

Bathymetric Survey – Lake Lookover would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. It is also advisable to conduct a bathymetry prior to the installation of an aeration system in order to better assess potential locations for diffusers.

Biochar – Lake Lookover may benefit from the addition of biochar. These would be installed in the form of buoys with biochar bags suspended underneath. Biochar bags could be placed in multiple areas of the lake to absorb some of the nutrients introduced to the water column through internal loading or from the watershed. Areas of known concentrated stormwater input are also preferred, so incoming nutrients can be intercepted. These bags would likely be installed in spring at the start of the growing season and replaced approximately halfway through the growing season.

Floating Wetland Islands – Lake Lookover may also benefit from the installation of floating wetland islands. These structures serve to absorb some nutrients from the water column before they can be used by algae and would be best placed in the shallower southern end of the waterbody. They also can provide habitat for fish and other aquatic animals.

Vegetation Management – Lake Lookover was observed to feature moderate populations of aquatic plants throughout the waterbody. While aquatic vegetation is beneficial when growing in smaller populations for fish habitat, sediment settling, and nutrient uptake, large populations can lead to imbalances in the fishery, water flow issues, and dissolved oxygen crashes at the end of the season when the vegetation decomposes. While these plants can be treated with herbicides, mechanical removal is another viable option. Physical removal of plants has an added benefit of removing nutrients from the waterbody.

LOWER MOUNT GLEN LAKE

Lower Mount Glen Lake is a moderately-sized lake with a relatively large watershed, which contains the watersheds for Upper Mount Glen Lake and Lindy's Lake. The lake's external phosphorus load is modeled to largely originate from septic systems in the watershed. While the lake was measured to feature anoxia at the bottom of the water column and modeled to feature increased internal loading, this is a small contribution to the lake's total annual phosphorus load when compared to the external load. The lake's plankton samples were dominated by cyanobacteria during the August and October events.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends that the Township-owned parking lot adjacent to the beach area be converted from asphalt and loose gravel to vegetated pavers or loose gravel. Further details regarding this recommendation are provided in the following report section.

IN-LAKE RECOMMENDATIONS

Aeration – Lower Mount Glen Lake may benefit from the installation of an aeration system in order to keep the water column relatively well-mixed during the summer months. This would in turn likely reduce bottom anoxia and associated increased internal phosphorus loading. This would be particularly effective if diffusers can be located in the deep northeastern area of the lake, where bottom anoxia was measured in 2022. Prior to the installation of an aeration system, however, a bathymetric study and further water quality sampling are advised.

Bathymetric Survey – Lower Mount Glen Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. It is also advisable to conduct a bathymetry prior to the installation of an aeration system in order to better assess potential locations for diffusers.

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. Lower Mount Glen Lake may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

UPPER MOUNT GLEN LAKE

Upper Mount Glen Lake is a small-to-moderately sized, shallow lake with a relatively large watershed, which contains the watershed Lindy's Lake. As with many other lakes in this study, the lake's most prevalent source of phosphorus is modeled to be septic system influence. Due to the Lake's shallow depth, internal loading is not estimated to be a large source of phosphorus for the lake. The lake was observed to feature a large degree of sedimentation, resulting in its shallow depth. Additionally, the lake was observed to feature sparse aquatic plant growth, including a single specimen of the invasive floating plant water chestnut.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends several potential projects for the reduction of stormwater, nutrients, and/or sediment entering Upper Mount Glen Lake. In the mailbox parking area, currently owned by the Lindy's Lake Association, it is recommended that the current asphalt pavement be converted to a vegetated paver system, as well as the removal of invasive plants and planting of native vegetation. At a catch basin alongside Otterhole Road, it is recommended that the existing stormwater system be fitted with an MTD in order to intercept sediment entering the lake via the connecting inlet. A nearby grass area may also be converted to a bioretention system to further treat this runoff.

The stream entering the lake from Lindy's Lake appears to convey a large amount of sediment via streambank erosion, and it is recommended that the stream be further investigated in order to ascertain the source of this sediment.

A further recommendation is the planting of riparian vegetation and a bioswale along the lake's southern shoreline in the open area between Sanders Court and Mountainside Road. A vegetated swale may also be installed in the strip of mowed grass alongside Otterhole Road between the two southern inlets. At a culvert headwall downstream of a small impoundment on Otterhole Road, a cobble swale and further vegetation may be installed in order to intercept sediment entering the lake via runoff from the road.

Upstream of the lake, a stream segment was identified flowing under Otterhole Road and appeared to receive inputs from Larson Road and Otterhole Road. A series of recommended projects at this site include stabilization of the streambank, the installation of a bioswale above the inlet and headwall, a vegetated conveyance system, and the installation of a porous pavement or vegetated paver system at the Norvin Green State Forest trailhead parking lot. Another parking area on Schofield Road may also be improved with one of these two alternative paving methods as well as a vegetated bioswale between the parking area and the receiving stream.

Further details for each of the above recommendations are provided in the following report section.

IN-LAKE RECOMMENDATIONS

Bathymetric Survey – Upper Mount Glen Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. It is also advisable to conduct a bathymetry prior to the installation of an aeration system in order to better assess potential locations for diffusers.

Biochar – Upper Mount Glen Lake may benefit from the addition of biochar. These would be installed in the form of buoys with biochar bags suspended underneath. Biochar bags could be placed in multiple areas of the lake to absorb some of the nutrients introduced to the water column through internal loading or from the watershed. Areas of known concentrated stormwater input are also preferred, so incoming nutrients can be intercepted. These bags would likely be installed in spring at the start of the growing season and replaced approximately halfway through the growing season.

Dredging - Dredging is the removal of sediments that have accumulated on the bottom of a waterbody. In Upper Mount Glen Lake, this would be particularly effective if utilized on the shallow, southern portion of the waterbody. Dredging a waterbody can have a variety of positive effects, including the physical removal of a large amount of nutrients and a potentially large reduction in aquatic vegetation. Spatterdock in particular are usually best controlled by removal of the entire root structure, and dredging may aid with this. However, prior to dredging operations various local and state-level permits will need to be obtained. Additionally, the Mount Glen Lakes community will need to conduct a dredging feasibility study, in which any additional topographic information is collected in order to generate the signed and sealed engineering drawings required for the permit. This also includes detailed chemical tests of sediment samples in order to assess for containments and physical qualities, as these will in part determine where and how dredge spoils can be disposed of. Dredging can be a very expensive operation, but the positive impacts to the lake would likely be immediately noticeable in years following operations.

Floating Wetland Islands – Upper Mount Glen Lake may also benefit from the installation of floating wetland islands. These structures serve to absorb some nutrients from the water column before they can be used by algae and would be best placed in the shallower southern end of the waterbody. They also can provide habitat for fish and other aquatic animals.

MT. LAUREL LAKE

Mt. Laurel Lake consists of two small-to-moderate sized basins and features a large watershed, which contains the watershed of Lake Lookover. As with many other lakes in this study, the lake's most prevalent source of phosphorus is modeled to be septic system influence. Similarly to Upper Mount Glen Lake, Mt. Laurel Lake features a large degree of sedimentation, particularly in the southern basin. This area also contains dense growths of vegetation. Due to its shallow depths, internal loading is not estimated to be a large source of phosphorus for the lake.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

At a stormwater system on Clinton View Terrace, an MTD may be installed for the interception and treatment of runoff from this road. Additionally, the nearby grass area may be converted into a rain garden or small bioretention basin. Princeton Hydro also recommends the replacement of a gravel area near the lake's main inlet with either native vegetation or a pervious paving system, depending on the use of this area. At a series of catch basins on Commanche Lane, inserts may be installed to prevent debris from flowing through the system and into the lake. This area could alternatively be fited with a bioretention system to catch stormwater runoff.

Princeton Hydro also recommends strategies to reduce the impervious surface area of the Mt. Laurel Park parking lot. This may be achieved with porous pavement, vegetated pavers, or vegetated parking islands that serve to function as bioretention areas.

These recommendations are further detailed in the following report section.

IN-LAKE RECOMMENDATIONS

Bathymetric Survey – Mt. Laurel Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. A bathymetric survey and assessment of sediment depth is also required prior to conducting dredging.

Dredging - Dredging is the removal of sediments that have accumulated on the bottom of a waterbody. In Mt. Laurel Lake, this would be particularly effective if utilized on the shallow, southern portion of the waterbody. Dredging a waterbody can have a variety of positive effects, including the physical removal of a large amount of nutrients and a potentially large reduction in aquatic vegetation. However, prior to dredging operations various local and state-level permits will need to be obtained. Additionally, the Mt. Laurel Lake community will need to conduct a dredging feasibility study, in which any additional topographic information is collected in order to generate the signed and sealed engineering drawings required for the permit. This also includes detailed chemical tests of sediment samples in order to assess containments and physical qualities, as these will in part determine where and how dredge spoils can be disposed of. Dredging can be a very expensive operation, but the positive impacts to the lake would likely be immediately noticeable in years following operations.

Floating Wetland Islands – Mt. Laurel Lake may also benefit from the installation of floating wetland islands. These structures serve to absorb some nutrients from the water column before they can be used by algae and would be best placed in the shallower southern end of the waterbody. They also can provide habitat for fish and other aquatic animals.

MOUNTAIN SPRINGS LAKE

Mountain Springs Lake is a small waterbody with a relatively small watershed. A majority of the phosphorus entering the lake is modeled to originate from septic systems within the watershed. While the lake does feature some anoxia and corresponding internal phosphorus loading, this is a relatively small source of the lake's total phosphorus load.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Few areas of municipal or community property are present in the Mountain Springs Lake watershed; however, a small area of shoreline was identified on the southern end of the lake adjacent to the beach area. Princeton Hydro recommends the planting of a vegetated buffer in this area to reduce erosion.

Private property owners are also encouraged to conduct small-scale stormwater management practices on their own land, such as rain gardens or vegetative pavers.

Further information regarding these recommendations is provided in the following report section.

Bathymetric Survey – Mountain Springs Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. A bathymetric survey and assessment of sediment depth is also required prior to conducting dredging.

Biochar – Mountain Springs Lake may benefit from the addition of biochar. These would be installed in the form of buoys with biochar bags suspended underneath. Biochar bags could be placed in multiple areas of the lake to absorb some of the nutrients introduced to the water column through internal loading or from the watershed. Areas of known concentrated stormwater input are also preferred, so incoming nutrients can be intercepted. These bags would likely be installed in spring at the start of the growing season and replaced approximately halfway through the growing season.

Floating Wetland Islands – Mt. Laurel Lake may also benefit from the installation of floating wetland islands. These structures serve to absorb some nutrients from the water column before they can be used by algae and would be best placed in the shallower southern end of the waterbody. They also can provide habitat for fish and other aquatic animals.

PINECLIFF LAKE

Pinecliff Lake is one of the larger waterbodies in the study and features a large watershed. Increased anoxic loading was not observed to occur in 2022, however this may occur during other years. Septic systems in the watershed are modeled to be the largest annual contributor of phosphorus. The lake was observed in 2022 to feature notable densities of planktonic algae and cyanobacteria.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

The grass areas adjacent to the West Milford Department of Transportation (DOT) building are potential locations for bioretention systems that can function to remove nutrients and sediment from stormwater runoff originating in surrounding areas. Porous pavement may also be installed in parts of the building's parking lot. Another parking lot that this or other similar projects may occur on is that of the West Milford Presbyterian Church. A prefabricated treatment device may also be installed to intercept and treat runoff. Porous pavement may also be used in parts of the West Milford Police Department Building's parking lot; the grass area nearby may also be used for a bioretention system or green infrastructure (GI) practice.

A drainage stream east of Pinecliff Lake Drive was observed to feature highly eroded banks. Princeton Hydro recommends the stabilization of these streambanks in order to reduce erosion. Another drainage stream flowing under Pinecliff Lake Drive was observed to feature accumulated sediment and is suspected to contain an under-sized pipe, however further investigation will be needed to ascertain this. Curbs and swales alongside the road in this area would further assist in directing stormwater and preventing erosion, while clearing out associated catch basins should be conducted periodically to maintain function.

At a catch basin on the corner of Pinecliff Lake Drive and Park Lane, recommendations for potential projects include the daylighting of a pipe on Park Lane and installing a bioretention basin, bioswale, or prefabricated stormwater plant in a nearby greenspace, depending on limitations posed by utilities, as well as the ownership of the land. A catch basin located near the corner of Vista Road and Pinecliff Lake Drive is another potential location for a similar project, again depending on land ownership.

Flooding and associated sediment was observed at the corner of Sylvan Way and Pinecliff Lake Drive and may be treated with the installation of curbs, the establishment of vegetated conveyances along the roadsides, or the installation of an MTD inline with the existing stormwater system in order to reduce sediment flowing through the system. A catch basin at the corner of Arcata Drive and Pinecliff Lake Drive may be improved in a similar fashion.

These recommendations are described in further detail in the following report section.

IN-LAKE RECOMMENDATIONS

Bathymetric Survey – Pinecliff Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. A bathymetric survey and assessment of sediment depth is also required prior to conducting dredging, if this is an option the community wishes to pursue in the future.

EutroSORB F® Bags – A large amount of nutrients are modeled to enter Pinecliff lake from its main tributary, Belcher Creek. This may be mitigated with the use of the SePro product EutroSORB F®, a compound designed to remove SRP from flowing water. These products can be installed in streams to remove phosphorus prior to entry into a lake. It should be noted however that EutroSORB F® bags need to be periodically changed to achieve continued proper removal rates. Additionally, installation of bags into the stream may require permits through the NJDEP.

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. Pinecliff Lake may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

POST BROOK FARMS LAKE

Post Brook Farms Lake is a relatively small waterbody and features a watershed that, while mostly forested, features notable areas of developed land. The lake featured a degree of anoxic internal phosphorus loading in 2022 and was observed to experience periodical cyanobacteria blooms. As with many other lakes in the study, septic tank influence is modeled to produce the largest annual source of nutrients.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the installation of a rain garden near the intersection of Hancock Drive and Schofield Road. This would serve to remove sediment and nutrients from road runoff. A similar project is also recommended for near the intersection of Osage Drive and Schofield Road. Princeton Hydro also recommends increasing soil infiltration ability on the "ramp" leading down to the beach area near Schofield Drive. This may be accomplished by paving this ramp with vegetated pavers and by reestablishing a native vegetative buffer at the adjacent shoreline.

Additionally, multiple projects could be implemented to reduce sediment entering the lake from the concrete pipes draining Schofield Road's and Osage Drive's catch basins. These include the installation of a MTD on Schofield Road, a regrading of the impacted shoreline area, a regrading and re-vegetation of the tributary stream adjacent to Osage Drive, and the installation of gutters and leaders on the pavilion and shed roofs near the beach area to re-direct water to a small rain garden. More information about each of these recommendations is available in the following report section.

IN-LAKE RECOMMENDATIONS

Aeration – Post Brook Farms Lake may benefit from the installation of an aeration system in order to keep the water column relatively well-mixed during the summer months. This would in turn likely reduce bottom anoxia and associated increased internal phosphorus loading. This would be particularly effective if diffusers can be located in the deepest area of the lake near the dam, where bottom anoxia was measured in 2022. Prior to the installation of an aeration system, however, a bathymetric study and further water quality sampling are advised.

Bathymetric Survey – Post Brook Farms Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. A bathymetric survey and assessment of sediment depth is also required prior to conducting dredging, and is recommended prior to installing an aeration system.

Dredging - Dredging is the removal of sediments that have accumulated on the bottom of a waterbody. In Post Brook Farms Lake, this may be particularly effective if utilized in the shallower areas of the waterbody, such as the beach and adjacent to the inlet. Depending on sediment depths, however, dredging may be beneficial if conducted in other areas as well. Dredging a waterbody can have a variety of positive effects, including the physical removal of a large amount of nutrients and a potentially large reduction in aquatic vegetation. However, prior to dredging operations various local and state-level permits will need to be obtained. Additionally, the Post Brook Farms Lake community will need to conduct a dredging feasibility study, in which any additional topographic information is collected in order to generate the signed and sealed engineering drawings required for the permit. This also includes detailed chemical tests of sediment samples in order to assess containments and physical qualities, as these will in part determine where and how dredge spoils can be disposed of. Dredging can be a very expensive operation, but the positive impacts to the lake would likely be immediately noticeable in years following operations.

Floating Wetland Islands – Post Brook Farms Lake may also benefit from the installation of floating wetland islands. These structures serve to absorb some nutrients from the water column before they can be used by algae and would be best placed in shallower portions of the waterbody, such as near the two small inlets. They also can provide habitat for fish and other aquatic animals.

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. Post Brook Farms Lake may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

SHADY LAKE

Shady Lake is a relatively small waterbody with a notable amount of developed land in its watershed. The lake was not observed to feature bottom anoxia in 2022, although this may occur in other years. The lake features notable vegetation growth, however a portion of this occurs at the bottom of the water column and likely does not pose a significant nuisance to lake users. Septic systems in the watershed are estimated to be the largest contributors of nutrients each year in Shady Lake.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the establishment of a riparian buffer between the northern side of Poplar Grove Terrace and the shoreline. This would serve to reduce erosion and the sediment load entering the lake. More information regarding this recommendation is provided in the following report section.

IN-LAKE RECOMMENDATIONS

Bathymetric Survey – Shady Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. A bathymetric survey and assessment of sediment depth is also required prior to conducting dredging, if this is an option the community pursues in the future.

Biochar – Shady Lake may benefit from the addition of biochar. These would be installed in the form of buoys with biochar bags suspended underneath. Biochar bags could be placed in multiple areas of the lake to absorb some of the nutrients introduced to the water column through internal loading or from the watershed. Areas of known concentrated stormwater input are also preferred, so incoming nutrients can be intercepted. These bags would likely be installed in spring at the start of the growing season and replaced approximately halfway through the growing season.

Floating Wetland Islands – Shady Lake may also benefit from the installation of floating wetland islands. These structures serve to absorb some nutrients from the water column before they can be used by algae and would be best placed in the shallower western end of the waterbody, as well as by the inflow from the small pond to the north. They also can provide habitat for fish and other aquatic animals.

UPPER GREENWOOD LAKE

Upper Greenwood Lake is one of the larger waterbodies in the study by surface area and features a relatively large watershed. As with many of the other waterbodies in the study, the lake features a largely developed shoreline and receives a large annual load of nutrients from septic systems in the watershed. The lake was not observed to feature bottom anoxia in 2022, however this may occur during other years.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Upper Greenwood Lake's watershed affords multiple potential projects. Princeton Hydro recommends the stabilization of the eroding banks on both sides of Spruce Point Trail. An MTD may also be installed in line with the stormwater system receiving runoff from Spruce Point Trail and Warwick Turnpike. Another potential project involves the installation of a porous or vegetative paving system at the Greenwood Baptist Church's parking lot in order to reduce stormwater runoff. A rain garden may also be installed between this parking lot and the lake.

In the open green space adjacent to the inlet south of Dover Road, a bioretention system may be installed in order to retain stormwater, increase groundwater infiltration, and sequester nutrients. Invasive species present in the riparian buffer in this area can be removed and native vegetation can also be planted to reduce erosion.

A bioretention system is also recommended at the northern end of the lake where open green space exists between the lake and North Lake Shore Drive. A riparian buffer could also be planted in this area at the shoreline to reduce erosion and sediment inputs into the lake.

Princeton Hydro also recommends the installation of porous pavement or vegetated pavers in a parking area near the intersection of North Lakeshore Drive and Papscoe Road. The compacted lawn in this area may also be replaced with native meadow vegetation in order to increase soil infiltration and remove sediment and some pollutants from stormwater. A porous or vegetated paving system can also be installed at the Living Word Alliance Church's parking lot. Small raingardens could also be installed to capture runoff from the leaders that drain the church's roof.

More details regarding these potential projects is provided in the following report section.

IN-LAKE RECOMMENDATIONS

Biochar – Upper Greenwood Lake may benefit from the addition of biochar. These would be installed in the form of buoys with biochar bags suspended underneath. Biochar bags could be placed in multiple areas of the lake to absorb some of the nutrients introduced to the water column through internal loading or from the watershed. Areas of known concentrated stormwater input are also preferred, so incoming nutrients can be intercepted. These bags would likely be installed in spring at the start of the growing season and replaced approximately halfway through the growing season.

EutroSORB F® Bags – A notable amount of nutrients are modeled to enter Upper Greenwood Lake from its tributaries. This may be mitigated with the use of the SePro product EutroSORB F®, a compound designed to remove SRP from flowing water. These products can be installed in streams to remove phosphorus prior to entry into a lake. It should be noted however that EutroSORB F® bags need to be systemically changed upon expiration to achieve continued proper removal rates. Additionally, installation of bags into the stream may require permits through the NJDEP.

Floating Wetland Islands – Upper Greenwood Lake may also benefit from the installation of floating wetland islands. These structures serve to absorb some nutrients from the water column before they can be used by algae and would be best placed in the shallower southern end of the waterbody, as well as by the inflow from the small pond to the north. They also can provide habitat for fish and other aquatic animals.

Nutrient Inactivation and/or Sequestration - The application of products such as Alum or Phoslock® can be used to remove phosphorus from the water column, making it unavailable to algae. Upper Greenwood Lake may benefit from applying alum during instances of increased algae growth during the summer. Due to the tendency of alum to lower the pH of water, prior to application, an alum bench test must first be performed. The purpose of this test is to assess the approximate amount of alum that can be applied to the waterbody before the pond's pH drops to a level dangerous to fish and other aquatic life.

VAN NOSTRAND LAKE

Van Nostrand Lake is a relatively moderately-sized but shallow waterbody with a watershed largely consisting of forested land and wetlands. As such, the lake is estimated to receive a relatively low annual nutrient load from its watershed. The lake was not observed to feature bottom anoxia in 2022, however this may occur during other years. Algae densities in Van Nostrand Lake were not observed to be problematic, however the lake is largely dominated by floating vegetation.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Given Van Nostrand Lake's watershed, which is almost entirely comprised of forested land and wetlands, little restoration is needed within the watershed. Any restorative efforts will therefore likely need to take place in the lake itself; these are described below.

IN-LAKE RECOMMENDATIONS

Bathymetric Survey – Van Nostrand Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. A bathymetric survey and assessment of sediment depth is also required prior toconducting dredging.

Dredging - Dredging is the removal of sediments that have accumulated on the bottom of a waterbody. In Van Nostrand Lake, this may be particularly effective if utilized in the shallower northwestern areas of the waterbody. Depending on sediment depths, however, dredging may be beneficial if conducted in other areas as well. Dredging a waterbody can have a variety of positive effects, including the physical removal of a large amount of nutrients and a potentially large reduction in aquatic vegetation. However, prior to dredging operations various local and state-level permits will need to be obtained. Additionally, Van Nostrand Lake residents will need to conduct a dredging feasibility study, in which any additional topographic information is collected in order to generate the signed and sealed engineering drawings required for the permit.

Vegetation Management – Van Nostrand Lake was observed to feature moderate-to-dense populations of aquatic plants throughout the waterbody. While aquatic vegetation is beneficial when growing in smaller populations for fish habitat, sediment settling, and nutrient uptake, large populations can lead to imbalances in the fishery, water flow issues, and dissolved oxygen crashes at the end of the season when the vegetation decomposes. In the case of Van Nostrand Lake, large amounts of floating-leaved vegetation such as watershield and white water lily may also prevent atmospheric mixing of oxygen into the water column in parts of the waterbody. Van Nostrand Lake residents have stated that herbicidal treatment has been found in the past to not be feasible in the lake without resulting in undesired environmental damage. Mechanical removal is another viable option and may provide the added benefit of removing some nutrients from the waterbody. As Van Nostrand Lake does not feature a boat ramp, however, logistical difficulties may exist in launching a mechanical harvester.

WONDER LAKE

Wonder Lake is a small-to-moderately sized, shallow waterbody with a largely forested watershed, although there is a notable amount of developed land near its western shoreline. A majority of the lake's watershed-based nutrient load is estimated to originate from septic systems. The lake is also estimated to feature a sizeable internal yearly phosphorus load. Floating leaves and submerged aquatic vegetation dominate almost the entirety of the lake's surface area.

Based on these observations, Princeton Hydro recommends the following:

WATERSHED-BASED RECOMMENDATIONS

Princeton Hydro recommends the replacement of a grassy area at the end of Pecan Lane be replaced with native meadow vegetation in order to intercept stormwater, increase infiltration, and sequester nutrients. Further work can be performed by homeowners on individual lots to manage residential stormwater, such as the use of rain gardens or rain barrels.

Further information regarding these suggested projects is provided in the following report section.

IN-LAKE RECOMMENDATIONS

Aeration – Wonder Lake may benefit from the installation of an aeration system in order to keep the water column relatively well-mixed during the summer months. This would in turn likely reduce bottom anoxia and associated increased internal phosphorus loading. This would be particularly effective if diffusers can be located in the deepest area of the lake near the western shoreline, where bottom anoxia was measured in 2022. Prior to the installation of an aeration system, however, a bathymetric study and further water quality sampling are advised. Furthermore, given the shallow depths and dense vegetation in Wonder Lake, dredging and/or vegetation removal may be necessary.

Bathymetric Survey – Wonder Lake would likely benefit from an updated bathymetric survey. In addition to the generation of a depth map, this survey would collect data that can be used to better refine limnological models. A bathymetric survey and assessment of sediment depth is also required prior to conducting dredging.

Dredging - Dredging is the removal of sediments that have accumulated on the bottom of a waterbody. This can have a variety of positive effects, including the physical removal of a large amount of nutrients and a potentially large reduction in aquatic vegetation. However, prior to dredging operations various local and state-level permits will need to be obtained. Additionally, Wonder Lake residents will need to conduct a dredging feasibility study, in which any additional topographic information is collected in order to generate the signed and sealed engineering drawings required for the permit.

Vegetation Management – Wonder Lake was observed to feature moderate-to-dense populations of aquatic plants throughout the waterbody. While aquatic vegetation is beneficial when growing in smaller populations for fish habitat, sediment settling, and nutrient uptake, large populations can lead to imbalances in the fishery, water flow issues, and dissolved oxygen crashes at the end of the season when the vegetation decomposes. In the case of Wonder Lake, large amounts of floating-leaved vegetation such as white water lily may also prevent atmospheric mixing of oxygen into the water column in parts of the waterbody. Many of the plants present in Wonder Lake can be treated with herbicides. Mechanical removal is another viable option and may provide the added benefit of removing some nutrients from the waterbody. If dredging were to occur on the lake, this would also likely result in large reductions in vegetation growth in the dredged areas.

GENERAL RECOMMENDATIONS

Princeton Hydro recommends the following actions that apply to most if not all waterbodies in this study. As above, these are split into watershed-based and in-lake recommendations.

WATERSHED-BASED RECOMMENDATIONS

As will be further explained in the next section of this report, Princeton Hydro recommends the stabilization of lake shorelines, the enhancement of the riparian zone (the area where the shoreline meets the water's edge), and creating clearly defined and stabilized watercraft access points. While certain areas are recommended for some of the waterbodies in their respective recommendations, this applies to all areas of lakes in the study where shoreline erosion may be a problem.

IN-LAKE RECOMMENDATIONS

Annual Water Quality Monitoring – Princeton Hydro strongly recommends the establishment of an annual water quality monitoring program. This not only allows for the establishment of long-term trends but allows lake managers to assess the progress and effectivity of established management implementations, detect problems as they arise, and set management goals. Ideally, a monitoring program should follow the timing and methodology utilized by Princeton Hydro in 2022, with at least three events occurring over the course of a year, and each event featuring the sampling of *In-situ* and discrete water quality data. Particulars and attention to other components can be tailored to suit an individual lake's needs, and indeed may change over the course of several years as a lake community's needs change.

Septic System Influence Assessments – As mentioned in the watershed modeling section, homeowner septic systems can contribute to a large percentage of a lake's annual phosphorus and nitrogen loads. This can particularly be a significant factor on lakes surrounded by homes, such as many of those assessed in this study. Individual homeowners can reduce their impact on a lake by keeping their septic system regularly maintained and by upgrading them as needed. Any issues found to occur with a particular septic system should be addressed as soon as possible so as to keep advanced nutrient loading to a minimum.

A "septic-snooper" assessment can be performed to identify areas of a lake where septic effluent is leaching into the water column. In such a survey, *In-situ* data would be collected at several points around the entirety of the developed portion of a lake's shoreline. Sharp increases in specific conductivity can be indicative of septic system influence, which can then be further tested for by the collection of discrete water samples for the analysis of bacterial counts and nutrients such as nitrates. Samples collected at the surface of the mid-lake or dam station should also be collected for comparison.

Successful septic management involves the integration of public education, product modification, septic system inspection and maintenance, and water conservation practices. Routine inspections and pump outs (once every three years) are the two best, but often the most controversial, elements of septic management programs.

There is an innate resistance by homeowners to periodic inspections or to follow a pump out schedule. Basically, the prevailing thought among most homeowners is "if it flushes, it's OK". However, as has been demonstrated through multiple nationwide septic management studies, routine inspections help decrease the occurrence of large-scale failures through the early identification of the more easily corrected, less costly problems. Routine pump outs also 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. Interestingly, most septic failures can be linked to the clogging and failure of the septic field.

Additionally, homeowners should be educated regarding 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 on septic management are readily available through the NJDEP, NALMS and regional watershed and environmental groups. A variety of public information septic management fact sheets are available through the USEPA's Small Flows Clearing House (www.nesc.wvu.edu), which specializes in the dissemination of information pertaining to septic systems and other types of on-site waste water treatment systems. This includes information pertaining to septic tank additives, enzymes, and bacteria inoculants, none of which have any positive benefits. Such products often give a false sense of maintenance to the property owner and may actually dissuade them from regularly pumping or inspecting their system.

Aeration - Aeration is an in-lake management technique used to convert an anoxic (anaerobic) environment into an oxic (aerobic) environment. The main purpose of an aeration systems is to preclude the internal release of phosphorus from the anoxic bottom sediment of a lake that often occurs during periods of thermal stratification. There are various aeration techniques that can be used to positively affect dissolved oxygen concentrations. Some techniques manage oxygen levels throughout the entire water column while others focus on the management of oxygen within a limited, defined portion of the water column. The two commonly used aeration techniques include destratification systems and hypolimnetic aeration systems. Due to the relatively shallow nature of the study lakes throughout West Milford Township and the fact that they do not support cold-water fisheries, a destratification system would likely be the best aeration technique.

With a destratification system, compressed air is used to vertically circulate the entire water column in a manner that prevents thermal stratification from becoming established or from persisting. This essentially results in relatively uniform, surface to bottom, water column temperatures. Because water temperatures are essentially uniform, there are minimal density differences throughout the water column. Without the presence of any thermal gradients preventing mixing, the entire vertical water column can be easily circulated. It is the exposure of the water to the atmosphere that results in full water-column reoxygenation rather than directly from the compressed air.

When properly designed and operated, destratification can be accomplished by the placement of a limited number of compressed air diffusers in the deeper portion of the subject lake. Aeration systems are generally operated from April through September when they should run 24/7. The cost for the purchase and installation of an aeration system is dependent on the number of diffusers and the location of the onshore compressors, as the rubber tubing is typically the most expensive component. Once installed, maintenance is relatively simple and involves changing the air filter a couple of times per year and compressor maintenance every few years. After installation, annual costs include the utility bill to run the compressors during the growing season.

Biochar

Biochar is a processed wood material that has a high affinity to adsorb a variety of pollutants. There is currently a strong interest in using biochar to remove phosphorus from water since it tends to be the primary limiting nutrient for freshwater algae. Specifically, elevated phosphorus concentrations not only increase algae biomass, but also favor cyanobacteria, the algal group that has the potential to produce cyanotoxins and other compounds that may impact the health of humans, pets, and livestock.

This material can be placed into flotation balls, sausages, or cages and tethered along a beach area swimming line, where an inlet enters the lake, or within streams themselves. Biochar set out in lakes and ponds, including stormwater ponds. It has been shown to remove dissolved phosphorus directly out of the nearshore waters, contributing toward limiting algal growth. Biochar set in streams will intercept these nutrients as the water passes through. Additionally, the relatively low cost of the Biochar and its re-use as a form of mulch make it a particularly attractive means of contributing toward the removal of in-lake phosphorus. Biochar strategically placed in lakes offers the opportunity to remove internally released phosphorus from the system, further complimenting the watershed management measures that reduces nutrient loads closer to the source. As such, biochar can remove legacy phosphorus and other nutrients that have built up in the sediments over time from the system completely, especially if the biochar is removed and replaced throughout the season.

Dredging - Dredging is an effective, but expensive, lake management technique. Dredging involves the removal of accumulated unconsolidated sediments from the bottom of a lake. A dredging feasibility study is required to determine what contaminants, if any, are present in the sediment as well as to determine the cost-effectiveness of such an operation. Dredging feasibility studies include, at a minimum, an updated bathymetric assessment and sediment sampling.

Dredging has multiple benefits, including deepening, nutrient control (removal), toxic substance removal, and rooted macrophyte control. All these benefits, except for toxic substance removal, would improve the quality of most of these study lakes. Sediment removal directly results in the deepening of a lake and provides nutrient control through the removal of phosphorus-rich sediment, which can otherwise cause internal phosphorus loading in lakes that stratify and become anoxic in the deeper water during the summer months. Sediment removal also results in the direct removal of plant matter as well as viable substrate for plant growth. Dredging costs vary greatly based on several factors, including the amount of proposed dredged material, what contaminants are present, and which type of dredging (mechanical, hydraulic, etc.) is applicable.

Floating Wetland Islands - FWIs are constructed of recycled plastic material, are typically planted with native, water loving vegetation and then anchored to the lake bottom. Functionally, these units have been utilized to slow inflow and precipitate sediments. Furthermore, the high surface area of the constructed wetland material and root mass of planted vegetation serve as habitat for bacteria which assimilate and process phosphorus and nitrogen. Nitrogen uptake also occurs via direct assimilation from the plants.

The manufacturer of the FWIs typically collects information prior to manufacturing in order to design an area and material density which is optimized for the intention of the installer. These islands can be installed alone, or for more effectiveness, be utilized in conjunction with emergent vegetation or other shoreline restoration methods described in this report.

Invasive Species Management - Invasive Species management is a broad term but in this report is generally referred to as invasive plant management. Common aquatic invasive plants, such as curlyleaf pondweed (*Potamogeton crispus*), Eurasian watermilfoil (*Myriophyllum spicatum*), brittle naiad (*Najas minor*), and *Phragmites sp.*, among others, outcompete native species. Due to a lack of native predators, these invasive species often grow to nuisance densities which can impede recreation and completely displace native species from the local ecosystem. At excessive densities, invasive SAV can act as a source of nutrients to the lake when the plants senesce.

The two most common forms of invasive plant management include herbicide applications and mechanical harvesting. The best invasive plant management programs are adaptive and involve early inspection, rapid action and a collaborative approach. A good control program is designed to control excessive nuisance plant growth but not eliminate native plant populations. Aquatic plants are part of a healthy, balanced lake ecosystem that provide nutrient uptake, as well as food and habitat for insects and fish. Additionally, native shoreline and riparian vegetation stabilizes the soil and reduces the rate of shoreline and streambank erosion.

8.0 WATERSHED-BASED CONCLUSIONS AND RECOMMENDATIONS

One of the primary reasons for conducting this Township-wide study was to identify locations throughout the various watersheds that can be modified to reduce the annual pollutant load to the receiving waterbodies. The data that was generated in Section 3, Hydrologic and Pollutant Loading Analysis, was utilized in preparation of the field-based watershed assessments throughout the Township. Specifically, the subwatersheds that were identified as contributing the largest pollutant loads were prioritized for restoration. However, locations throughout the various watersheds that were not necessarily within the highest contributing subwatersheds but were identified as having easily manageable (correctable) pollutant loads were also prioritized. These locations often include public and open spaces that can easily accommodate GI. Using the data generated in Section 3 and the watershed-based field assessments, a list of best management practices (BMPs) is provided to the Township in this section of the report. Emphasis has been given to bioretention type systems that can be implemented on a lot-specific or regional scale. If applicable, preliminary base cost estimates have been developed for the design and construction of each recommended stormwater management BMP. All of these BMPs should be eligible for funding through the NJDEP 319(h) program. Applications are accepted annually by the NJDEP. The majority of the restoration efforts and BMPs in this section are included in the New Jersey Stormwater BMP Manual.

This section corresponds to the third of the EPA elements and consists of a description of the management measures necessary in the various watersheds throughout the West Milford Township community to achieve load reductions as well as a description of the areas where those measures will be implemented. This is one of the most important components of this document and consists of a list of projects that could be designed and implemented to reduce Total Suspended Solids (TSS), Total Phosphorus (TP), and other pollutant loads entering the lakes. In addition to the nutrient removal, the project recommendations also include projects to improve flooding and climate change resiliency.

Princeton Hydro reviewed desktop information including parcel boundaries, soils, topography, and land use/landcover as well as aerials to identify potential sites. These sites were then field evaluated to determine recommendable BMP(s), site constraints, and confirm feasibility to accommodate GI and provide efficient pollutant removal. GI refers to natural and engineered ecological systems that treat stormwater in a way that mimics natural process; ex: bioretention systems or rain gardens that receive stormwater and sequester nutrients. In addition to GI, general recommendations for stormwater management and riparian zone improvements are also included in the report.

Princeton Hydro evaluated and identified sites within the watersheds of the twenty-one (21) areas of interest within the Township. These areas of interest are primarily lakes and ponds and their associated watershed or drainage area. Figures 124-143 on the following pages depict these water bodies, and the site locations described in more detail in the subsequent sections. Table 253 presents a list of proposed BMPs, the amount of TSS removed, and estimated project costs for each site. The waterbodies included in this study include the following:

- Algonquin Waters
- Bubbling Springs
- Carpi Lake
- Farm Crest Acres Pond
- Forest Hill Lake
- Gordon Lakes
- High Crest Lake
- Johns Lake
- Kitchell Lake
- Lindy's Lake
- Lake Lookover
- Lower Mount Glen Lake
- Upper Mount Glen Lake
- Mt. Laurel Lake
- Mountain Springs Lake
- Pinecliff Lake
- Post Brook Farms Lake
- Shady Lake
- Upper Greenwood Lake
- Van Nostrand Lake
- Wonder Lake

Given the private nature of most of the lakes, initiating these projects would require the Township to serve as the "steward" for the lakes and their watershed. In terms of financial assistance for the design and implementation of any recommended projects, a number of potential avenues of funding should be considered and possibly pursued, such as:

- Federal and/or state grants, loans or technical assistance. Example programs include the state's Non-Point Source 319(h) program, federal and state environmental education grants and other sources such as US EPA, US Army Corp of Engineers, and possibly United States Department of Agriculture.

- Small-scale county or municipal grants or projects that fund the planting of native vegetation.

- Establishment of unique agreements such as the creation of wetlands as part of a mitigation bank to compensate for the loss of wetlands associated with development within the watershed.

- Cooperative agreements between private property owners (i.e. residential developments, golf courses) and local / county agencies to implement stabilization and/or vegetation-based projects.

- Other modes of funding such as private, non-profit sources, land or tax credit incentives and municipal agreements for future development or establishment of open space lands.

Specifically, the following list of potential funding sources is provided. Additional funding sources may be or become available in beyond those listed below. More details on the potential sources of funding through the programs listed below can be found at www.nj.gov/dep/grantandloanprograms.

- Non-Point Source Pollutant Control Grants (funds provided to NJDEP through Section 319 (h) of the federal Clean Water Act) to address watershed-based, non-point source pollution.

- Water Quality Management Planning Pass-Through Grants (funds provided to NJDEP through Section 604 (b) of the federal Clean Water Act), primarily to conduct wastewater management planning activities and develop management plans for on-site wastewater treatment systems.

- Dam Restoration & Inland Water Projects Loan Program (1992 Dam Restoration and Clean Water Trust Fund) can provide low-interest loans to assist in the funding of dam restoration, flood control projects, water pollution control projects, and water-related recreation and conservation projects.

- Green Acres Grants & Loans (funds provided through previous Green Acres bond issues and the 1998 Garden State Preservation Trust) can be used by municipalities or counties to acquire and/or develop municipal or county land for public recreation and conservation purposes.

- Green Acres Nonprofit Acquisition Grants (funds provided through previous Green Acres bond issues and the 1998 Garden State Preservation Trust) can be used by tax-exempted, non-profit organizations to acquire open space for recreation and conservation purposes statewide, and to develop outdoor recreational facilities in certain urban or densely populated municipalities and counties. All land funded under this program must be open to the public.

- Environmental Infrastructure Financing Program (funds provided by NJDEP and the New Jersey Environmental Infrastructure Trust) can provide low-interest loans for the construction of a variety of water quality protection measures and for open space acquisition.

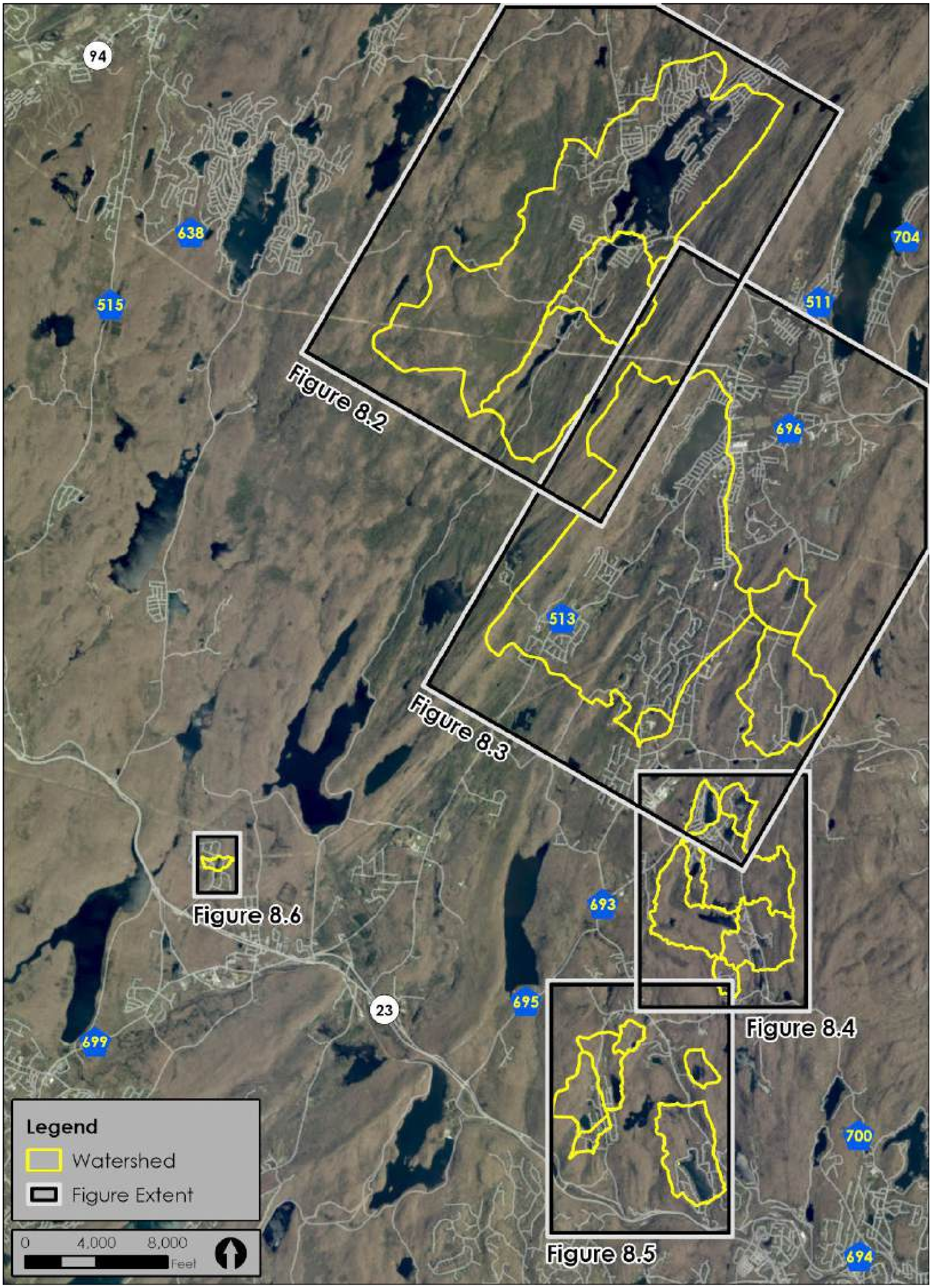


Table 253. Watershed BMP Site Summary

Site	Proposed BMP	TSS REMOVAL Rate (%)	Potential Project Cost ($)
Lake Lookover			
1A	Vegetated conveyance systems along the south side of Brookfield Road	60 - 80	$12,000 - $30,000
1B	Shoreline buffer along the north side of Brookfield Road	60 - 80	$30,000 - $60,000
2A	Conversion of a portion of the beach parking lot to porous pavement	80	$65,000 - $85,000
2B	Shoreline buffer plantings	60 - 80	$30,000 - $55,000
Mt. Laurel Lake			
3A	Manufactured Treatment Device along Clinton View Terrace	See N.J.A.C. 7:8-5.7(d)2	$500,000 - $1,000,000
3B	Rain garden / bioretention system adjacent to Clinton View Terrace	60 - 90	$10,000 - $25,000
4A	Vegetated buffer along Clinton Road	60 - 80	$15,000 - $25,000
4B	Stabilized porous surface at lake access point	80	$35,000 - $65,000
5A	Catch basin inserts along Commanche Drive	See N.J.A.C. 7:8-5.7(d)2	$5,000 - $10,000
5B	Prefabricated bioretention system along Commanche Drive	60 - 80	$25,000 - $100,000
6A	Conversion of a portion of the Mt. Laurel Park parking lot to porous pavement	80	$500,000 - $800,000
6B	Conversion of portions of Mt. Laurel Park parking lot to bioretention areas	90	$75,000 - $175,000
Upper Greenwood Lake			
7A	Bank stabilization and vegetated conveyance along Spruce Point Trail	60 - 80	$7,500 - $15,000
7B	Manufactured Treatment Device along Warwick Turnpike / Spruce Point Trail	See N.J.A.C. 7:8-5.7(d)2	$750,000 - $1,500,000
8A	Conversion of a portion of the Greenwood Baptist Church parking lot to porous pavement	80	$400,000 - $700,000
8B	Rain garden / bioretention system in the Greenwood Baptist Church parking lot	60 - 90	$40,000 - $70,000
9A	Bioretention system adjacent to the N Lake Shore Drive and Dover Road Inlet	90	$50,000 - $125,000

9B	Riparian buffer establishment and invasive species treatment along the N Lake Shore Drive and Dover Road inlet	60 - 80	$12,500 - $25,000
10A	Bioretention system(s) between N Lake Shore Drive and the northern cove	90	$90,000 - $175,000
10B	Establishment of a shoreline buffer along the northern cove shoreline	60 - 80	$40,000 - $60,000
11A	Conversion of a portion of the parking lot on N Lakeshore Dive to porous pavement	80	$250,000 - $450,000
11B	Establishment of a shoreline buffer near N Lakeshore Drive and Papscoe Road	60 - 80	$30,000 - $55,000
12A	Conversion of a portion of the Living Word Alliance Church parking lot to porous pavement	80	$500,000 - $800,000
12B	Rain gardens or downspout planters in front of the Living Word Alliance Church	60 - 80	$5,000 - $15,000
Bubbling Springs Lake			
13	Stabilized conveyance system and native plantings	60 - 80	$200,000 - $600,000
14A	Bioretention system in the Bubbling Springs Park parking lot	90	$95,000 - $190,000
14B	Conversion of a portion of the Bubbling Springs Park parking lot to porous pavement	80	$500,000 - $1,000,000
Pinecliff Lake			
15A	Bioretention system in the grass areas in front of the DOT building	90	$235,000 - $300,000
15B	Conversion of a portion of the parking lot to porous pavement	80	$300,000 - $500,000
16A	Conversion of a portion of the West Milford Presbyterian Church parking lot to porous pavement	80	$800,000 - $1,200,000
16B	Conversion of portions of the West Milford Presbyterian Church parking lot to bioretention areas	90	$60,000 - $110,000
16C	Installation of a prefabricated bioretention system in the West Milford Presbyterian Church parking lot	90	$50,000 - $100,000
17A	Bioretention system between the West Milford Police Department building and Union Valley Road	90	$75,000 - $130,000
17B	Conversion of a portion of the West Milford Police Department building to porous pavement	80	$300,000 - $500,000
18A	Streambank stabilization along the drainage stream east of Pinecliff Lake Drive	80	$100,000 - $300,000
18B	Additional hydrologic and hydraulic evaluations along the drainage stream west of Pinecliff Lake Drive. Cost is reflective of potential restoration measures	-	$400,000 - $900,000

19A	Bioretention system at the corner of Pinecliff Lake Drive and Park Lane	90	$85,000 - $150,000
19B	Bioswale at the corner of Pinecliff Lake Drive and Park Lane	60 - 80	$55,000 - $150,000
19C	Installation of a designed and/or prefabricated stormwater planter	60 - 80	$50,000 - $125,000
20	Bioswale near the corner of Vista Road and Pinecliff Lake Drive	60 - 80	$85,000 - $150,000
21A	Vegetated conveyance systems along Sylvan Way and Pinecliff Lake Drive	60 - 80	$50,000 - $80,000
21B	Manufactured Treatment Device near the corner of Sylvan Way and Pinecliff Lake Drive	See N.J.A.C. 7:8-5.7(d)2	$500,000 - $1,000,000
22	Vegetated conveyance systems along Arcata Lane	60 - 80	$50,000 - $80,000
Carpi Lake			
23	Rain garden / bioretention system between the restaurant parking lot and Morestown Road	60 - 90	$40,000 - $70,000
Kitchell Lake			
24	Riparian buffer along the inlet that flows under Kitchell Lake Drive	60 - 80	$40,000 - $70,000
25	Shoulder and bank stabilization / culvert and inlet modifications	60 - 80	$250,000 - $500,000
Lindy's Lake			
26	Installation of porous pavement bands along Woodside Street	80	$500,000 - $800,000
27	Conversion of the asphalt apron on Otterhole Road to porous pavement or pavers	80	$7,500 - $12,000
Upper Mount Glen Lake			
28A	Conversion of the mailbox parking area on Lindy's Drive at Otterhole Road to a porous pavement system	80	$90,000 - $130,000
28B	Establishment of a vegetated filter strip at the back of the parking area on Lindy's Drive at Otterhole Road	60 - 80	$25,000 - $45,000
29A	Manufactured Treatment Device along Otterhole Road	See N.J.A.C. 7:8-5.7(d)2	$500,000 - $1,000,000
29B	Bioretention system at the corner of Otterhole Road and Lindy's Drive	90	$85,000 - $150,000
30	Additional evaluation of the source of sediment	-	$5,000 - $10,000
31	Bioretention system in the open field at the corner of Otterhole Road and Pool Drive	90	$75,000 - $150,000
32A	Bioswale along Otterhole Road between Sanders Court and Mountainside Road	60 - 80	$90,000 - $165,000
32B	Vegetated shoreline buffer between Otterhole Road and Upper Mount Glen Lake	60 - 80	$7,500 - $12,000

33	Vegetated conveyance system along Otterhole Road	60 - 80	$7,000 - $20,000
34	Vegetated conveyance system and a cobble swale along Otterhole Road	60 - 80	$35,000 - $55,000
35A	Streambank stabilization measures along Otterhole Road	80	$20,000 - $45,000
35B	Bioswale along Otterhole Road	60 - 80	$170,000 - $260,000
35C	Vegetated conveyance systems along Larsen Road	60 - 80	$35,000 - $60,000
35D	Conversion of the trail head parking area to porous pavement or vegetated pavers	80	$150,000 - $250,000
36A	Conversion of the parking area on Schofield Road to porous pavement	80	$150,000 - $300,000
36B	Vegetated conveyance system along Schofield Road	60 - 80	$10,000 - $15,000
Lower Mount Glen Lake			
37	Conversion of the Lower Mount Glen Lake parking area to porous pavement	80	$150,000 - $300,000
Post Brook Lake			
38	Rain garden at the corner of Hancock Drive and Schofield Road	60 - 80	$40,000 - $100,000
39	Rain garden at the corner of Osage Drive and Schofield Road	60 - 80	$50,000 - $100,000
40A	Stabilized vegetated paving and shoreline buffer plantings at the north end of Post Brook Lake	60 - 80	$175,000 - $300,000
40B	Vegetated filter strip planting at the north end of Post Brook Lake	60 - 80	$55,000 - $100,000
41A	Manufactured Treatment Device along Schofield Road	See N.J.A.C. 7:8-5.7(d)2	$500,000 - $1,000,000
41B	Sediment forebay at the northwest end of Post Brook Lake	90	$500,000 - $750,000
41C	Riparian plantings and minor regrading along the tributary stream to the northwest of Post Brook Lake	60 - 80	$100,000 - $165,000
41D	Gutter leaders draining to a rain garden or bioretention practice at the pavilion	60 - 80	$50,000 - $100,000
Gordon Lakes			
42A	Bioretention system at the south end of the gravel and asphalt commercial lot along Otterhole Road	90	$75,000 - $120,000
42B	Conversion of a portion of the gravel and asphalt commercial lot along Otterhole Road to porous pavement	80	$100,000 - $150,000
43A	Streambank stabilization measures along the main inlet to Upper Gordon Lake	80	$35,000 - $55,000
43B	Shoreline buffer plantings at the north end of Lower Gordon Lake along East Park Drive	60 - 80	$50,000 - $75,000

Shady Lake			
44	Shoreline buffer plantings along the southwest shoreline at Poplar Grove Terrace	60 - 80	$15,000 - $25,000
Mountain Springs Lake			
45	Shoreline buffer plantings along the Mountain Springs Lake shoreline	60 - 80	$7,500 - $12,000
Wonder Lake			
46	Vegetated filter strip at Pecan Lane and Leonard Avenue	60 - 80	$25,000 - $45,000
Forest Hills Lake			
47	Conversion of a portion of the two parking lots on Forest Hill Drive to porous pavement	80	$250,000 - $350,000
Johns Lake			
48	Shoreline buffer plantings along the shoreline of Johns Lake	60 - 80	$50,000 - $75,000
49A	Vegetated conveyance with check dams at the northwest end of Johns Lake	60 - 80	$65,000 - $125,000
49B	Conversion of maintained lawn to meadow	60 - 80	$35,000 - $60,000
50A	Installation of gutters, drop tubes, and leaders at the small bathroom building at the north end of Johns Lake	-	$4,500 - $6,500
50B	Two large stormwater planters at the small bathroom building at the north end of the lake	60 - 80	$4,000 - $5,500
51A	Installation of gutters, drop tubes, and leaders at the pavilion	-	$13,500 - $18,500
51B	Four large stormwater planters at the pavilion	60 - 80	$8,000 - $10,000
51C	Stabilization of drainage path with rip rap	60 - 80	$3,000 - $5,000
52	Vegetated conveyance systems with check dams at the north end of Johns Lake	60 - 80	$175,000 - $200,000
High Crest Lake			
53A	Vegetated filter strips between the Apshawa Preserve parking lot and the tributary	60 - 80	$30,000 - $100,000
53B	Bioswale between the Apshawa Preserve parking lot and the stream	60 - 80	$35,000 - $70,000
53C	Riparian buffer plantings along the tributary south of the Apshawa Preserve parking lot	60 - 80	$35,000 - $80,000
53D	Installation of a gravel stabilization grid in the Apshawa Preserve parking lot	60 - 80	$200,000 - $300,000
54A	Shoreline buffer plantings along the shoreline of the northeastern cove	60 - 80	$125,000 - $175,000

54B	Catch basin inserts along High Crest Drive	See N.J.A.C. 7:8-5.7(d)2	\$5,000 - \$10,000
54C	Manufactured Treatment Device along High Crest Drive	See N.J.A.C. 7:8-5.7(d)2	\$500,000 - \$1,000,000
55A	Conversion of the sidewalk in front of Apshawa Elementary School to porous pavement	80	\$350,000 - \$450,000
55B	Retrofitted green roof at Apshawa Elementary School	60 - 80	\$1,500,000 - \$2,500,000
55C	Conversion of the north side of the parking lot at Apshawa Elementary School to porous pavement	80	\$300,000 - \$450,000
55D	Bioretention system at the north end of the Apshawa Elementary School parking lot	90	\$200,000 - \$350,000
56	Porous pavement conversion, gutter and leader installation, and planting beds at the High Crest Lake picnic area	80	\$40,000 - \$60,000
57	Shoreline buffer plantings along the shoulder of High Crest Drive, south of the beach	60 - 80	\$50,000 - \$65,000
Farm Crest Lake			
58	Shoreline buffer plantings along the southwest shoreline of the upper lake	60 - 80	\$30,000 - \$55,000
59	Bioswale along Doremus Road	60 - 80	\$75,000 - \$150,000
60	Rain garden or bioretention system at the intersection of Doremus Road, Crest Hill Drive, and Greendale Drive	60 - 90	\$75,000 - \$130,000
61	Shoreline buffer plantings along the northern shoreline of Farm Crest Lake	60 - 80	\$45,000 - \$70,000
Notes: 1. Site locations are shown on the above figures 2. Total suspended solids (TSS) removal efficiencies are based on the New Jersey Stormwater BMP Manual 3. The costs presented are approximate and subject to variability over time and the sizing of the BMP			

The cost estimates provided below are estimates for the entire project phase, including design, engineering, possible regulatory permitting, and implementation/installation (construction). While the cost estimates are predicted based on the entire project phase, final costs will vary based on many components that are involved in project design and implementation. Some of these components include, but are not limited to:

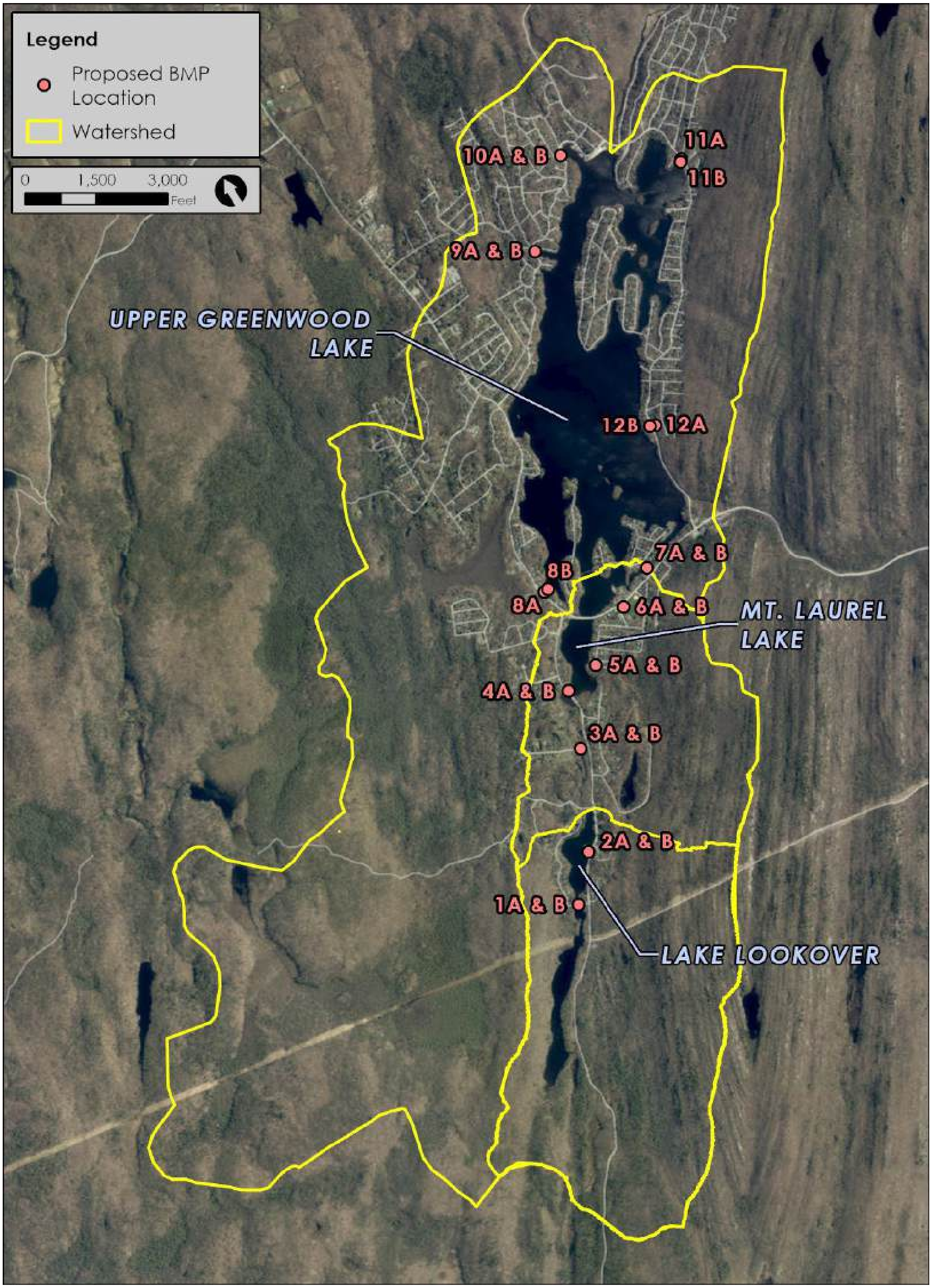
- **Site Investigations** – Part of the design process includes several different onsite investigation efforts including topographic survey, wetland delineation, and soils investigations. These investigations and the information gathered during them provide an understanding of the site conditions, any potential design challenges, and permitting pathways for the site.
    - **Depth to Bedrock** – The presence of shallow bedrock can result in implementation complications and a substantial increase in implementation costs.

- **Depth to Water Table** – The presence of a shallow water table may indicate the presence of a wetland and/or recharge area for groundwater. Thus, this can result in complications as well as an increase in permitting and implementation costs.
- **Utility Conflicts** – Location of sewer lines, gas lines, power lines, fiber optic lines all need to be located and mapped before any earth-moving or infrastructure work can be initiated. Without such information results could be extremely costly and even disastrous.
- **Permit Requirements** – Depending on the site features and its location relative to the lake and associated waterways, regulatory permitting can vary from none to minimal to substantial. Thus, the potential required permitting must be determined to quantify the total costs associated with the design phase. While general permitting costs were estimated in the proposed cost for each project, the fees can vary based on access, size of the overall project and project type which have not been determined at this phase. The costs do not include permits specific to the Highlands Region. Due to the location of lakes and their watersheds being in the protected Highlands Region, additional permitting may be required.

- **Access and Ownership** – Issues such as rights-of-way and easements need to be identified and agreements in place prior to the progression of the design. Additionally, the source of the funding for implementation may limit where a project can be implemented. For example, typically if a project is being funded through an NPS 319 grant, the project site typically must be located on public / community lands. Private land can be not used for a project site for such grant funding; however, private easements or access approval can be allowed.

- **Maintenance Requirements** – The key to the long-term effectiveness of any watershed / stormwater project is for it to be well maintained. This will include routine activities such as clean-outs and media replacements as well as non-routine activities such as repairs or additional work after particularly large storms. The party responsible for the maintenance of the project needs to be well established and that party needs to be well informed on the maintenance requirements and costs. Any shared services agreements need to be well established prior to the initiation of a project.

It should also be noted that due to the location of the sites in the Highlands Region, Highlands Act exemptions may be required for certain projects depending on the type of property. These potential Highlands Act exemptions were not considered during the creation of this document, and thus will need to be considered during the next phase of project development.


Legend
Proposed BMP Location
Watershed
0
1,500
3,000
Feet
UPPER GREENWOOD LAKE
MT. LAUREL LAKE
LAKE LOOKOVER
10A & B
11A
11B
9A & B
12B
12A
7A & B
8B
8A
6A & B
5A & B
4A & B
3A & B
2A & B
1A & B

8.1 LAKE LOOKOVER

Lake Lookover is located at the northern end of a small, almost entirely forested watershed. Forested land accounts for approximately 75% of the total watershed area and wetlands account for approximately 22%. There is only one main road, Clinton Road, that traverses the entire watershed in a north-south direction. Clinton Road abuts the eastern shoreline of Lake Lookover in the northern end of the watershed. Clinton Road connects with a smaller gravel residential road that wraps around the southern and western shorelines of the lake. The gravel road was heavily eroded in many locations during the site visit. The lake receives the majority of its inflow from Bearfort Waters, a long and narrow impoundment located directly south of Lake Lookover, separated only by an earthen dam and the gravel road at the southern end of the lake. There is a small beach and parking lot along the eastern shoreline of Lake Lookover while the western shoreline is mostly residential.

SITE 1: BROOKFIELD ROAD

Brookfield Road is a small gravel road at the southern end of Lake Lookover that separates the lake from the earthen dam associated with Bearfort Waters. Brookfield Road was heavily rutted and eroding during the site visit and numerous potholes where turbid water was pooling were observed. Active erosion is occurring on both sides of the outlet structure and at the toe of the grass embankment of the earthen dam. Runoff from Brookfield Road drains directly into the outlet structure along the southern edge of the road in absence of curbs, swales, or other stormwater structures to direct the surface flow to the outlet. Gravel, road grit, and other debris from Brookfield Road were accumulating on either side of the outlet structure, which itself drains directly to Lake Lookover. The northern side of Brookfield Road is located directly along the southern shoreline of the lake and lacks any vegetative buffer.


Photos 1-2. Erosion along Brookfield Road

Recommendation Site 1: The recommendation for this site is the installation of vegetated conveyance systems on both sides of the dam outlet structure to prevent further erosion of the gravel road and grass embankment (1A). The vegetated conveyance systems would be most effective directly adjacent to the outlet structure, as this is where the most extensive erosion was occurring and most of the pollutants were accumulating. They would extend to the east and west of the outlet structure along the grass embankment. Depending on site constraints related to the size of the road and modifying the grass embankment associated with the dam, it's also possible to install either curbs or rip-rap along the bottom of the grass embankment further away from the outlet structure that would prevent additional erosion along the grass embankment further up the road and could convey the runoff to the vegetated conveyance systems.

This site would also benefit from converting the gravel road to a paved road, thus greatly reducing the erosion from the surface of the road and contributing a major source of pollution in the form of TSS. This would reduce the overall pollutant load to Lake Lookover, even if the vegetated conveyance systems are installed, as well as reduce the amount of maintenance and cleaning of the vegetated conveyance systems, if installed. If the road is converted to pavement, the vegetated conveyance systems and curbs/rip-rap should still be installed as pavement would increase the stormwater flow rate on Brookfield Road, thus increasing the rate of erosion along the grass embankment if not protected.

A vegetated shoreline aquatic buffer (1B) should be installed on the northern side of Brookfield Road directly along the southern shoreline as an addition to any other practice suggested.

Cost Site 1A: The approximate cost for design, permitting, and implementation of approximately 200 linear feet of vegetated conveyance is estimated to be between $12,000 and $30,000.

Cost Site 1B: The approximate cost for design, permitting, and implementation of approximately 1,000 square feet of vegetated shoreline aquatic buffer planting is anticipated to be between $30,000 and $60,000.

SITE 2: BEACH PARKING LOT

There is a small asphalt parking lot with an approximate drainage area of 4,000 square feet, located just outside of the beach fence line and between the eastern shoreline of the lake and Clinton Road. Stormwater appears to drain away from the road and accumulates along the fence before draining towards the lake in both directions. Leaves and sediment were accumulating along the fence line and a few small puddles were present during the site visit. The lake is located within approximately 20 – 30 feet of the edge of the asphalt on either side. The shoreline here is poorly vegetated and exhibiting signs of minor erosion on both sides of the parking lot, likely a result of the sheet flow from the asphalt surface in the parking lot. Trees are present along the shoreline on either side but minimal understory vegetation which would reduce the volume and rate of stormwater flow and filter pollutants prior to reaching the lake.


Photos 3-4. Leaves and sediment accumulating along the beach parking lot fence line

Recommendation Site 2: The recommendation for this site includes the conversion of the back of the parking lot to a porous or vegetative paving strip. Additionally, the shoreline buffer on both sides of the parking lot should be enhanced with native, understory vegetation. The installation of a porous or vegetative paving strip would reduce the volume of stormwater that drains via surface flow to the lake, thus reducing bank erosion and resulting sediments entering the water. Coupled with planting of native, understory vegetation along these banks would further reduce erosion by ensuring that robust root systems hold the soil in place and other plant tissues perform evapotranspiration.

Cost Site 2A: The approximate cost for design, permitting, and implementation of approximately 1,000 square feet of porous pavement conversion is anticipated to be between $65,000 and $85,000.

Cost Site 2B The approximate cost for design, permitting, and implementation of approximately 1,000 square feet of enhanced shoreline buffer planting is anticipated to be between $30,000 and $55,000.

8.2 MT. LAUREL LAKE

Mt. Laurel Lake is located downstream of Lake Lookover to the north. Thus, the entire Lake Lookover watershed is located within the Mt. Laurel Lake watershed. Similar to Lake Lookover, the Mt. Laurel Lake watershed is mostly forested with a cluster of residential development around the shoreline of the lake. Forested land accounts for approximately 67% of the total watershed area, while wetlands account for approximately 21%. In addition to the residential development directly around the lake, there are a few additional residential streets to the south of the lake off of Clinton Road, the main road in the watershed. The lake receives the majority of its inflow from an unnamed tributary that discharges from the northern end of Lake Lookover and travels along the western side of Clinton Road.

SITE 3: CLINTON VIEW TERRACE CATCH BASIN

Clinton View Terrace is a cul-de-sac off of Clinton Road approximately halfway between Lake Lookover and Mt. Laurel Lake. The stormwater runoff from the road drains to the unnamed tributary via catch basins and subsurface pipes located on both sides of the road. The two terminal catch basins are located directly over the tributary on Clinton View Terrace. There is a small grass area with a telephone pole and other infrastructure along the western bank of the tributary, on the northern side of Clinton View Terrace.

Photos 5-6. View of the unnamed tributary on the northern side of Clinton View Terrace

Recommendation Site 3: The primary recommendation (Site 3A) for this site is the installation of a MTD with filter media, in line with the existing subsurface stormwater system that receives drainage from the stormwater conveyance systems on both sides of the road. Additionally (Site 3B), depending on site constraints related to the telephone pole, the open grass area located on the western bank of the tributary could potentially be converted into a rain garden or small bioretention area. This would receive surface runoff that would otherwise flow to one of the terminal catch basins located directly over the stream and would require a curb cut and regrading to achieve the necessary elevations. This GI practice would provide stormwater volume reduction, additional pollutant removal and be easily accessed for maintenance.

Cost Site 3A: The approximate cost for design, permitting, and implementation of an MTD is anticipated to be between $500,000 and $1,000,000 depending on size and depth.

Cost Site 3B: The approximate cost for design, permitting, and implementation of a rain garden or small bioretention area is between $10,000 and $25,000.

SITE 4: CLINTON ROAD INLET

There is a gravel pull-off area on the western shoreline of Mt. Laurel Lake, just north of the main inlet on Clinton Road. This site does not look like an official boat launch, but it may be being used as a launch for car-top boats. The gravel goes down to the water's edge and appears to be eroding into the lake in some locations. Just south of the gravel area, between the guard rail along Clinton Road and the shoreline of the lake, is a poorly vegetated strip of land that could be enhanced. It appears any runoff from that side of Clinton Road flows directly to the strip of land, towards the lake and the gravel area.

Photos 7-8: Gravel area along Clinton Road

Recommendation Site 4: If the gravel area (4A) is not being used as boat launch, or if there is another location that can be used for this purpose, the gravel area should be converted to a vegetated buffer. Additionally, the poorly vegetated strip that extends along Clinton Road to the south of the gravel area should be enhanced with native vegetation to create a functioning riparian buffer at the shoreline. The enhanced vegetation in this location would prevent gravel and other debris from washing directly into the lake from the busy, Clinton Road.

If the gravel area must remain as a hard surface for lake access, the gravel should be replaced with a more stable form of pervious material. Under this scenario (4B), it would be beneficial to still incorporate some form of GI to reduce the stormwater volume and flow. An enhanced vegetated buffer can still be planted along this section of the road, leaving only the smallest area of impervious surface that would be necessary for lake access.

Cost Site 4A: The approximate cost for design, permitting, and implementation of vegetated buffer is between $15,000 and $25,000.

Cost Site 4B: The approximate cost for design, permitting, and implementation of conversion to a stabilized porous surface is between $35,000 and $65,000.

SITE 5: COMMANCHE LANE AND SIDE STREETS

Commanche Lane has a series of catch basins that receive stormwater from the residential community along the northeast shoreline of Mt. Laurel Lake. During the site visit, the catch basins on Commanche Lane at the south end of the community were filled with leaves and other debris. The catch basins likely drain directly to Mt. Laurel Lake on the opposite side of the houses.

Photo 9: Catch basin on Commanche Drive

Recommendation Site 5: The catch basins should be periodically cleared out to maintain proper drainage. Failing to properly maintain the catch basins can dramatically slow or completely stop the passage of stormwater which can result in localized flooding issues. If the catch basins are properly cleared but are subject to an extensive amount of debris accumulation, simple catch-basin inserts can be installed to prevent the material from clogging the pipes or discharging directly into the lake (Site 5A). Catch basin inserts are effective in removing coarse debris, such as sediment, trash, and select liquids, like oil. However, inserts will not remove nutrients such as nitrogen or phosphorus efficiently. The catch-basin inserts also have a small capacity for pollutant accumulation, and thus need to be maintained on a regular basis for proper functionality.

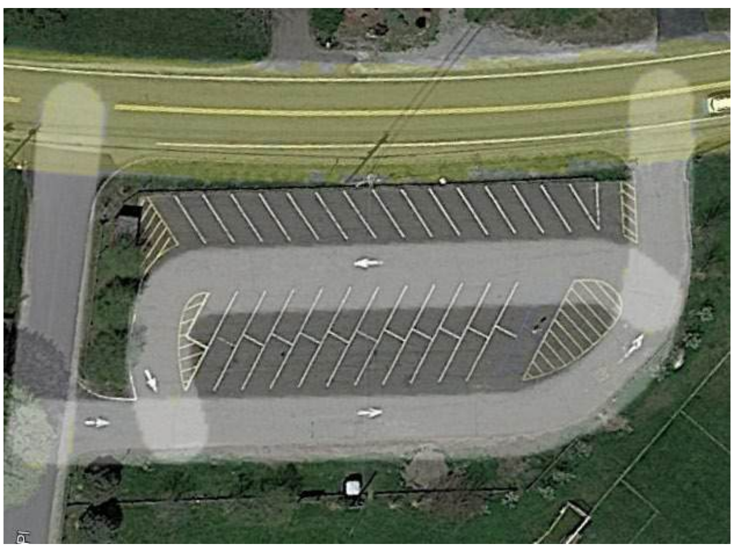
An alternative recommendation (Site 5B) involves the installation of a prefabricated, a decentralized bioretention system to supplement stormwater management in this section of the neighborhood. However, these devices would not eliminate the amount of sediment that is flowing into and accumulating in the catch basins from upstream and would need to be serviced periodically.

Cost Site 5A: The approximate cost for design, permitting, and implementation for catch basin inserts is between $5,000 and $10,000 depending on number of locations and type.

Cost Site 5B: The approximate cost for design, permitting, and implementation of prefabricated bioretention system is between $25,000 and $100,000 depending on size and depth.

SITE 6: MT. LAUREL PARK AND BALL FIELD PARKING LOT

There is an asphalt parking lot of approximately 19,000 square feet located on the corner of Warwick Turnpike and Tyler Place that is associated with the Mt. Laurel ball fields and park. There are no catch basins or other stormwater infrastructure located in the parking lot.




Photos 10-11: Mt. Laurel Park and ball field parking lot

Recommendation Site 6: The primary recommendation for this site involves decreasing the overall amount of impervious surface present, allowing for the infiltration of stormwater and the subsequent filtering out of pollutants from the system. This can be achieved in a variety of ways, including porous pavement (6A), vegetated pavers, or vegetated, depressed parking lot islands that function as bioretention areas (6B). The use of porous pavement in lieu of asphalt surface would not result in the loss of any parking spaces. Additionally, these measures would allow for increased infiltration of stormwater into the ground and the sequestration of pollutants.

Cost Site 6A: The approximate cost for design, permitting, and implementation of converting approximately half the parking lot to porous pavement is between $500,000 and $800,000.

Cost Site 6B: The approximate cost for design, permitting, and implementation of converting a portion of the parking lot bioretention areas is between $75,000 and $175,000 depending on size and depth.

8.3 UPPER GREENWOOD LAKE

Upper Greenwood Lake is located north of and downstream of Mt. Laurel Lake. Thus, the entire Mt. Laurel Lake watershed, which also includes the Lake Lookover watershed, is located within the Upper Greenwood Lake watershed. The lake receives the majority of its inflow from Mt. Laurel Lake. The two lakes are separated by a few small roads and/or bridges and it is likely that there is some mixing between the two lakes through the existing large culverts when the water level is at normal height.

Given the above, all of the watershed restoration measures for both of the above-named lakes would function to reduce the pollutant load to Upper Greenwood Lake. Although there is dense residential development around the shoreline of Upper Greenwood Lake, especially on the western shoreline, the watershed is mostly forested, accounting for approximately 57% of total watershed area while wetlands account for approximately 26%.

SITE 7: ISLAND TRAIL

A large culvert located under Island Trail, just off of Warwick Turnpike separates the southeast part of Upper Greenwood Lake from the eastern part of Lower Mt. Laurel Lake. The water feature at this location is narrow and resembles a canal. The water on both sides of the culvert was stagnant during the site visit in April 2022, with minor algal growth and a film across the surface. There are multiple catch basins on Island Trail and Warwick Turnpike that discharge directly into this side channel. Surface runoff from Island Trail also appears to drain directly into the side channel at multiple locations, resulting in extensive erosion of both the asphalt road edge above the culvert, as well as the banks of the channel directly adjacent to Island Trail. Erosion of the asphalt road edge was extensive on the eastern side and the pavement was becoming compromised. The bank of the channel adjacent to a section of concrete bulkhead on the southwest side of Spruce Point Trail was steep and poorly vegetated, resulting in additional erosion.


Photos 12-13. Erosion along both sides of Island Trail

Recommendation Site 7: The primary recommendation (Site 7A) for this site is the stabilization of the eroding banks of the channel on both sides of Island Trail, with an emphasis on the southwest and northeast portions. This would include the stabilization of the compromised portion of the asphalt road and the installation of curbs or a similar, simple stormwater conveyance system that would direct the surface flow to defined sections of the stabilized banks rather than over the middle of the channel where it's currently eroding.

A secondary recommendation (Site 7B) involves the installation of a MTD with filter media in line with the existing subsurface stormwater system currently receiving drainage from Island Trail and Warwick Turnpike. Additional investigation into the volume of water that passes through the stormwater system in this location would need to be conducted, but based on the size of the outlet pipe, it appears to be substantial. As noted above, the water in the channel is shallow and appears stagnant. Algae, including both surface filamentous algae and potentially harmful cyanobacteria, thrive in nutrient rich stagnant water. A MTD with filter media would reduce the accumulation of sediment in the channel thereby preventing further filling in and reduction in water depths. Additionally, an MTD reduces the amount of nutrients discharging into the lake by settling and sequestering the material inside the device, thereby reducing the available nutrients that feed algal growth.

Cost Site 7A: The approximate cost for design, permitting, and implementation of bank stabilization and installing a vegetated conveyance is between $7,500 and $15,000. Asphalt repair and/or installation of concrete curbing in lieu of vegetated conveyance is not included in the above estimate.

Cost Site 7B: The approximate cost for design, permitting, and implementation of an MTD is anticipated to be between $750,000 and $1,500,000 depending on size and depth.

SITE 8: GREENWOOD BAPTIST CHURCH

Greenwood Baptist Church is located on the eastern side of Warwick Turnpike, on the southwestern shoreline of Upper Greenwood Lake. There is a gravel parking lot measuring approximately 7,500 square feet adjacent to the church building. Portions of the parking lot appeared to be remnant asphalt indicating it may have been fully paved at one time. The gravel parking lot extends to the steep shoreline of the lake which has little vegetation other than a single row of trees. The parking lot was in poor condition at the time of the site visit with multiple large potholes that have formed as a result of traffic patterns and erosion from stormwater flows. Improving the management of stormwater and drainage throughout the parking lot would not only improve aesthetics, but also minimize loose gravel and sediment transportation to the lake during precipitation.


Photos 14-15. Gravel parking lot at the Greenwood Baptist Church

Recommendation Site 8: The first recommendation (Site 8A) for this site is the installation of a porous or vegetative paving system throughout the parking area. Introducing an option such as stabilized, permeable grass pavers would reduce pothole formation and standing water as well as infiltrating and slowing stormwater velocity as it flows to the lake either on or below grade. The presence of vegetation and stone subbase enables infiltration and allows for sediment settling and pollutant removal, which is especially important in parking areas where oils and other fluids drip onto the ground from vehicles. This option would preserve the number of and help delineate parking spaces within the existing lot. This approach can be combined with options given below or approached as a stand-alone project.

An additional option (Site 8B) to address drainage in the parking lot is the installation of a rain garden at the rear of the parking lot between the lot and the lake. Rain gardens and similar BMPs increase site resilience to the effects of climate change and provide enhanced visual aesthetics for properties. Given the space requirements, available parking space may be minimally reduced. Given the lot's location directly adjacent to the lake, new planting within the rain garden would also serve to enhance the existing, sparse riparian area and stabilize the bank soils.

Cost Site 8A: The approximate cost for design, permitting, and implementation of converting the entire parking lot to porous pavement is between $400,000 and $700,000.

Cost Site 8B: The approximate cost for design, permitting, and implementation of a rain garden or small bioretention area is between $40,000 and $70,000 depending on depth and the need for imported media.

SITE 9: NORTH LAKE SHORE DRIVE AND DOVER ROAD INLET

There is an area of open green space and a gravel pull-off located adjacent to a drainage stream that receives stormwater from a substantial portion of the surrounding neighborhood. Part of this area is designated as a fire lane and water draft site which may limit what, if any, modifications can be done in this location. There are overhead power lines along the side of North Lake Shore Drive which may present additional site constraints. The recommendations provided below assume there remains enough room between the stream and fire lane to incorporate GI. A large puddle was present between the grass and road during the site visit in

April 2022 indicating poor drainage. Additionally, loose gravel was present in this area which likely enters the lake during rainfall events. The stream was lacking sufficient vegetative buffer and the bank was eroding in one location. Greenwood Lake is located approximately 80 – 90 feet from North Lake Shore Drive, south of the stream, and the stream itself has a total length of approximately 80 – 100 linear feet.

Multiple BMP options are presented for this site since there will likely be considerable site constraints to consider. Depending on site constraints, these measures can be implemented independently or in conjunction with one another.

Photos 16-17. Open grass area between the stream and fire lane

Recommendation Site 9: The first recommendation (Site 9A) for this site is the implementation of a bioretention system in the open grass area between the drainage stream and the fire lane; this could also include a portion of the gravel area between the road and the grass. The creation of a bioretention system and minor regrading would create a sheet flow connection from the road, allowing for stormwater retention, infiltration and the sequestration of nutrients through native vegetation and soil media. A portion of the runoff from North Lake Shore Drive drains to a catch basin located directly across the street from the lake and then travels under the grass area via a small pipe that discharges into the drainage stream. Depending on site constraints and elevations, the subsurface pipe could be modified to discharge directly into the bioretention system. Further investigations would need to be conducted to determine the depth to groundwater given the proximity to the lake.

A second recommendation (Site 9B) that could be done independently or in addition to the bioretention system involves the enhancement of the stream riparian buffer through management of invasive plant species and planting new, native vegetation. The root structures of native plants will increase streambank integrity and reduce erosion caused by stormwater that discharges into the stream from the pipe off of North Lakeshore Drive. Rip rap could be added at the pipe outlet as an additional method of attenuating erosive flows.

Cost Site 9A: The approximate cost for design, permitting, and implementation of a bioretention area is between $50,000 and $125,000 depending on depth and size.

Cost Site 9B: The approximate cost for design, permitting, and implementation of an aquatic riparian buffer planting and invasive species treatment is between $12,500 and $25,000 depending on size and extent of treatment required.

SITE 10: NORTH LAKE SHORE DRIVE COVE

There are a series of catch basins on North Lake Shore Drive around the small cove at the northern end of the lake that receive stormwater runoff from the community north and west of the cove. The cove is lined with small docks for boat mooring but there is a large area of open green space between the cove and the road. The stormwater pipes from the catch basins travel under this grassy area before discharging directly into the lake. There are at least three main pipes that discharge into the cove at this location with two of the pipes in relatively close proximity to each other along the western half of the cove. Portions of the open space, including the shoreline,were in poor condition, with little grass and signs of compaction and erosion. Much of the shoreline was lacking a vegetative buffer aside from a few small trees.

Photos 18-19. Open space between North Lake Shore Drive and the northern cove

Recommendation Site 10: The first recommendation (Site 10A) for this site is the implementation of a bioretention system in the open grass area between North Lake Shore Drive and the lake. The system could consist of one large bioretention system that receives drainage from multiple catch basins, or the creation of multiple, smaller bioretention systems that each receive drainage from one catch basin. In addition to stormwater from the catch basins, a bioretention system could receive sheet flow from directly from the road that bypasses the catch basins, which likely occurs during heavy rain. Further investigation would need to be conducted to determine the contributing drainage areas and depth to groundwater given the close proximity to the lake to ensure proper design and sizing. A second recommendation (Site 10B) that could be considered independently or in addition to the bioretention system is the creation of a vegetated shoreline buffer through new native plantings. The root structures of these plants would strengthen the slopes and soils of the existing shoreline, reduce erosion and further limit sediment inputs into the lake.

Cost Site 10A: The approximate cost for design, permitting, and implementation of a bioretention area is between $90,000 and $175,000 depending on depth and size.

Cost Site 10B: The approximate cost for design, permitting, and implementation of an aquatic shoreline buffer planting and invasive species treatment is between $40,000 and $60,000.

SITE 11: PARKING LOT ON NORTH LAKESHORE DRIVE NEAR PAPSCOE ROAD

There is a small asphalt parking lot on the west side of North Lake Shore Drive, near the intersection with Papscoe Road, along the northeast shoreline of the lake. The lot is approximately 5,500 square feet and extends to North Lake Shore Drive, with no curbs or other separation between the lot and road. Based on the existing grades, the parking lot likely receives some stormwater runoff from the road. There is one catch basin in the southern corner of the parking lot which collects the majority of the runoff from the lot. There is a circular, concrete structure in the center of the parking lot with two manholes; however, it's function was not evident at time of observation, but should be confirmed prior to further design recommendations. A grass area between the parking lot and the lake that is approximately 3,300 square feet in area leads to the shoreline of the lake which is lined with large rocks and a large patch of the invasive *Phragmites australis* was observed growing along the entire length of shoreline.


Photos 20-21. Parking lot and grass area on North Lake Shore Drive

Recommendation Site 11: The first recommendation (Site 11A) for this site is the installation of a porous or vegetated paving system throughout the parking area. Introducing an option such as permeable grass pavers would aid in slowing stormwater runoff and giving it time to infiltrate before it reaches the lake via sheet flow or the catch basin outlet pipe. The gravel media and vegetation allow for infiltration of water into the ground where sediment settling and pollutant removal would occur.

A second recommendation (Site 11B) involves removing some or all of the compacted lawn and replacing it with native meadow vegetation that has deeper root systems to increase natural soil drainage and filter additional stormwater of sediments and select pollutants. This type of planting strategy will also help reduce the presence of geese on the site and thereby reduce the additional nitrogen source created by their droppings.

Cost Site 11A: The approximate cost for design, permitting, and implementation of converting the entire parking lot to porous pavement is between $250,000 and $450,000 depending on type and depth of storage zone.

Cost Site 11B: The approximate cost for design, permitting, and implementation of an aquatic shoreline buffer planting and invasive species treatment is between $30,000 and $55,000.

SITE 12: LIVING WORD ALLIANCE CHURCH

Living Word Alliance Church is located on the southeastern shoreline of Upper Greenwood Lake on North Lake Shore Drive. The church is located directly along the water and a larger asphalt parking lot (14,000 square feet) associated with the church is located directly across North Lake Shore Drive. There is a catch basin in the center of the large parking lot that appears to receive stormwater from the entire parking lot, though at the time of visiting, there was a large puddle around the structure following a rain event the previous night. The parking lot also appears to receive additional stormwater runoff from a portion of North Lake Shore Drive due south of the parking lot. Across the street, there is a strip of grass and a small shrub bed located between the front of the church and the uncurbed road. Leaders from the church roof discharge directly onto the grass area where signs of erosion and sodden grass were present.

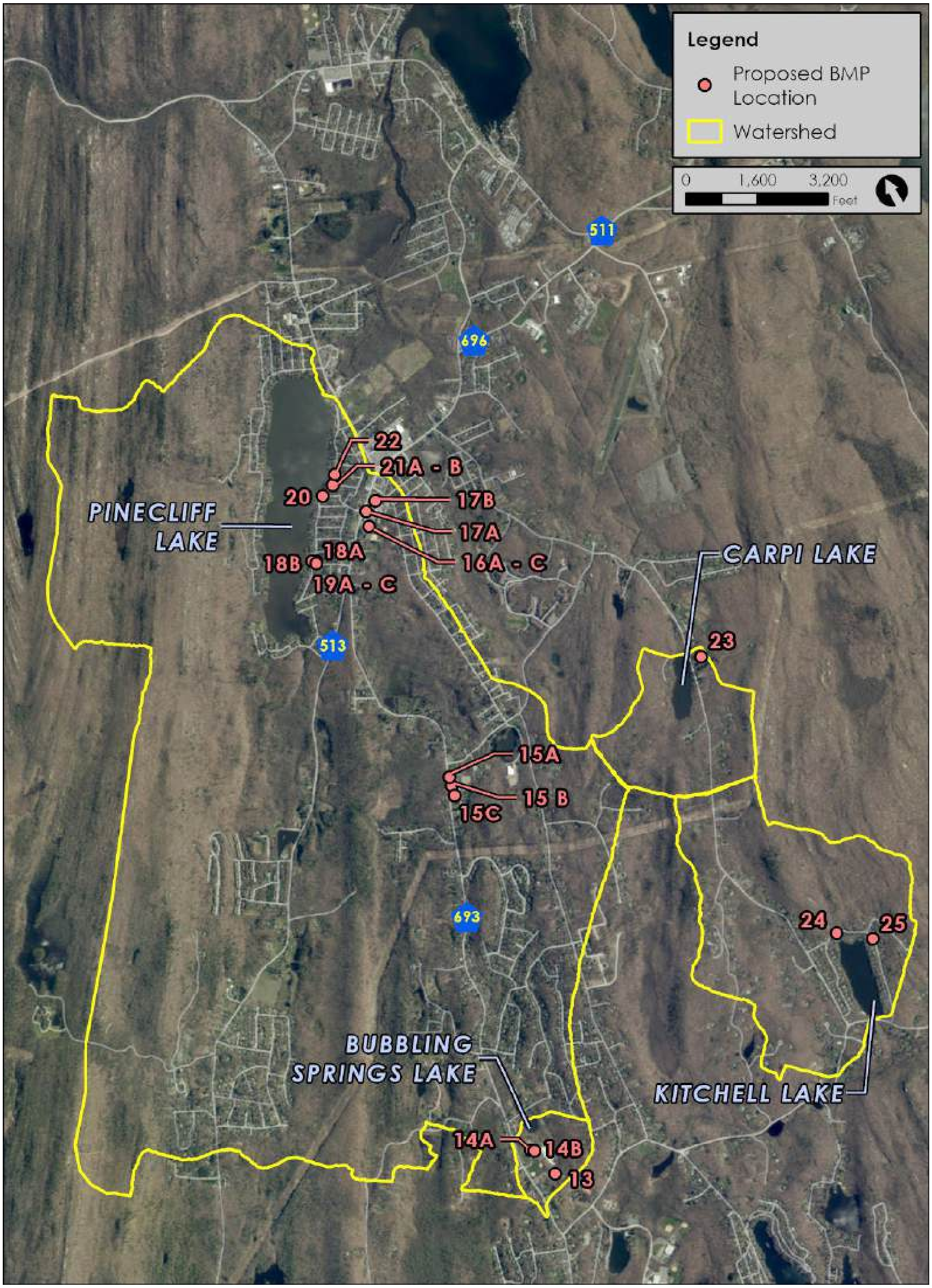

Photos 22-23. Living Word Alliance Church parking lot and front lawn

Recommendation Site 12: The first recommendation (Site 12A) for this site is the conversion of the asphalt surface to a porous or vegetated paving system in the large parking lot. Reducing the volume of runoff from this lot will also reduce the transportation of debris, sediments and nutrients that get carried into the system during rainfall events which are likely contributing to the clogging of the existing catch basin.

The second recommendation (Site 12B) for this site is the creation of at least two small-scale rain gardens or downspout planters in front of the church that receive runoff from the two leaders that drain the roof. The native vegetation and enhanced soil media in these systems would infiltrate stormwater into the void spaces and trap sediments and/or nutrients before they can enter runoff and eventually the lake.

Cost Site 12A: The approximate cost for design, permitting, and implementation of converting half of the parking lot to porous pavement is between $500,000 and $800,000 depending on type and depth of storage zone.

Cost Site 12B: The approximate cost for design, permitting, and implementation of downspout planters is between $5,000 and $15,000.


Legend
Proposed BMP Location
Watershed
0 1,600 3,200
Feet
511
696
513
693
PINECLIFF LAKE
CARPI LAKE
BUBBLING SPRINGS LAKE
KITCHELL LAKE
22
21A - B
20
17B
17A
16A - C
18B
18A
19A - C
23
15A
15 B
15C
24
25
14A
14B
13

8.4 BUBBLING SPRINGS LAKE

Bubbling Springs Lake is a small waterbody in Bubbling Springs Park. The lake is located at the northern end of a small, mostly forested watershed. Macopin Road runs through the western side of the watershed and there are a few residential properties along it that are included in the watershed. The rest of the watershed is located mainly within Bubbling Springs Park, which includes asphalt parking lots, ball fields, an open grass area, and a swimming pond that is open to the public during the summer months. The park is used as a day camp during the summer months. There is an access road and an open bare soil area just south of the swimming pond where trees have been cleared. This area was flooded and exhibiting signs of severe erosion at the time of the site visit on 8 April 2022. Drainage leaving the swimming pond flows north to the main body of Bubbling Springs Lake. The swimming pond water level was lowered by approximately 10 feet during the site visit.

SITE 13: OPEN AREA SOUTH OF THE SWIMMING POND

The open area south of the swimming pond in Bubbling Springs Park that was flooded and severely eroding includes a gravel access road and a large bare soil and leaf litter-filled area where trees had recently been cleared. Based on observations, this area may have been used for camp-related activities. Water was ponding across the gravel road at the southern end of the park from a recent rain. The elevation drops approximately 30 feet between the back road and the swimming pond, including a steep decline immediately between the road and the bare soil area, which had resulted in the formation of multiple gullies leading to the swimming pond. The drainage continued to travel the gravel road and eventually split into two gullies just upstream of the swimming pond. Water was also observed ponding around the southern and western shorelines of the swimming pond and slowly flowing into the pond at two locations. This resulted in further erosion of the pond bed which was exposed from maintenance drainage at the time of the site visit. The small volume of water that was accumulated in the swimming pond was discolored and stagnant.

Photos 24-27: Flooding and erosion in Bubbling Springs Park

Recommendation Site 13: A more detailed investigation into the hydrology of this section of the park will need to be conducted before any specific restoration measures are provided. More specifically, it will need to be known where the main source of the road flooding originates and if this is a typical occurrence following rain events. However, the erosion observed during the site visit was significant and is likely leading to impaired water quality in both the swimming pond and the main Bubbling Springs Lake just downstream of the swimming pond. The erosion that was occurring along the pond bed was exacerbated by the low water level.

Without detailed information on the hydrology and the specific uses of this section of the park, only a general recommendation can be made. This location would benefit from any action that stabilizes the bare soils that were previously being held at least partially in place by trees that were removed. A broad recommendation (Site 13A) for the eroded gullies is a stabilized conveyance system that may include pools and steps, given the grade of the site; this could be similar to a regenerative stormwater conveyance system. Such a system would be beneficial in addressing the gullying by creating a properly sized and textured path to attenuate energy and direct the runoff while filtering out sediments. This would also include the planting of native trees, shrubs, grasses, and perennial vegetation throughout the site, in addition to any conveyance system, to help stabilize the soil and prevent additional erosion.

Cost Site 13: The approximate cost for design, permitting, and implementation of the potential recommendations is between $200,000 and $600,000 depending on the level and length of restoration required based on hydrological analysis.

SITE 14: BUBBLING SPRINGS PARKING LOT

A large asphalt parking lot in Bubbling Springs Park, located northwest of the swimming pond and south of Bubbling Springs Lake is drained by catch basins located in the northwest, southwest and northeast corners of the and the northern two appear to drain directly into the lake. The catch basin in the northwest corner of the parking lot is adjacent to an open grass area, with the outlet pipe travelling under the grassed area to the lake. A visual investigation of this catch basin from the surface shows the inlet pipe located approximately three feet below the pavement surface and the outlet pipe is approximately six feet below the pavement surface. Note that these depths are estimates and no actual measurements were made during the initial site visit. This catch basin had a significant flow passing through it as observed at time of visit, however, at the upstream catch basin, no flow was seen. Given the observed condition, it is possible that there is groundwater influence or the lower catch basin is receiving additional flow from another structure located away from the parking lot.

Photos 28-29. Catch basin in the northwest corner of the parking lot

Recommendation Site 14: The primary recommendation (Site 14A) for this site is the creation of an in line bioretention system in the grass area located just down gradient of the northern catch basins. This would involve the modification of the outlet pipe that currently travels under the grass area so that it discharges into the BMP. The bioretention area would allow for the temporary holding, infiltration and then slow release of treated stormwater back into the ground and/or system via an outlet structure. The resulting filtration of pollutants and decrease in overall stormwater volume to the waterbody will provide an increase in water quality in the lake. The deep positioning of the outlet pipe under the pavement could be a constraint with regard to this recommendation and would necessitate a more detailed study of the elevations and required BMP sizing. An alternative recommendation (Site XB) is a pavement conversion from the existing asphalt to a porous pavement along the northern half of the parking lot. These management measures could also be done in conjunction with one another to create redundancies in the system and capture the maximum volume of runoff from the parking lot, thereby significantly reducing pressure on the system low flow and storm events.

Cost Site 14A: The approximate cost for design, permitting, and implementation of a bioretention area is between $95,000 and $190,000 depending on depth, size, and ability to connect to the existing pipe.

Cost Site 14B: The approximate cost for design, permitting, and implementation of converting about 9,000 square feet of the parking lot to porous pavement is between $500,000 and $1,000,000 depending on type and depth of storage zone.

8.5 PINECLIFF LAKE

Pinecliff Lake is located at the northern end of a relatively large watershed. Bubbling Springs Lake is located within the much larger Pinecliff Lake watershed, in the far southeast corner. Though the Bubbling Springs Lake watershed is small and relatively far from Pinecliff Lake, the watershed restoration measures for Bubbling Springs Lake would also have positive impacts on Pinecliff Lake. Although there is much residential development adjacent to the shoreline of Pinecliff Lake and along Union Valley Road and Macopin Road, the two main roads, the watershed is mostly forested. The lake receives the majority of its inflow from Belcher Creek to the south, although there are many smaller contributing sources, both natural and stormwater runoff-generated, that discharge into the lake around the shoreline.

SITE 15: WEST MILFORD DEPARTMENT OF TRANSPORTATION BUILDING

The West Milford Department of Transportation (DOT) building is located on the northbound side of Macopin Road. There is a large open grass area in front of the building that separates parking from the building and extends to Macopin Road. There are smaller grassed areas around the building as well. A series of connected catch basins on both sides of Macopin Road, directly in front of the large grass, area appear to drain stormwater from approximately half of the asphalt parking lot located to the south of the building, as well as a large portion of stormwater runoff from the building roof and the entire paved drive in front of the building. Another series of connected catch basins on Macopin Road just north of the building property, in addition to the ones described above appear to drain to a small tributary of Belcher Creek in the forested area across Macopin Road from the DOT building and property.

Photos 30-31. Stormwater drainage in front of the West Milford DOT building

Recommendation Site 15: The primary recommendation for this site (Site 15A) is the creation of bioretention systems in the two open grass areas separating the road from the parking area and drive in front of the DOT building. The proposed practice would divert as much stormwater as possible from the building, parking lots, and potentially the road, into the bioretention systems. Removing or reducing the contributing sediments and nutrients from the building and surrounding pavements will increase water quality and reduce peak flows into Belcher Creek. An additional recommendation (Site 15B) that can be done separately or in conjunction with bioretention system(s) involves the conversion of strategic areas throughout the parking lot to porous pavement.

Cost Site 15A: The approximate cost for design, permitting, and implementation of a bioretention area is between $235,000 and $300,000 depending on depth, size, and ability to connect to the existing pipe.

Cost Site 15B: The approximate cost for design, permitting, and implementation of converting about 5,000 square feet of the parking lot to porous pavement is between $300,000 and $500,000 depending on type and depth of storage zone.

SITE 16: WEST MILFORD PRESBYTERIAN CHURCH

The West Milford Presbyterian Church is located south of the West Milford Police Department building and Township library on Union Valley Road. There is a large asphalt parking lot behind the church with multiple catch basins that appear to all drain to Union Valley Road. The terminal catch basin located near the entrance to Union Valley Road is large and the asphalt was cracked and settling around the structure. It is assumed based on visual observations that runoff from the parking lot flows through this catch basin before discharging to a pipe on Union Valley Road. One of the smaller catch basins in the eastern corner of the parking lot near the field was completely filled in with sediment and leaves.

Photos 32-33. West Milford Presbyterian Church parking lot

Recommendation Site 16: The primary recommendation for this site involves interrupting the amount of impervious surface present and increasing infiltration and sequestration of pollutants. This can be achieved in a variety of ways, including conversion of portions of the lot to porous pavement or vegetated pavers (16A), creation of vegetated, depressed parking lot islands (16B), and/or prefabricated treatment devices (16C) that include planting components. Initiating one or a combination of these efforts will reduce the load on the stormwater drainage system allowing for on-site treatment and infiltration and this reducing harmful inputs that ultimately find their way into tributaries to the lake. Regarding the lot in whole or in part would be necessary for on-site solutions.

Cost Site 16A: The approximate cost for design, permitting, and implementation of converting approximately one third of the parking lot to porous pavement is between $800,000 and $1,200,000.

Cost Site 16B: The approximate cost for design, permitting, and implementation of converting a portion of the parking lot bioretention areas is between $60,000 and $110,000 depending on size and depth.

Cost Site 16C: The approximate cost for design, permitting, and implementation of prefabricated bioretention systems is between $50,000 and $100,000 depending on size, depth and quantity required.

SITE 17: WEST MILFORD POLICE BUILDING AND PARKING LOT

The West Milford Police Department building is located on the south side of Union Valley Road. The building is surrounded by a large asphalt shared, municipal parking lot, and several large, curbed grass areas between the parking lot and Union Valley Road. There is a curbside catch basin in the western corner of the parking lot that appears to drain a large portion of the parking lot on the southeast side of the building. This catch basin appears to drain to the next downstream structure on Union Valley Road via a pipe that travels under the grass area between the building and the street. Note that the existing retention basin that is adjacent to the lot appears to receive drainage from the library and associated parking lots to the west and no connection to the police lot was observed at the time of site visit.

Photos 34-35. Parking lot and grass area in front of the Police Department building

Recommendation Site 17: The primary recommendation (Site 17A) for this site is the creation of a bioretention system or other GI practice in the open grass area between the parking lot and Union Valley Road. However, a more detailed investigation into the specifications of the subsurface pipe that travels under the grass area would need to be conducted to determine if a GI practice would be possible here. A second option (Site 17B) if a bioretention practice is not feasible involves the conversion of strategic locations throughout the parking lot to a porous pavement. An unsecured area of dumped aggregates and building materials was noted on a steep slope in the southwest area of the lot. Thes appear to be surplus cobbles, broken asphalt and smaller items that have the potential to pulverize and be washed into the runoff stream as non-point source pollution. It is recommended to secure this area with silt fence for storage or move the materials to a less vulnerable location.

Cost Site 17A: The approximate cost for design, permitting, and implementation of a bioretention area is between $75,000 and $130,000 depending on depth, size, and ability to connect to the existing pipe.

Cost Site 17B: The approximate cost for design, permitting, and implementation of converting about 5,000 square feet of the parking lot to porous pavement is between $300,000 and $500,000 depending on type and depth of storage zone.

SITE 18A: DRAINAGE STREAM EAST OF PINECLIFF LAKE DRIVE

A large drainage stream passes through residential properties east of Pinecliff Lake Drive, between Willow Lane and Park Lane, before passing through a culvert under Pinecliff Lake Drive. Both streambanks were eroding significantly and did not appear to contain much vegetation with the exception of some small trees. Some of these trees had exposed roots from the extensive bank scour and will likely topple if the erosion continues to undermine the root structures. There was a low flow in the stream channel during the site visit in April 2022, but judging by the extensive erosion and the size of the streambanks, this stream likely has significant flow during and following storm events. Finally, there were a few sections of remnant concrete pipe encountered along the streambed.


Photos 36-37. Extensive streambank erosion in the unnamed tributary that passes under Pinecliff Lake Drive

Recommendation Site 18A: The recommendation at this site is the removal of the remnant pipe sections and the stabilization of the eroding streambanks. The stabilization measures will vary depending on the height and slope of the bank, the cause of the erosion, and the flow rates through the reach. Reducing the amount of sediment unnecessary erosion should be prioritized. Further investigation is necessary to determine the extent of the stabilization required.

Cost Site 18A: The approximate cost for design, permitting, and implementation of streambank stabilization measures on 200 linear feet of stream is between $100,000 and $300,000 depending on access, density and the assumption that the existing channel is a candidate for simple stabilization measures within the existing banks.

SITE 18B; CHANNELIZED DRAINAGE STREAM WEST OF PINECLIFF LAKE DRIVE

The drainage stream from Site XA flows through a culvert under Pinecliff Lake Drive and then discharges into a smaller, partly channelized stream, west of Pinecliff Lake Drive. It was difficult to assess the condition of this stream from the road, but it appears a pipe is buried under the sediment and rock which then discharges into the partly channelized stream approximately 25 feet from Pinecliff Lake Drive. The current function of the extensive sediment and rock that has built up in the first 25 feet of stream is not known at this time. A large volume of sediment had also accumulated in the road along the guard rail above the stream, which is likely a result of the poor stormwater drainage in the general area. There were no curbs or swales to direct stormwater flow on the streets and many of the catch basins were filled in with sediment, road grit and organic material.


Photos 38-39. Drainage stream west of Pinecliff Lake Drive

Recommendation Site 18B: It appears that the pipe is undersized; however, additional hydrologic and hydraulic evaluations need to be conducted to determine the most appropriate recommendation for this site. Possible recommendations following the additional evaluations could include the installation of a larger culvert, overtopping protections, enlargement of the upstream side, or a combination of these recommendations.

A general recommendation for this section of the neighborhood involves the creation of curbs or swales along the streets to help better direct stormwater and to prevent the erosion of residential lawns. Additionally, the catch basins should be cleared out periodically, as many were observed to be compromised in function due to being clogged or filled in with material.

Cost Site 18B: The approximate cost for design, permitting, and implementation of the potential recommendations is between $400,000 and $900,000 depending on the level and length of restoration required based on hydrological analysis.

SITE 19: CORNER OF PINECLIFF LAKE DRIVE AND PARK LANE

The site is on the corner of Pinecliff Lake Drive and Park Lane, just south of the drainage stream from Site XA. An existing catch basin was observed to be experiencing flowing water for hours after a rain event that morning, indicating it likely receives stormwater drainage from a relatively large tributary area. There is an open, grassed space between the catch basin and the adjacent drainage stream; however, there are also overhead power lines and utility poles present which may pose a constraint on restoration opportunities. Similar to other areas in this neighborhood, the transition area between the road and the lawn was lacking a curb and was a source of sediment caused by erosion from stormwater flows. It is not currently known if this land is private or municipal.

Photos 40-41. Catch basin on the corner of Pinecliff Lake Drive and Park Lane

Recommendation Site 19: Potential restoration measures for this site are dependent on site constraints regarding the overhead powerlines and the land ownership of the green space. The first recommendation (Site 19A) is daylighting the pipe on Park Lane that drains to the catch basin further up the road and creating a bioretention basin across the open green space that outlets into the drainage stream. This restoration measure would be the most complex practice and would require additional investigation to determine the feasibility.

A second option (Site 19B) would be to daylight the same pipe on Park Lane, but create a bioswale along the edge of the green space where it meets the road that drains to the catch basin on the corner. Both the option above and this option decrease the erosive forces of the overland stormwater flow that is currently affecting the grass area. Both options would also allow for increased infiltration of stormwater and the sequestration of nutrients and pollutants before discharging into Pinecliff Lake.

A third option (Site 19C) is the installation of a designed and/or prefabricated stormwater planter along the side of the road. Additional information on stormwater planters is provided at the end of this section of the report.

Cost Site 19A: The approximate cost for design, permitting, and implementation of a bioretention system is between $85,000 and $150,000 depending on depth, size and ability to connect to the existing pipe.

Cost Site 19B: The approximate cost for design, permitting, and implementation of a bioswale is between $55,000 and $150,000 depending on depth, size and the need for curbing.

Cost Site 19C: The approximate cost for design, permitting, and implementation of a designed and/or prefabricated stormwater planter is between $50,000 and $125,000 depending on size, depth and quantity required.

SITE 20: CORNER OF VISTA ROAD AND PINECLIFF LAKE DRIVE

At the intersection of Pinecliff Lake Drive and Vista Road, a catch basin near the intersection was observed to be filled to capacity with sediment, road grit, and organic matter during the site visit in April 2022. A puddle was forming around the grate and a large volume of sediment was accumulating in the road in this location. This catch basin appears to drain directly to Pinecliff Lake through a subsurface pipe that travels under an open grass patch between two houses on Pinecliff Lake Drive. Further investigation into the ownership or easement status of this piece of land would need to be conducted to determine possible BMP interventions.

Photos 42-43. Filled in catch basin and open grass area on Pinecliff Lake Drive

Recommendation Site 20: The recommendation for this site is dependent on ownership of the land, as well as potential interference from overhead power lines or general size restrictions within the area. Regardless, the discharge pipe that drains the catch basin and travels under the grass area could be daylighted and converted to a bioswale. This would allow for increased infiltration of stormwater and the sequestration of pollutants before discharging into Pinecliff Lake. In addition to general catch basin maintenance, the source of sediments in the road should be identified and general measures taken to eliminate the incidence purposeful or accidental spillage of materials into the roadway.

Cost Site 20: The approximate cost for design, permitting, and implementation of a bioswale is between $85,000 and $150,000 depending on depth, size and the need for curbing.

SITE 21: CORNER OF SYLVAN WAY AND PINCELIFF LAKE DRIVE

The intersection of Sylvan Way and Pinecliff Lake Drive was observed to be partially flooded at the time of the site visit in April 2022. The catch basin at the corner was filled with sediment, road grit, and other organic. Larger rocks and gravel were also accumulating over the catch basin. The site visit occurred the day after a rain event and this type of condition was observed in multiple locations in this neighborhood on the eastern shoreline of Pinecliff Lake, this site being the most severe. One of the contributing factors is a lack of curbs or similar stormwater conveyance measures along many roads in the neighborhood. As a result, stormwater is eroding the edges of lawns and creating small gullies, and the eroded sediment is filling in the catch basins and other components of the drainage system in this area.

Photos 44-45. Flooding around a filled in catch basin on the corner of Sylvan Way and Pinecliff Lake Drive

Recommendation Site 21: The primary recommendation for this site (Site 21A) is addressing the cause of negative inputs at the source by preventing the erosion of the lawns throughout the neighborhood. The installation of roadside curbs will divert and direct stormwater flow to the catch basins while eliminating contact with and erosion from the edge of the lawns. A superior option, although requiring more space, is the design and construction of vegetated conveyances along the sides of the roads to collect, direct and filter stormwater on its way to the catch basins. If the above options are not feasible, or in the sediment load is determined to be too heavy for such measures, an MTD (Site 21B) with filter media can be installed in-line with the current stormwater system. The MTD would allow for the settling of particulate matter at the bottom of the device and releasing peak stormwater flows slowly either into the ground or back into the drainage system. This approach reduces the strain on the existing system during heavy rains. While MTD's have greater storage capacities, they, like catch basins, must be cleaned out periodically to maintain proper functionality.

Cost Site 21A: The approximate cost for design, permitting, and implementation of approximately 1,000 linear feet of vegetated conveyance is between $50,000 and $80,000. This estimate only includes a sample of 1,000 linear feet of the practice while the recommendation applies to many areas within the neighborhood. The cost of concrete curbing is not included in this estimate.

Cost Site 21B: The approximate cost for design, permitting, and implementation of an MTD is anticipated to be between $500,000 and $1,000,000 depending on size and depth.

SITE 22: CORNER OF ARCATA LANE AND PINECLIFF LAKE DRIVE

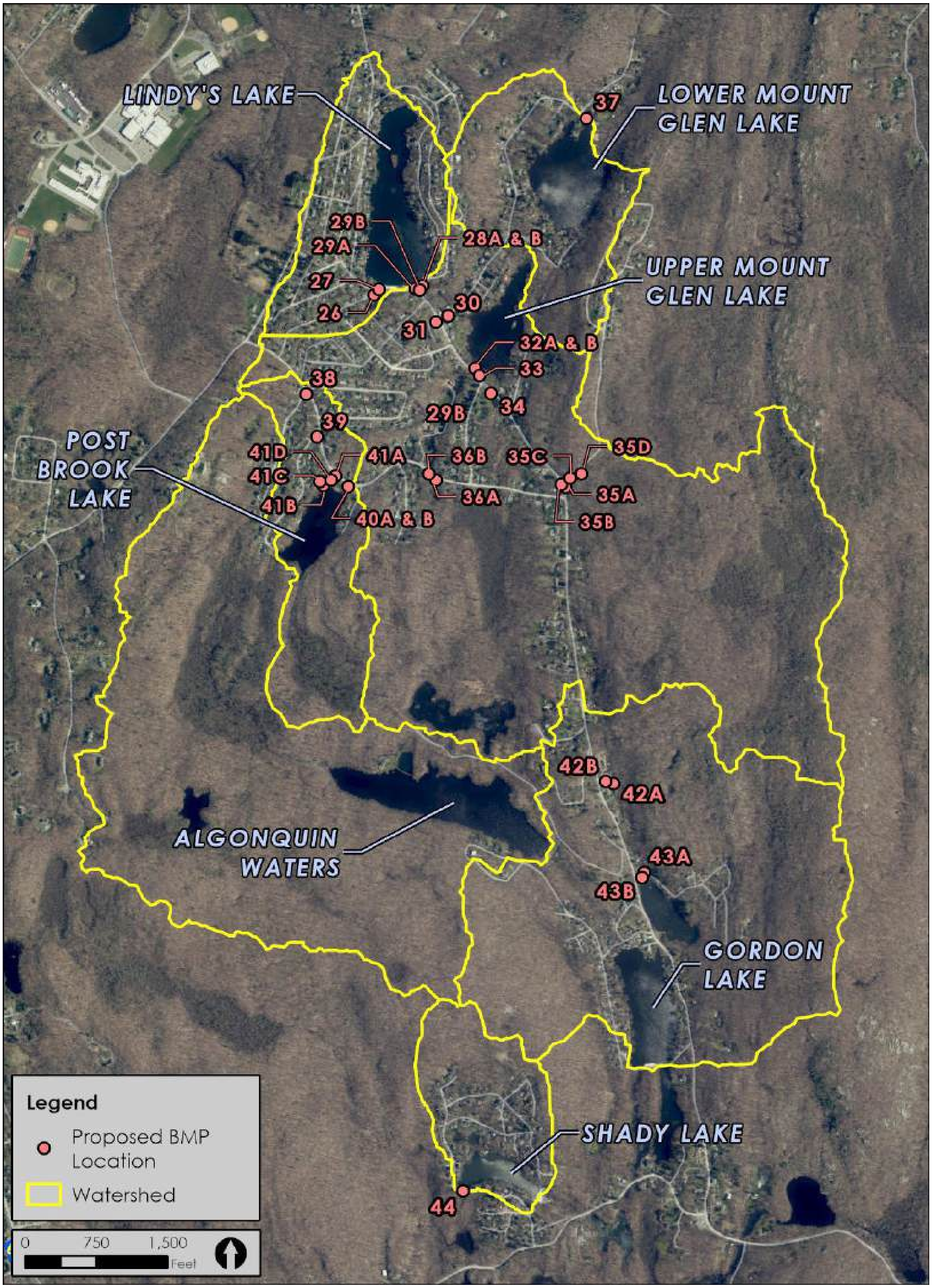
Similar to many of the catch basins in this neighborhood, the catch basin on the corner of Pinecliff Lake Drive and Arcata Lane was filled to capacity with sediment, road grit, and other organic matter as observed on the April 2022 site visit. Less water was pooling around this catch basin than at other locations, but there was a small puddle and the inlet was barely visible under the accumulated sediment. The majority of the stormwater draining here comes from Arcata Lane which has a r steep incline. The road drops approximately 40 feet in elevation over a distance of approximately 575 feet from the start of the road to the catch basin on Pinecliff Lake Drive, meaning that stormwater flows downhill at faster speeds with increased erosive force. There are no curbs in the immediate vicinity of the catch basin on Arcata Lane or Pinecliff Lake Drive. The steep incline and lack of curbs are resulting in erosion of the front lawns on Arcata Lane. The property on Arcata Lane immediately adjacent to the catch basin was showing signs of extensive erosion and a small gully had formed between the road and grass.


Photos 46-47. Filled in catch basin and erosion along Arcata Lane

Recommendation Site 22: The recommendation for this site is the same as the recommendation for the catch basin on Pinecliff Lake Drive and Sylvan Way- the design and construction of curbs or vegetated swales to convey the stormwater without causing extensive erosion. Arcata Lane and Sylvan Way are both steep roads which results in increased flow velocities of stormwater runoff, making it a high priority for implementing effective stormwater control measures to decrease the rate of erosion and the associated infilling of catch basins.

As a general recommendation for this entire neighborhood, the catch basins require scheduled clean outs to prevent localized flooding and the accumulation of sediment and other pollutants on the roads. These actions should be undertaken in compliance with any updated MS4 permit requirements applicable to the Township.

Cost Site 22: The approximate cost for design, permitting, and implementation of approximately 1,000 linear feet of vegetated conveyance is between $50,000 and $80,000. This estimate only includes a sample of 1,000 linear feet of the practice while the recommendation applies to many areas within the neighborhood. The cost of concrete curbing is not included in this estimate.


LINDY'S LAKE
LOWER MOUNT GLEN LAKE
37
29B
29A
28A & B
27
26
UPPER MOUNT GLEN LAKE
30
31
32A & B
33
38
34
29B
39
POST BROOK LAKE
41D
41A
36B
35C
35D
41C
41B
36A
35A
40A & B
35B
42B
42A
ALGONQUIN WATERS
43A
43B
GORDON LAKE
SHADY LAKE
44
Legend
Proposed BMP Location
Watershed
0
750
1,500
Feet

8.6 CARPI LAKE

Carpi Lake is located at the northern end of a small, mostly forested watershed. Forested land accounts for approximately 88% of the total watershed while wetlands account for another 12%; developed land accounts for less than 1% of watershed area. The lake is not hydraulically connected to any of the other study lakes included in this project. The lake's largest inlet appears to be at the southern end, with a few other small inlets around the lake. The entire northern and western shorelines are located on private property to which access was not granted for physical observation. The eastern shoreline abuts the busy Morsetown Road towards the northern end of the lake but is separated from the road by a forested area towards the southern end of the eastern shoreline. Due to the multiple constraints, no specific restoration sites were identified from the limited accessible area during the site assessment in April 2022.

SITE 23: PARKING LOT EAST OF MORSETOWN ROAD

An aerial review of the watershed on Google Earth reveals a restaurant parking lot east of Morsetown Road. The site was not physically observed, but appears to be one of the only impervious surfaces in the watershed that is not a road or a private residence.

Photo 48. Impervious parking lot

Recommendation Site 23: A portion of the green area west of the parking lot can be converted into a rain garden that would receive stormwater drainage from the parking lot. This would allow for increased infiltration and sequestration of pollutants before discharging to Carpi Lake.

Cost Site 23: The approximate cost for design, permitting, and implementation of a rain garden or small bioretention area is between $40,000 and $70,000.

8.7 KITCHELL LAKE

Kitchell Lake is located at the southern end of a small, mostly forested watershed. Forested land accounts for approximately 84% of watershed area while wetlands account for another 5%. The watershed begins just south of the Carpi Lake watershed; however, the two watersheds are located on opposite sides of a ridge and thus are not hydraulically connected. Morsetown Road spans the entire watershed, directly in the middle, in addition to a few smaller residential roads, including a road that wraps around the entire lake. There are residential properties around the entire lake except for the southern end. There is a beach area in the southeast corner and the dam and spillway are located at the southern end of the lake.

SITE 24: KITCHELL LAKE DRIVE STREAM CROSSING

A stream that drains approximately 46 acres of mostly forested land flows under Kitchell Lake Drive at the northern end of the lake. The receiving stream south of the road is low-lying with minimal streambank height, and the flow likely spreads out on either side of the observed channel during periods of heavy flow. The stream then discharges into a small pond, which drains to another small stream that discharges into Kitchell Lake. The receiving stream and pond south of Kitchell Lake Drive are located on what is assumed to be a residential property.



Photos 49-50. Stream north of Kitchell Lake Drive (left) and receiving stream and pond (right)

Recommendation Site 24: Proposed design for this site will be dependent on property ownership of the land around the stream and pond south of Kitchell Lake Drive. The primary recommendation is enhancement of the riparian and shoreline buffer around the stream and pond, respectively. Native, flood-tolerant vegetation along the banks and shoreline would stabilize the soils thereby reducing erosion and providing a buffer for sediment and nutrients entering and being transported by the stream into the lake.

Cost Site 24: The approximate cost for design, permitting, and implementation of a riparian buffer planting is between $40,000 and $70,000 depending on density and access.

SITE 25: STREAM CROSSING ON KITCHELL LAKE DRIVE EAST

Another small stream that drains approximately 77 acres of mostly forested land flows under Kitchell Lake Drive East at the northeastern end of the lake. There are no curbs on this section of the road and the shoulders are either small rocks or compacted, bare soil with sparse or no grass. The shoulder areas that are not rock are showing signs of erosion from stormwater runoff. There is a concrete apron directly over the stream on the west side of the road that conveys stormwater from the road directly into the stream.

Photos 51-52. Stream crossing on the west side of Kitchell Lake Drive East

Recommendation Site 25: This upstream side of the road would benefit from stabilizing and increasing the bank height to minimize overtopping. The runoff from the dirt shoulder appears to be a major contributor to erosion requires stabilization via installation of a stone or vegetated shoulder, if velocities allow, that then empties into a reconfigured upstream forebay area. The compacted bare soil areas of the shoulder, as well as the banks of the stream, can be amended and planted (with condition-adapted native vegetation to reduce stormwater-generated erosion and provide a buffer from sediment and nutrients entering the stream.

Also necessary for successful mitigation of negative impacts at this site would be to remove the concrete apron over the stream in lieu of a culvert, regrade the banks at the inflow and outflow and provide vegetated cover and/or stone that will resist erosion. Detailed hydrologic and hydraulic calculations would be necessary to optimize the culvert and determine the amount of free board required. An inlet box or boxes and upgraded headwall may serve to reduce the failure of the existing shoulder.

Cost Site 25: The approximate cost for design, permitting, and implementation of the above recommendations including shoulder and bank stabilization as well as culvert and inlets is anticipated to be between $250,000 and $500,000.

RESIDENTIAL STORMWATER MANAGEMENT

Due to the high volume of residential development throughout the small watershed, there is little to no room for GI on municipal land. As such, watershed management will primarily be enacted in the form of small-scale practices on individual lots. These measures include rain barrels, rain gardens, directing gutter downspouts away from impervious surfaces, small filter strips and grass swales, and vegetated pavers, among others. More information on these small-scale general stormwater management measures can be found at the end of this section.

8.8 LINDY'S LAKE

Lindy's Lake is located in a very small watershed comprised of mostly residential development. Residential land accounts for approximately 94% of the total watershed area. The lake does not appear to have any major inlets; thus, any watershed restoration efforts will focus on stormwater management in the residential community surrounding the lake. The outlet is located at the southeastern end of the lake where it discharges under Lindy's Drive and empties into Upper Mount Glen Lake, a short distance away. Given the small size of the watershed and the abundance of residential development, GI potential on municipal property will likely be limited.

SITE 26: WOODSIDE STREET AND OTTERHOLE ROAD

The intersection at Woodside Street and Otterhole Road located to the southwest from the beach entrance at Lindy's Lake, sits at the bottom of a slope draining runoff from the roads in the residential area uphill and southwest of the intersection. The asphalt on Woodside Street is in poor condition and leaf litter and sediment accumulate at the edges of pavement as well as at the two inlets at the bottom of the slope. No curbs or formal ditches exist on Woodside Street and ponding water was visible along the edges of pavement. The two inlets at the bottom of the slope appear to cross under Otterhole Road to drain toward the lake. At least one residence has an earthen area just off the edge of pavement being used for parking, otherwise there appears to be no on-street parking allowed on Woodside Street.

Photos 53-54. Inlet at east side (left) of Woodside Street and inlet at west(right) side looking at Lindy's Beach entry gate to the north

Recommendation Site 26: The primary recommendation for this site is to install curbs and porous pavement in three- to four-foot-wide bands along the road edges to collect, direct, and filter runoff from the road while trapping leaf litter and sediment before they reach the storm inlets. The narrow width of the road is particularly restrictive to other BMP options. Required vehicular access to a large residential driveway at the mouth of the intersection creates a challenge to altering the geometry of the intersection for additional GI interventions (e.g. bump-outs or neck-downs). It is also recommended that the existing pavement be repaired and/or maintained to better direct water into the proposed conveyances. There are approximately 1,000 linear feet on each side of the road, from the catch basin inlets at the top of the slope to the intersection, that could be converted to porous pavement.

Cost Site 26: The estimated cost for design, permitting and construction of the proposed BMP for approximately 8,000 square feet of porous pavement conversion is between $500,000 and $800,000.

SITE 27: ASPHALT APRON ON OTTERHOLE ROAD

There is a small asphalt apron at the entrance to the beach area located along Otterhole Road. There is currently a small curb along the apron that directs most stormwater towards the catch basin.

Photos 55-56. Asphalt apron and the approximate drainage area along Otterhole Road

Recommendation Site 27: The asphalt apron can be replaced with a strip of vegetated or porous pavement and the low curb could be removed to allow for the stormwater from the street to infiltrate into the porous material rather than flow directly to the catch basin. A low curb may be required between the pavers and the beach to keep stormwater from migrating onto the sand area via sheet flow.

Cost Site 27: The estimated cost for design, permitting and construction of the proposed BMP for approximately 100 square feet of porous pavement conversion is between $7,500 and $12,000.

RESIDENTIAL STORMWATER MANAGEMENT

Due to the high volume of residential development throughout the small watershed, there is little to no room for GI on municipal land. As such, watershed management will have to come through the form of small-scale practices on individual lots. These measures include rain barrels, rain gardens, directing gutter downspouts away from impervious surfaces, small filter strips and grass swales, vegetative pavers, among others. More information on these small-scale general stormwater management measures can be found at the end of this section.

8.9 UPPER MOUNT GLEN LAKE

Upper Mount Glen Lake is located at the northern end of a large watershed relative to the size of the lake. The lake is located to the east and downstream of Lindy's Lake. The two lakes are only separated by approximately 700 feet, thus, any watershed restoration efforts in the Lindy's Lake watershed will reduce the pollutant load to Upper Mount Glen Lake as well. Forested land accounts for approximately 46% of the total watershed area while residential land accounts for approximately 35% and wetlands account for approximately 15%. The eastern shoreline of the lake is mostly forested, with a few houses clustered at the southern end, while the western shoreline is mostly residential. A small inlet from Lindy's Lake passes through residential properties on the southwest shoreline before discharging into the lake. The main tributary of Upper Mount Glen Lake empties into the southeastern end of the lake, just north of Otterhole Road. A smaller inlet enters the lake slightly to the west of the main inlet, also just north of Otterhole Road.

SITE 28: MAILBOX AREA PARKING LOT ON LINDY'S DRIVE AT OTTERHOLE ROAD

The asphalt parking area located at the top of bank from the outlet from Lindy's Lake has deteriorating pavement which is a source of particulates and small sediments that become mobilized into the tributary stream as it drains Lindy's Lake and connects into Upper Mount Glen Lake in the watershed immediately below. The parking lot looks to primarily be used for short term parking for mail pickup and delivery. A poorly vegetated strip of land between the back of the parking lot and the steep, but previously stabilized slope down to the outlet, receives trash and accumulated sediment and debris that gets washed downslope in rain events. This slope contains some invasive plant species. Additional runoff with sediment load flows back onto Lindy's Drive to get picked up by a catch basin inlet to on the southwest corner of the intersection with Otterhole Road.

Photos 57-58. Asphalt parking area just below Lindy's Lake outlet (left) and edge of pavement condition at east edge of lot overlooking stream channel below outlet

Recommendation Site 28: Appropriate BMPs for this site include converting the existing impervious asphalt pavement to either a vegetated paver with a geogrid underlayment for increased loading capacity or porous concrete to reduce runoff, filter sediment and potentially provide infiltration back into the ground. Due to the amount of in and out traffic and variation in grades, unit pavers are not recommended. Removal of invasive plant species and replanting with deeply-rooted native plants to act as a buffer, filter sediment and provide evapotranspiration. Planting and pavement conversion together will protect slope stability and water quality entering the system via the outlet stream and/or the catch basin inlet.

Cost Site 28A: The estimated cost for design, permitting and construction of the proposed BMP for the approximately 1400 square feet of porous pavement conversion is between $90,000 and $130,000.

Cost Site 28B: The estimated cost for design, permitting and construction of the proposed BMP for the approximately 1200 square feet of vegetated filter strip is between $ 25,000 and $45,000.

SITE 29: CATCH BASIN ON OTTERHOLE ROAD

There is a curbside catch basin near the Otterhole Road and Lindy's Drive intersection. The catch basin receives drainage from the stretch of Otterhole Road along the southern end of Lindy's Lake and discharges directly to the outlet stream that drains from Lindy's Lake. There is also an open patch of grass approximately 1,200 square feet across the street from the catch basin, directly between where the two roads connect and the outlet stream. The subsurface outlet pipe from the catch basin likely travels directly under or immediately adjacent to the grass area.

Photos 59-60. Catch basin on Otterhole Road and the grass area adjacent to the stream

Recommendation Site 29: The recommendation (Site 29A) for this site is the installation of a MTD with filter media in line with the existing subsurface stormwater system, sited down-gradient of the catch basin. The lake inlet that this catch basin drains to is transporting a significant amount of sediment to Upper Mount Glen Lake, and all BMPs for reducing this load should be considered.

Additionally (Site 29B), depending on site constraints, the grass area on the corner of Otterhole Road and Lindy's Drive could be converted to a bioretention system that receives surface drainage from the road and potentially from the MTD. The MTD would provide pre-treatment for sediment, nutrients, and oils and the bioretention system would significantly slow down the flow rate to the receiving inlet stream by allowing for the detention and infiltration of stormwater into the ground. Both practices provide filtration of pollutants and the settling out of solids from the water. The receiving stream has a steep pitch and is known to be a significant source of sediment to Upper Mount Glen Lake. Additional investigation into the current depth of the outflow pipe from the catch basin would be required to determine feasibility and parameters for incorporating the manufactured treatment outflow into the bioretention system.

Cost Site 29A: The approximate cost for design, permitting, and implementation of an MTD is anticipated to be between $500,000 and $1,000,000 depending on size and depth.

Cost Site 29B: The approximate cost for design, permitting, and implementation of a bioretention system is between $85,000 and $150,000 depending on depth, size and site complexity.

SITE 30: OUTLET FROM LINDY'S LAKE ON BROADWAY AT OTTERHOLE ROAD

The outlet from Lindy's Lake passes through numerous residential properties and drops approximately 50 feet in elevation from Lindy's Drive down to street level at Broadway near the intersection with Otterhole Road. The stream segment upstream of Broadway is channelized and narrow with a few stepped pools as it drops in elevation. The stream then passes, piped, under Broadway and remains underground, passing through a 20'-wide easement between two residential properties before discharging into Upper Mount Glen Lake. There is an access chamber with surface grate located in the lawn within the easement. According to a resident and evidence from aerial imagery, this inlet has deposited a significant amount of sediment over time, so much so that the adjacent landowners have begun to utilize the new land formed as a result.


Photos 61-62. Stepped outlet channel from Lindy's Lake (left) Clean out for piped portion of conveyance between two homes (right)

Aerial view of deposited sediment in
Upper Mount Glen Lake

Recommendation Site 30: A more detailed investigation into the source of the sediment should be conducted before a specific recommendation is provided. Dredging is an option to remove the sediment that has already accumulated in the lake. However, the source of the sediment must first be identified and addressed before NJDEP would approve a dredging permit. It is believed that streambank erosion along the steep inlet from Lindy's Lake is the primary source of the sediment. A detailed survey of the inlet stream, which would likely require access from private properties, is recommended as the first step in addressing the source of sedimentation to the lake.

Cost Site 30: The estimated cost for additional evaluation of the source of sediment is estimated to be between $5,000 and $15,000.

SITE 31: OPEN FIELD ON THE CORNER OF OTTERHOLE ROAD AND POOL DRIVE

An open lawn area exists on the corner of Otterhole Road and Pool Drive, adjacent to a catch basin located on Otterhole Road. The catch basin is in the middle of a steep section of road and receives drainage from the northwest. Stormwater discharges to the next catch basin down slope via a subsurface pipe located to the southeast along Otterhole Road. Given the steep grade, stormwater likely flows down the hill at a fast rate, causing erosion closer to the lake. Pool Drive is a small residential road that wraps around the grass field and is also relatively steep, dropping in elevation towards Otterhole Road. Through speaking with a local resident during the site visit, it was stated that the grass field is associated with a residential property. While this would make any restoration measures unachievable without the support of the landowner, a recommendation is still provided.


Photos 63-64. Catch basin on Otterhole Road and the open grass field

Recommendation Site 31: The primary recommendation for this site is the installation of a bioretention system or rain garden in the open grass field. A small system could be designed to receive sheet flow from both Otterhole Road and Pool Drive. Some regrading and excavation to increase and direct the amount of sheet flow that drains to the system would be required in addition to a new inlet and outlet/overflow structure to return the reduced overall volume of water, treated, to the piped system.

Cost Site 31: The approximate cost for design, permitting, and implementation of a bioretention system is between $75,000 and $150,000 depending on depth, size, and site complexity.

SITE 32: LAKE SHORE ON OTTERHOLE ROAD BETWEEN SANDERS COURT AND MOUNTAINSIDE ROAD

The small portion of shoreline on the east side of Otterhole Road has an open view of the lake with a small, paved area, flagpole and picnic table. The site has a few cedar trees nearer to the road and the ground plane is compacted lawn to the water's edge. Fine sediment and road grit can be seen at least 10 feet into the lawn from the edge of road pavement and litter and leaf debris were observed in the water near the shoreline.

Photos 65-66. Compacted grass with pavers and flagpole (left) and visible sediment from road migrating into the lawn (right)

Recommendation Site 32: Low growing native plant material can be installed at this site, both at the edge of pavement (32A) in a bioswale (32B) to infiltrate and filter runoff from the road, as well as in a riparian buffer at the water's edge. The shoreline buffer planting will reduce the amount of sediment and debris from entering the lake while maintaining the view and open area for seating. Removing lawn at the water's edge and replacing with more robustly-rooted shrubs and grasses has been proven to discourage geese from coming onto lawn areas from the water by reducing the ease of access. Planting at the shoreline will also provide habitat for birds and insects in addition to preventing shoreline erosion while installing a bioswale will discourage parking withing the drip line of the existing trees, thereby extending their life expectancy.

Cost Site 32A: The estimated cost for design, permitting and construction of the proposed BMP's for approximately 1,850 square feet of bioswale is estimated to be between $ 90,000 and $165,000.

Cost Site 32B: The estimated cost for design, permitting and construction of the proposed BMP's for approximately 150 square feet of riparian shoreline buffer planting is estimated to be between $7,500 and $12,000 depending on density and access.

SITE 33: MOWED GRASS STRIP ALONG OTTERHOLE ROAD

The strip of mowed grass along the north side of Otterhole Road located between the two southern inlets has no curbs, and stormwater likely flows across the grass during rain events. Based on the elevation of the road and the direction the grass was folded, it is believed that runoff from this section of the road flows along the northern side of Otterhole Road, along the grass strip and into the inlet located directly between Sanders Court and Mountainside Road. A small amount of sediment and road grit were accumulating along the side of the road in this location.


Photos 67-68. Strip of mowed grass along Otterhole Road

Recommendation Site 33: The strip of mowed grass can be converted into a vegetated swale that receives sheet flow from Otterhole Road. This practice would allow for increased infiltration, the sequestration of nutrients and other pollutants, and the settling and removal of solids from the water. This practice would directly improve the water quality in the stormwater runoff that is treated, as well as reducing flow rate into the drainage stream, erosion in the path of flow and further reduction in overall pollutant load.

Cost Site 33: The estimated cost for design, permitting and construction of the proposed BMP's for approximately 120 linear feet of vegetated conveyance is estimated to be between $7,000 and $20,000.

SITE 34: HEADWALL AT IMPOUNDENT ON OTTERHOLE ROAD SOUTHEAST OF SANDERS COURT

The road shoulder along the west side of Otterhole Road is receiving and transporting sediment in the form of road grit and fine sediment, into the channel that flows from the small impoundment to the west via a culvert under the road and into Upper Mount Glen Lake. The existing curbing upslope of the headwall directs flows to the flatter, wider area of pavement at the foot of the wall. Here, sediment is deposited and concentrates around the wall leading to the scour condition seen in the photos below. During heavy flow events, it is expected that a larger amount of the accumulated sediment is mobilized and transported into the channel.


Photos 69-70. Erosion at culvert headwall and impoundment bank (left) and accumulation of sediment upstream of scour condition on west side of Otterhole Road

Recommendation Site 34: The asphalt curbing that exists upslope from the headwall could be replaced with a vegetated conveyance with check dams or other hard attenuation features, to slow down sheet flow, trap mobilized particulates and reduce overall volume reaching the headwall. This practice could be combined with a cobble swale at the base of the headwall creating a rough surface in lieu of the smooth asphalt shoulder to trap mobilized sediments before they reach the lawn at the south end of the wall. The cobble swale can then be easily accessed for cleaning and removing accumulated material. To realize these practices, the existing fence and curb would likely need to be moved back and required clearance to the top of the culvert verified with regard to constructability of a cobble swale. Assuming one or both components are installed, repairing the erosion at the end of the headwall can be achieved by placing larger stone and native grasses with robust root systems to hold soil in place against any remaining flow in lieu of the existing, shallowly rooted lawn.

Cost Site 34: The estimated cost for design, permitting and construction of the proposed BMPs for the approximately 550 linear feet of vegetated conveyance and 50 linear feet of cobble swale is between $ 35,000 to $55,000.

SITE 35: STREAM SEGMENT AT OTTERHOLE ROAD AND LARSEN ROAD

This site is a stream segment that flows from the west, under Otterhole Road and continues along the east side of the road before turning northeast into the Norvin Green State Forest woodlands. The stream receives drainage inputs from both Larsen Road and Otterhole Roads via sheet flow and various discharge pipes that empty directly into the channel.

35A: The banks of the stream on Otterhole Road are very close to the road and are minimally vegetated. The banks of the stream that are on the forested side look to be in relatively good health and show less evidence of erosion than the banks adjacent the road.

35B: A headwall on the west side of Otterhole Road at the culvert collects leaf litter, sediment and debris that in heavy rain events, are mobilized into the channel. An inlet upslope of the headwall on Otterhole Road outfalls into the channel and erosion of the stream bank is present here, but is primarily on private, residential property. There is an unpaved residential driveway apron just upslope of this inlet that contributes loose organic material to the accumulation that washes into the inlet.

35C: The upslope verges on the north and south sides of Larsen Road have little substantial vegetation and leaf litter, sediments and manmade debris collect at the edges of pavement, producing a potential source of nutrient loading into the stream.

35D: Finally, an asphalt paved parking lot that serves the state forest trailhead about 360 feet east of the intersection also drains onto Larsen Road and its associated inlets.

Photos 71-72. Discharge pipe from inlets up slope draining into stream (Left) Headwall and inlet on west side of Otterhole Road with debris and erosive banks and erosion at banks on residential properties

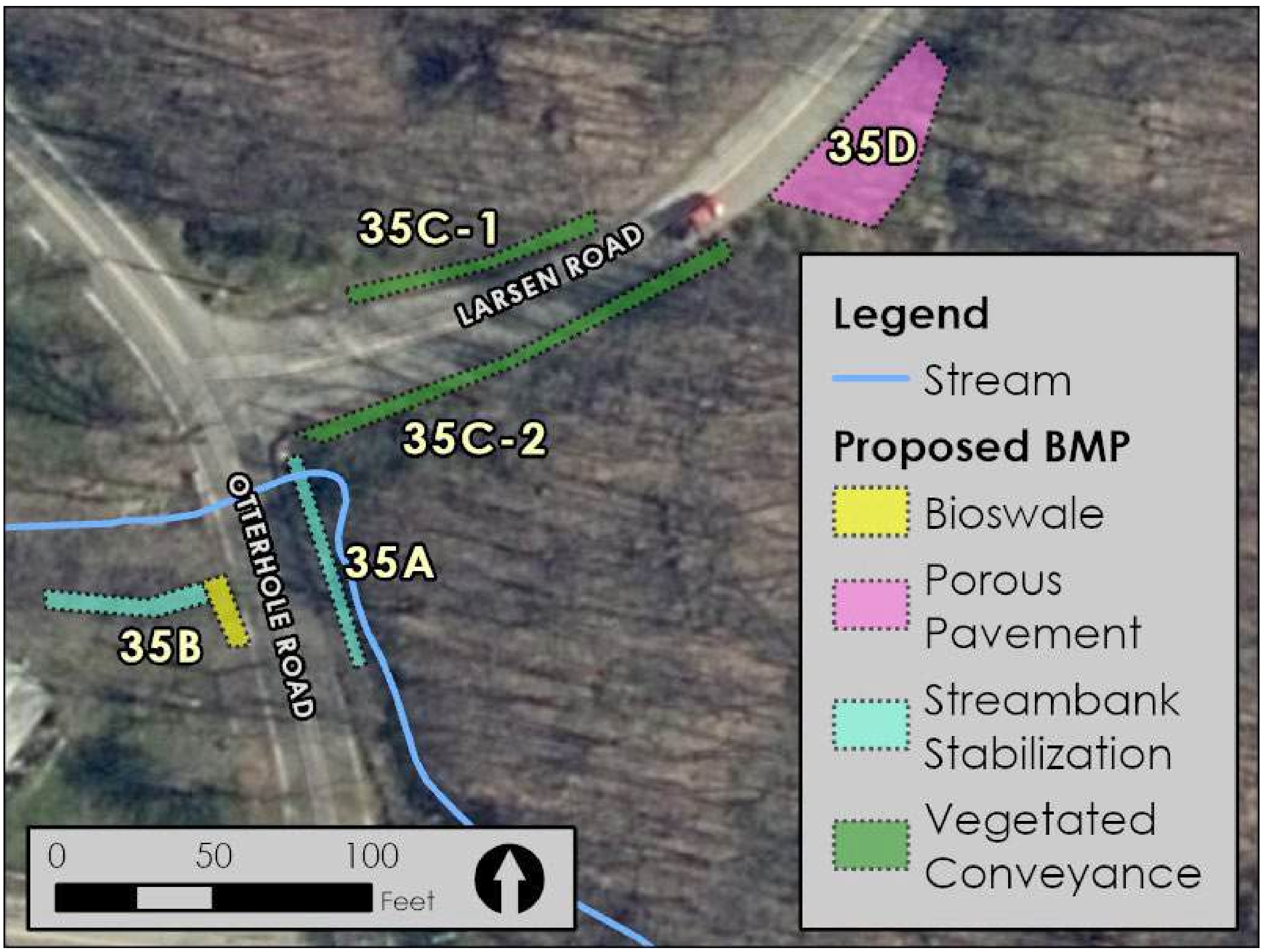
Recommendation Site 35: A series of practices at targeted sub-locations that affect this stream are recommended to reduce sediment loading and redirect or absorb stormwater runoff.

35A: Streambank stabilization measures can be incorporated along the road-adjacent bank along Otterhhole Road to support the steep and potentially erosive conditions. This would include planting with native vegetation and other materials to hold soil in place.

35B: Address the erosion of the road on the south side of Otterhole Road by installing a bioswale above the inlet and headwall, but below the residential driveway, to collect and sequester stormwater flows and sediment prior to reaching these areas and discharging into the stream. Streambank stabilization measures including native plantings and erosion control fabric (jute mesh) are recommended at the banks just upstream of the headwall to ensure those banks and existing trees remain intact and do not further erode. Further study of the stream would likely be needed to confirm the extent of the bank stabilization measures needed.

35C: To mitigate the sediment contributions of the east and west sides of Larsen Road, vegetated conveyances are recommended to filter runoff as it is conveyed downslope and into the stream or inlets. These conveyances will also act as a buffer to sequester leaf litter from entering the drainage way and potentially blocking inlet grates.

35D: The state forest parking area for the trail head could be converted to porous pavement or vegetated paver system to both reduce sediment that leaves the site and infiltrate precipitation. These practices would reduce the load on the piped storm drainage network and protect the stream from unnecessary runoff from the parking area which can contain multiple non-point source pollutants which play a major role in contributing to the impairment of stream health.



Aerial view of proposed management measures

Cost Site 35: The estimated cost for design, permitting and construction of the proposed BMPs for the above practices is estimated separately to allow for selection of practice and/or phased work as follows:

35A: The approximate cost for design, permitting, and implementation of streambank stabilization measures on 100 linear feet of stream is between $20,000 and $45,000 depending on access, density and the assumption that the existing channel is a candidate for simple stabilization measures within the existing banks.

35B: The approximate cost for design, permitting, and implementation of streambank stabilization measures on 700 linear feet of stream and the creation of approximately 750 square feet of bioswale is between $170,000 and $260,000 depending on access, density and the assumption that the existing channel is a candidate for simple stabilization measures within the existing banks.

35C: The estimated cost for design, permitting and construction of the proposed BMPs for the approximately 450 linear feet of vegetated conveyance is between $ 35,000 to $60,000.

35D: The estimated cost for design, permitting and construction of the proposed BMP for the approximately 2,500 square feet of porous pavement conversion is between $150,000 and $250,000.

SITE 36: PARKING AREA ON SCHOFIELD ROAD

There is a gravel and bare soil parking area on the south side of Schofield Road that was in poor condition at the time of the site visit, with small potholes and signs of erosion, including loose gravel near the road, evident throughout. There was also a large pile of loose sediment, gravel, and road grit at the back of the parking area, possibly accumulated over time when plows are operating during the winter. There is a small stream located approximately 75 feet from the edge of the parking area to the west that flows under Schofield Road and discharges into a small impoundment on the property across the street.

Photos 73-74. Parking area on Schofield Road and the approximate drainage path to the stream

Recommendation Site 36: The primary recommendation (Site 36A) involves the conversion of the parking area to a porous or vegetated pavement system to prevent the erosion of the area and to increase infiltration. A second recommendation (Site 36B) that could be done separately, or in conjunction with the first recommendation, is the installation of a vegetated swale along the road between the parking area and the receiving stream. Based on a review of the elevation of the surrounding area, the flow path appears to be in this general direction. If a potential porous paving system were designed with an underdrain rather than designed to infiltrate into the subsoil, the outlet structure could discharge into the vegetated swale that then drains directly into the receiving stream. Additional site investigation would need to be conducted to determine the feasibility of both recommendations. If the porous pavement is not feasible due to site constraints, a trench drain can be installed at the edge of the parking lot that captures drainage from the lot and discharges into the vegetated conveyance.

Cost Site 36A: The estimated cost for design, permitting and construction of the proposed BMP for the approximately 2,700 square feet of porous pavement conversion is between $150,000 and $300,000.

Cost Site 36B: The estimated cost for design, permitting and construction of the proposed BMPs for the approximately 70 linear feet of vegetated conveyance is between $ 10,000 to $15,000.

8.10 LOWER MOUNT GLEN LAKE

Lower Mount Glen Lake is located at the northern end of a large watershed relative to the size of the lake. The lake is located to the north and downstream of Upper Mount Glen Lake. Thus, the Lindy's Lake and Upper Mount Glen watersheds are nested within the Lower Mount Glen Lake watershed. Any watershed restoration measures in either of those subwatersheds will reduce the overall pollutant load to Lower Mount Glen Lake. The Lower Mount Glen subwatershed is mostly forested but has residential development around the southern and western shorelines of the lake. Forested land accounts for approximately 45% of the total watershed area while residential land accounts for approximately 35% and wetlands account for approximately 14%.

SITE 37: MOUNT GLEN LAKES PARKING AREA AND ACCESS

The paved and gravel parking area outside the gate to the private beach drains runoff to an inlet inside the gated beach area that discharges to a pipe below the outlet of the lake. However, based on visible drainage patterns observed on the ground, during heavy rain events, some runoff will also drain directly into Lower Mountain Glen Lake, carrying with it sand, vegetation and sediment from the road and lot.

Photos 75-76. Paved and gravel parking lot (left) and drainage path within the beach area (right)

Recommendation Site 37: The recommendation for this site is a pavement conversion from asphalt and loose gravel to a vegetated paver or stabilized gravel parking area to infiltrate runoff and reduce the amount of water that would make it into the lake. While there are additional benefits to reducing the volume of discharge and sediment entering below the dam and being transported to the next watershed, the proposed improvements at this site would mostly be realized outside of the Lower Mountain Glen Lake watershed itself.

Cost Site 37: The estimated cost for design, permitting and construction of the proposed BMP for the approximately 2,700 square feet of porous pavement conversion is between $150,000 and $300,000.

8.11 POST BROOK LAKE

Post Brook Lake is located in the middle of a small, mostly forested watershed. The watershed is narrow, with the lake extending from the western edge almost to the eastern edge. The lake receives drainage from the north, which is a small residential community as well as from the south which is forested land and wetlands. Forested land accounts for approximately 40.8% of the total watershed area while residential development accounts for approximately 39% and wetlands account for approximately 20%.

SITE 38: HANCOCK DRIVE AND SCHOFIELD ROAD

The site is a small open grass area located at the corner of Hancock Drive and Schofield Road. Stormwater that originates uphill of the grass area on Schofield Road appears to flow downhill on both Schofield Road and Hancock Drive, on both sides of the grass area. There is a low curb located on Hancock Drive that wraps around the intersection with Schofield Road. A review of images on Google Earth shows sediment and road grit accumulating along the curb at the intersection between the two roads.

Photos 77-78. Grass area at the intersection of Hancock Drive and Schofield Road

Recommendation Site 38: This site is an ideal candidate for the installation of a small rain garden. The creation of a rain garden would make a sheet flow connection from the road, allowing for stormwater retention and filtration of nutrients through native vegetation and soil media. Curb cuts can also be considered depending on the existing road grades. This practice would involve minor regrading in the grass area to create the depression required for the rain garden to hold water and drain efficiently. Property ownership is also a consideration on this site and should be determined and considered.

Cost Site 38: The approximate cost for design, permitting, and implementation of a rain garden or small bioretention system is between $40,000 and $100,000 depending on depth, size and site complexity.

SITE 39: OSAGE DRIVE AND SCHOFIELD ROAD

The proposed site is an open grass area located in a natural depression at the corner of Osage Drive and Schofield Road. There are no curbs to direct stormwater flow around the grass area on either street. There is a curb on Schofield Road further south, although this is downhill of the grass area.

Photos 79-80. Grass area within a natural depression on the corner of Osage Drive and Schofield Road

Recommendation Site 39: This site is an ideal candidate for the installation of a small rain garden. The creation of a rain garden would receive sheet flow connection from the road, allowing for water retention and filtration of nutrients through native vegetation and soil media. Property ownership on this site requires determination in addition to further study of soil permeability and sizing of the contributing drainage area.

Cost Site 39: The approximate cost for design, permitting, and implementation of a rain garden or small bioretention system is between $50,000 and $100,000 depending on depth, size and site complexity.

SITE 40: POST BROOK LAKE SHORELINE, UPPER SLOPE AND RAMP ACCESS

The area of the park that fronts Post Brook Lake has an earthen access ramp that is assumed to allow vehicular and/or boat access to the lake. The surface of this ramp is heavily compacted and terminates close to the water's edge in a flat lawn area that shows evidence of ponding and migrating sediments into the water from this location. Despite the steep slope of the ramp, it does not appear to receive any direct drainage from Schofield Road above, making it a limited source of erosive flows There is a small stand of the invasive plant, *Phragmites australis* that has established in this area of the shoreline which can be an indicator of increased sediment deposition.

The slope at the back of the park coming down from Schofield Street has had multiple layers of woodchips laid down and a small stockpile of additional chips are sitting at the base of the slope. The reason for this is unknown, but as the slope exceeds 33% in some areas, it is assumed this area does not get mowed and requires stabilization, which the woodchips are meant to provide.

Photos 81-83. Prhagmites stand at shoreline and bottom of earthen ramp (Top Left) Steep slope with wood chips and stockpiles (Top Right) and Bottom of earthen ramp looking upslope toward road (Bottom)

Recommendation Site 40: Recommended BMPs for the compacted ramp leading to the shoreline consist of increasing the infiltration ability of the soils that make up the ramp so less turbid water sheet flows into the lake. This will also encourage groundwater recharge in the aquifer. This increased ability to infiltrate can be achieved by installing a stabilized vegetated paving system such as Grass Pave or similar that will also accommodate any vehicular traffic while resisting compaction. Given that no tributary drainage area is coming from Schofield Road, a swale is likely unnecessary. Additional measures at this location include treating the invasive *Phragmites* stand and planting a riparian aquatic buffer planting of native, wet site-tolerant plants at the shoreline to reduce sediment from upslope entering the lake via sheet flow.

For the woodchipped slope area, it is recommended that the majority of the chips be removed and the slope be planted with a vegetated filter strip planting to stabilize the soils and decrease runoff and any ponding or muddy conditions that likely occur at the toe of the existing slope. A buffer planting of this size will also provide beneficial wildlife habitat for birds including winter foraging opportunities, which in turn can help keep the mosquito population down near the lake.

Cost Site 40A: The estimated cost for design, permitting and construction of the proposed BMPs is estimated to be between $175,000 and $300,000 for approximately 2,000 SF of stabilized vegetated paving and 1,000 SF of riparian aquatic buffer planting at the shoreline.

Cost Site 40B: The estimated cost for design, permitting and construction of the proposed vegetated filter strip planting at the slope is estimated to be between $55,000 and $100,000 for approximately 3,700 square feet, dependent on condition of soils, planting density, labor source and irrigation requirements.

SITE 41: POST BROOK LAKE SHORE FRONT SCHOFIELD ROAD INLET AND DISCHARGE PIPES

Catch basins from Schofield Road and Osage Drive discharge into the northeast corner of Post Brook Lake through concrete pipes. There appears to be a significant amount of sediment accumulation in the lake around the pipes with a stand of *Phragmites australis* growing in the sediment at the outfalls. The pipe from Schofield Road travels under the beach area and discharges into the lake from the north while the pipe from Osage Drive passes through residential property west of the lake into a small open channel before traveling through a section of pipe just prior to entering the lake. All the concrete pipes appear to have had their exiting inverts raised by the accumulated sediment levels in the lake and are currently at least partially clogged. The length and totality of the occlusion is unable to be determined from general observation.

The small shed and larger asphalt shingle- roofed picnic pavilion both contribute roof runoff that sheet flows onto the lawn and into the lake. Neither structure has gutters and/or leaders to direct the water once it falls onto the roofs and evidence of rills were observed where the water makes its way to the lake. This runoff will also eventually undermine the concrete slabs that the pavilion and shed both sit on. Evidence of this process is already visible at the shed.


Photos 84-85. Inlet on Schofield Road that drains to lake (left) and concrete pipe ends in sediment and Phragmites stand (right)

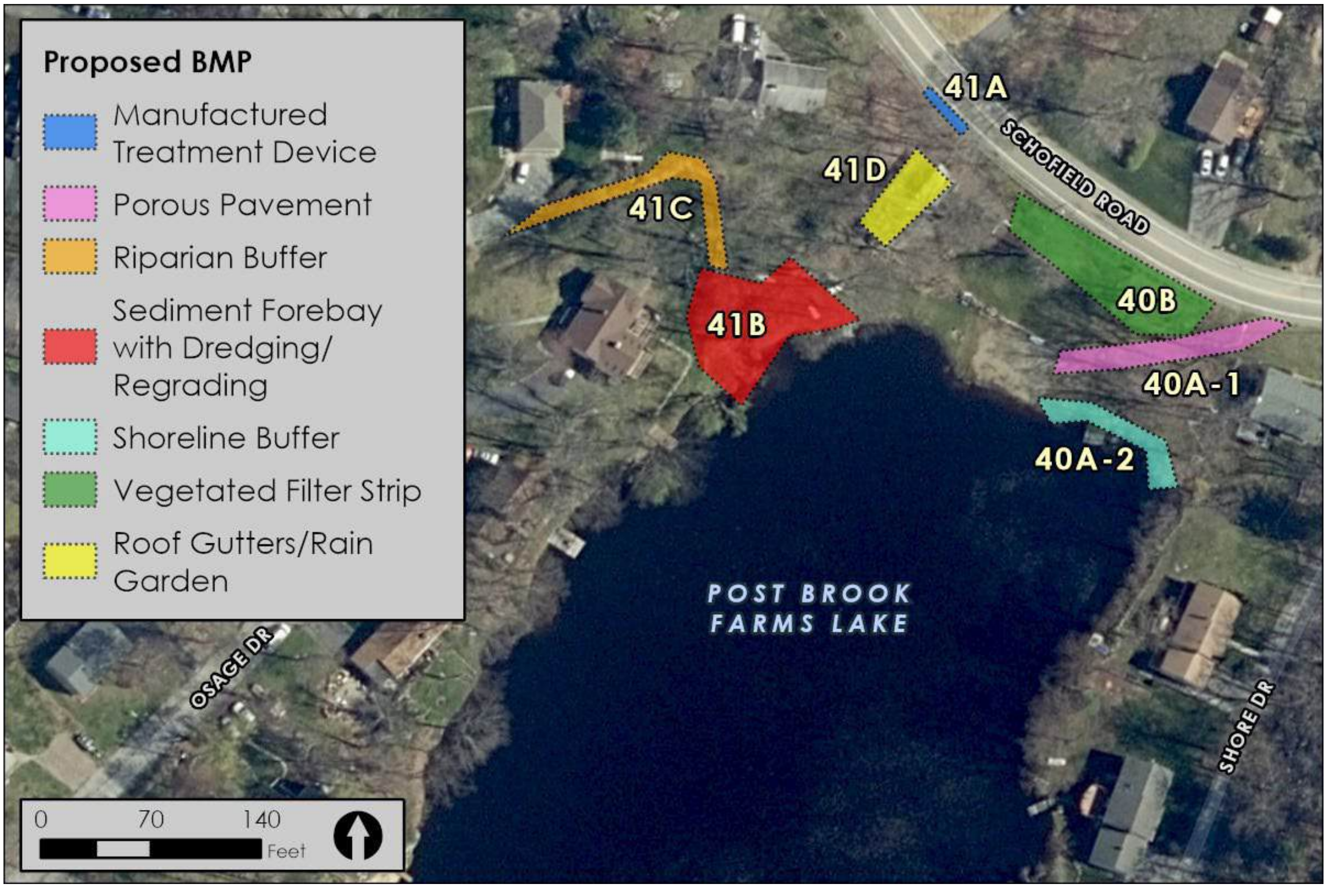
Recommendation Site 41: A series of BMP's are recommended for the series of areas above:

41A: The installation of an in-line MTD on Schofield Road as a pre-treatment device to address the apparently large amounts of sediment that have been flowing into the lake. The MTD will require a location that can be easily accessed for maintenance purposes.

41B: To address the likelihood that sediment will continue to accumulate at the lowest point in the system, it is recommended to cut back and regrade the existing shoreline area where the pipes currently discharge to create a shallower area, connection to the floodplain and a sediment forebay that will treat and settle any remaining sediments and prevent them from entering further into the lake. Daylighting portions of the existing pipes further up channel could also be explored to create additional flow length and habitat enhancements. Some maintenance dredging may be required to make this effort successful, but it is not accounted for in the cost estimate at this time.

41C: The tributary stream that flows from Osage Drive to the lake between three residential properties and into a concrete pipe before it enters the lake can be regraded and stabilized with riparian vegetation better suited to holding both the channel and banks in place and preventing further erosion. The pipe at the end can potentially be removed should the sediment forebay above be constructed to receive this discharge.

41D: Finally, gutters and leaders can be added to the existing pavilion and shed roofs and directed to a small rain garden the shed that could overflow to the sediment forebay. Directing this water and allowing it to infiltrate into the soil will be a more sustainable solution to preserve the building slabs, reduce erosion of the surrounding lawn as well as reducing concentrated flows of stormwater into the lake.



Aerial view of the proposed management measures at Sites 40 and 41

Cost Site 41: The estimated cost for design, permitting and construction of the proposed BMPs for the above practices is estimated separately to allow for selection of practice and/or phased work as follows:

41A: The estimated cost for design, permitting and construction of the proposed MTD is estimated to be between $500,000 and $1,000,000.

41B: The estimated cost for design, permitting and construction of the proposed sediment forebay at approximately 2,000 square feet is estimated to be between $500,000 and $750,000.

41C: The estimated cost for design, permitting and construction of the proposed riparian plantings and minor regrading encompassing approximately 3,500 SF along the tributary stream is between $100,000 and $165,000.

41D: The estimated cost for design, permitting and construction of the proposed gutters leaders at the existing building roofs and rain garden or small bioretention area in the adjacent area is estimated to be between $50,000 and $100,000.

8.12 ALGONQUIN WATERS

Algonquin waters is located at the eastern end of a watershed with little development. The lake is located to the southeast and downstream of Post Brook Farms. Thus, the Post Brook Farms watershed is nested within the Algonquin Waters watershed. Forested land accounts for approximately 73% of the watershed while wetlands account for approximately 16% and residential development accounts for approximately 10%. There is very little development around the shoreline of the lake. There is one large property on the northwest shoreline and a cluster of a few smaller properties on the southeast shoreline. Due to the fact that there are very few roads in the mostly natural Algonquin Waters subwatershed, there will not be many opportunities for watershed restoration. However, given the land use within the watershed, there is very little development or impervious surface of concern.

RESIDENTIAL STORMWATER MANAGEMENT

Due to the very small area of developed land within the watershed, there is little to no room for GI on municipal land. As such, watershed management will have to come through the form of small- scale practices on individual lots. These measures include rain barrels, rain gardens, directing gutter downspouts away from impervious surfaces, small filter strips and grass swales, vegetative pavers, among others. More information on these small-scale general stormwater management measures can be found at the end of this section.

8.13 GORDON LAKES

Lower Gordon Lake is located at the southern end of a large watershed relative to the size of the lake. The lake is southeast and downstream of Algonquin Waters. Thus, the Lindy's Lake and Algonquin Waters watersheds are both nested within the Gordon Lakes watershed. Forested land accounts for 72% of the total watershed area while wetlands account for approximately 10% and residential development accounts for approximately 14%. One of the main tributaries that discharges from Algonquin Waters enters Gordon Lake at the northern end of the lake. The other main tributary is in the northeast corner and drains the smaller, Upper Gordon Lake. There is dense shoreline development around the shoreline of Lower Gordon Lake with the exception of the southern end where the dam and outlet are located.

SITE 42: LARGE GRAVEL AND ASPHALT COMMERCIAL LOT ALONG OTTERHOLE ROAD

The large gravel and asphalt paved commercial lot along Otterhole Road is approximately 35,000 square feet in area. The lot is located in the northern section of the Gordon Lake subwatershed and drains to the tributary that feeds into Upper Gordon Lake. Based on an evaluation of the elevations in the lot, it appears the majority of the stormwater that falls on it drains to the southeast corner of the lot.

Photo 86-87. Large gravel and asphalt parking lot

Recommendation Site 42: The primary recommendation (Site 42A) for this site is the installation of a bioretention system in the southeast corner of the lot. Implementing this GI practice would allow for the sequestration of sediment within the soil and gravel media, infiltration of stormwater and capture of nutrients within the bioretention system. A secondary recommendation (Site 42B) is the conversion of a few parking spaces in front of the building to pervious pavement, or a similar material. This would allow for the infiltration of additional stormwater from the western side of the parking lot and keeping it from leaving the site. The existing loose gravel and deteriorated asphalt would need to be repaired and/or stabilized to prevent clogging of the porous pavement and/or bioretention system.

Cost Site 42A: The estimated cost for design, permitting and construction of the proposed bioretention system is estimated to be between $75,000 and $120,000 for approximately 1500 square feet, dependent on condition of soils, planting density, labor source and irrigation requirements.

Cost Site 42B: The estimated cost for design, permitting and construction of the proposed BMP for the approximately 1,600 square feet of porous pavement conversion is between $100,000 and $150,000.

SITE 43: INLET TO UPPER GORDON LAKE

The stream that discharges into the northern end of Upper Gordon Lake was in poor condition at the time of the site visit. Specifically, the streambanks were showing signs of erosion, the riparian buffer was absent, and there was extensive siltation evident in the streambed just upstream of the culvert on East Park Drive. There also appeared to be extensive sediment accumulation where the stream empties into Upper Gordon Lake. Finally, there was no shoreline buffer between East Park Drive and Upper Gordon Lake.


Photos 88-89. Erosion, sedimentation, and lack of a riparian buffer

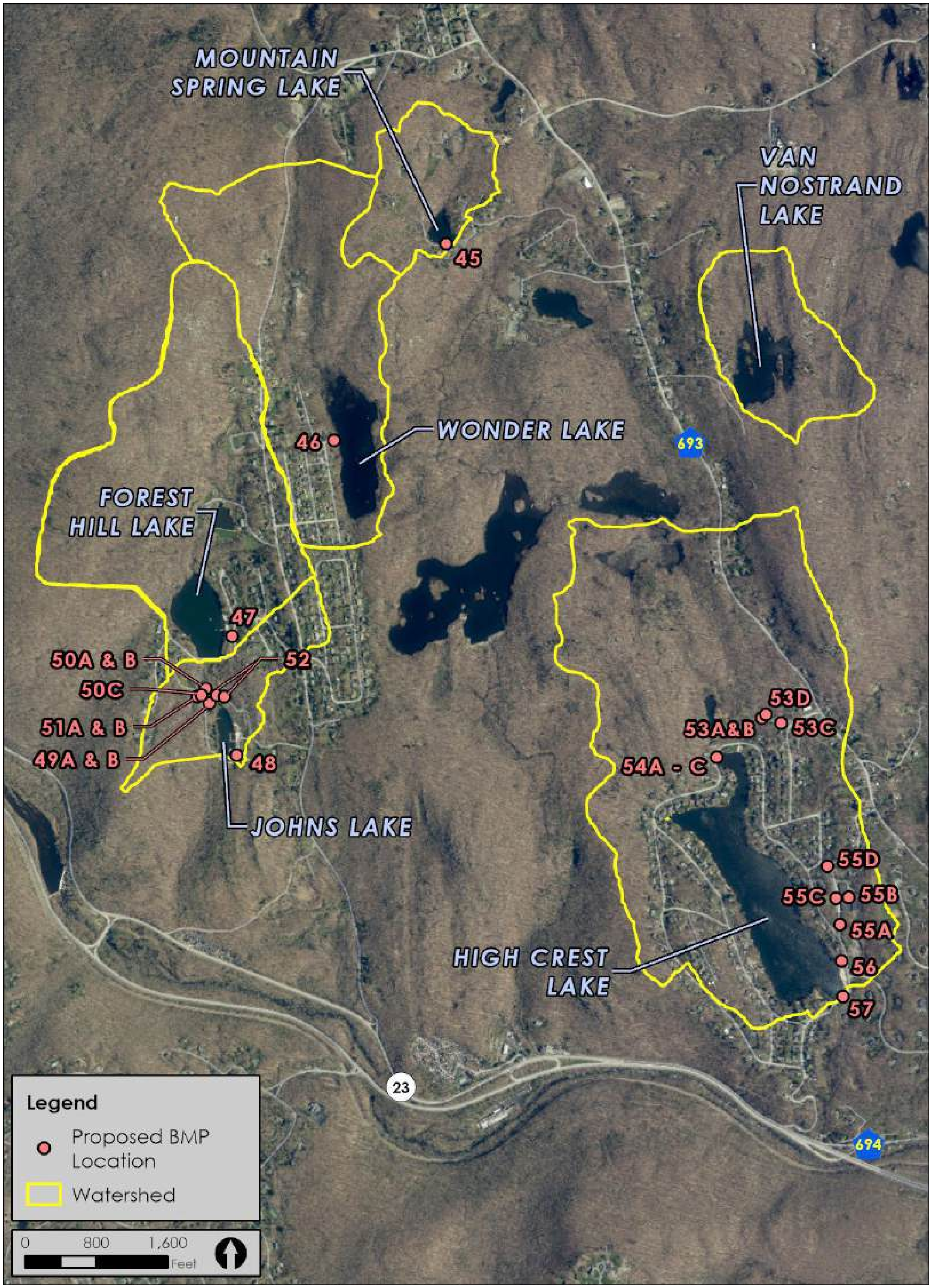
Recommendation Site 43: The primary recommendation (Site 43A) for this site is stream restoration, including bank stabilization and the establishment of a riparian buffer. The planting of riparian vegetation will help filter pollutants from stormwater as it flows over the streambanks. The root structures from the riparian vegetation will also reduce streambank erosion. The second recommendation (Site 43B) for this site involves the establishment of a shoreline buffer between East Park Drive and Upper Gordon Lake. Similar to the riparian buffer along the stream, a shoreline buffer will filter pollutants, such as sediment, nitrogen, and phosphorus, from stormwater as it flows overland.

Cost Site 43A: The approximate cost for design, permitting, and implementation of streambank stabilization measures on 200 linear feet of stream is between $35,000 and $55,000 depending on access, density and the assumption that the existing channel is a candidate for simple stabilization measures within the existing banks.

Cost Site 43B: The estimated cost for design, permitting and construction of the proposed BMP's is estimated to be between $50,000 and $75,000 for approximately 1,400 square feet of riparian aquatic buffer planting at the shoreline.

RESIDENTIAL STORMWATER MANAGEMENT

The land use in the Gordon Lakes watershed is dominated by forested land and wetlands, both of which are natural and would be logistically, economically, and environmentally difficult to modify. The majority of the remaining land in the watershed is residential land. However, the residential community around Lower Gordon Lake is extremely dense, with small streets and little room between properties. As such, watershed management will have to come through the form of small-scale practices on individual lots. These measures include rain barrels, rain gardens, directing gutter downspouts away from impervious surfaces, small filter strips and grass swales, vegetative pavers, among others. More information on these small-scale general stormwater management measures can be found at the end of this section.


MOUNTAIN SPRING LAKE
45
VAN NOSTRAND LAKE
46
WONDER LAKE
693
FOREST HILL LAKE
47
50A & B
52
50C
51A & B
49A & B
48
JOHNS LAKE
53D
53A&B
53C
54A - C
55D
55C
55B
55A
HIGH CREST LAKE
56
57
23
694
Legend
Proposed BMP Location
Watershed
0
800
1,600
Feet

8.14 SHADY LAKE

Shady Lake is located at the southern end of a small watershed. The upper half of the watershed is almost entirely forested while the lower half is mostly residential development. Forested land accounts for approximately 63% of the total watershed area while residential development accounts for approximately 37%. There is a small inlet at the northern end of the lake that flows under Poplar Grove Terrace. There is residential development around the shoreline of the lake except for the dam on the southeast shoreline.

SITE 44: SHADY LAKE SOUTHWEST SHORELINE AT POPLAR GROVE TERRACE

A narrow area of land exists between the north side of Poplar Grove Terrace and the water. There is little to no vegetation in this area and the asphalt at the edge of the road is crumbing leaving the water body vulnerable to uncontrolled inputs of eroded soils, leaves, asphalt pieces and other road debris.

Photos 90-91. Narrow shore off edge of pavement (left) looking east at road edge condition on north side of Poplar Grove Terrace (right)

Recommendation Site 44: The recommended BMP for this area is to install native shoreline buffer plantings that will also be low growing and road salt tolerant, to hold the land in place and act as a filter for any materials that would otherwise enter the lake. It is recommended to extend this buffer as far to the east as possible to maximize the area of benefit. A structural pavement edging could also be considered at this location to help retain the integrity of the road edge and mitigate crumbling or breakage.

Cost Site 44: The estimated cost for design, permitting and construction of the proposed BMP is estimated to be between $15,000 and $25,000 for approximately 530 square feet along the lake shore.

8.15 MOUNTAIN SPRINGS LAKE

Mountain Springs Lake is located at the southeastern end of a small, mostly forested watershed. Forested land accounts for approximately 80% of the watershed while residential development accounts for approximately 16%. There is only minor residential development around the immediate shoreline, resulting in a mostly forested shoreline. The main inlet to the lake is located at the northern end and drains mostly forested land.

SITE 45: MOUNTAIN SPRINGS LAKE SHORELINE

As noted, most of the shoreline of the lake is forested or on private property. There is a small section of shoreline on the southern end of the lake adjacent to the beach area, that was lacking a vegetative buffer with minor erosion of the shoreline occurring in this location.


Photos 92-93. Lack of shoreline buffer on the southern shoreline of Mountain Springs Lake

Recommendation Site 45: A vegetated buffer should be established here with native, road salt tolerant plants. The root structures of these plants would strengthen the shoreline and reduce erosion.

Cost Site 45: The estimated cost for design, permitting and construction of the proposed BMP is estimated to be between $7,500 and $12,000 for approximately 250 square feet along the lake shore.

RESIDENTIAL STORMWATER MANAGEMENT

Due to the small size of the watershed, there is little to no room for GI on municipal land. As such, watershed management will have to come through the form of small-scale practices on individual lots. These measures include rain barrels, rain gardens, directing gutter downspouts away from impervious surfaces, small filter strips and grass swales, vegetative pavers, among others. More information on these small-scale general stormwater management measures can be found at the end of this section.

8.16 WONDER LAKE

Wonder Lake is located at the southeast end of a small, mostly forested watershed. Forested land accounts for approximately 70% of the watershed while residential development accounts for approximately 28%. Most of the residential development occurs in the southwest corner of the lake, along the western shoreline. Germantown Road is a busy road that traverses the center of the northern half of the watershed, however, there are only a few residential properties along it. The main inlet, Matthews Brook, flows through forested land to the north of the lake and discharges into Wonder Lake in the northwest corner. Only a few residential properties are located directly on the lake. Most of the residential community to the west of the lake is separated from the lake by Leonard Avenue and a vegetated strip of land approximately 100 feet wide.

SITE 46: PECAN LANE AND LEONARD AVENUE

Pecan Lane runs perpendicular to Leonard Avenue at the northern end of Leonard Avenue and extends down towards the shoreline. It is not currently known if this extension of Pecan Lane is private property but it was overgrown at the time of the site visit and did not appear to be used as a boat launch or parking area. Runoff from Pecan Lane flows down this extension of the road and into Wonder Lake. There appeared to be a small, vegetated buffer at the end of Pecan Avenue.

Photos 94-95. Pecan Lane extending down to the shoreline of Wonder Lake

Recommendation Site 46: If this extension of Pecan Lane is not currently being used for a specific purpose, the area that is covered in leaves and downed trees in Photo 8.93 should be converted to native meadow vegetation to create a wide shoreline vegetative filter strip. The meadow vegetation would serve to intercept stormwater runoff that originates further to the west on Pecan Lane, reducing the flow rate, increasing infiltration, and sequestering nutrients.

Cost Site 46: The estimated cost for design, permitting and construction of the proposed vegetated filter strip planting is estimated to be between $25,000 and $45,000 for approximately 1,500 square feet, dependent on condition of soils, planting density, invasive species management and irrigation requirements.

RESIDENTIAL STORMWATER MANAGEMENT

Due to the presence of mostly residential development along the western shoreline of the lake, there is little to no room for GI on municipal land. As such, watershed management will have to come through the form of small-scale practices on individual lots. These measures include rain barrels, rain gardens, directing gutter downspouts away from impervious surfaces, small filter strips and grass swales, vegetative pavers, among others. More information on these small-scale general stormwater management measures can be found at the end of this section.

8.17 VAN NOSTRAND LAKE

Van Nostrand Lake is located in the southwest end of a very small watershed almost entirely comprised of forested land and wetlands. Specifically, forested land accounts for 84% of the total watershed area while wetlands account for the remaining 16%. There is essentially no development in the watershed with the exception one residential property on the western shoreline. Thus, there will be little room or necessity for watershed restoration around Van Nostrand Lake.

8.18 FOREST HILLS LAKE

Forest Hills Lake is located at the southern end of a mostly forested watershed. The only development within the watershed occurs in the form of a small residential community on the western shoreline of the lake and minor development along Germantown Road on the eastern edge of the watershed. Forested land accounts for approximately 87% of the total watershed area while developed land accounts for approximately 11%. The two main inlets are located along the northern shoreline, however the smaller of the two inlets on the northwest shoreline drains forested land. The larger of the two inlets drains a portion of the developed land along Germantown Road, north of the lake. This unnamed tributary also passes through a small impoundment on private property approximately 500 feet north of the lake. It is not currently known what the current use of the impoundment is, but there appears to be an engineered dam and outlet structure on the southern end of the impoundment.

SITE 47: TWO PARKING LOTS ON FOREST HILL DRIVE

There are two impervious asphalt paved parking lots on Forest Hill Drive along the southeastern shoreline of the lake that drain to catch basins on the road.

Photos 96-97. Asphalt parking lots on both sides of Forest Hills Drive

Recommendation Site 47: The primary recommendation for this site is the conversion of strategic locations in each parking lot to porous pavement. This would not reduce the number of parking spaces in the parking lots and would slow down the rate of flow into the lake and potentially allow for infiltration of treated stormwater into the groundwater for recharge.

Cost Site 47: The estimated cost for design, permitting and construction of the proposed BMP for the approximately 4,300 square feet of porous pavement conversion is between $250,000 and $350,000.

8.19 JOHNS LAKE

Johns Lake is located at the southern end of a mostly forested watershed. The lake is located approximately 550 ft. from Forest Hills Lake and receives the majority of its inflow from the outlet of Forest Hills Lake. Thus, any watershed restoration efforts in the Forest Hills Lake watershed will reduce the overall pollutant load to Johns Lake as well. Forested land accounts for approximately 81% of the total watershed area while developed land accounts for approximately 13%. The lake and surrounding land are used as a day camp during the summer months.

SITE 48: SOUTHERN SHORELINE

The southern shoreline of the lake lacks an adequate vegetated buffer.

Photo 98. Lack of shoreline buffer along Johns Lake

Recommendation Site 48: A vegetative buffer should be established here. The root structures of these native plants would strengthen the shoreline and reduce erosion.

Cost Site 48: The estimated cost for design, permitting and construction of the proposed BMP for approximately 2,000 square feet of aquatic riparian buffer at the shoreline is between $50,000 and $75,000.

SITE 49: CATCH BASIN AND EROSION ALONG THE NORTHWEST END OF JOHNS LAKE

Stormwater has eroded a gully downslope of a small catch basin along the northwest shoreline. The catch basin drains to a pipe that also receives drainage from a spring-fed stream, located approximately 40 feet to the west of the catch basin. The pipe discharges into the northern end of the lake, approximately 155 feet from the catch basin. The gully that has formed downslope of the catch basin indicates that the catch basin and/or pipe is not functioning properly and are either clogged or undersized. The grass around the gully is highly compacted and rocks were observed in the ground throughout the watershed; thus, the soil drainage in the local area should be further investigated for infiltration rates.



Photos 99-101. Eroded gully downslope of the catch basin, northwest of Johns Lake

Recommendation Site 49: An additional investigation into the cause of the poor drainage should be conducted. The pipe should be cleared of any potential blockages or resized to accommodate the flow. The current eroded gully should also be converted to a vegetated swale with check dams to attenuate any flow velocities. Site constraints relative to the soil conditions and permeability should be further evaluated as a part of this investigation. If any of the lawn can be removed and converted to a seeded meadow, this would aid in increasing infiltration into the soil and reducing runoff causing erosion.

Cost Site 49A: The estimated cost for design, permitting and construction of the proposed interventions for approximately 700 square feet of vegetated conveyance with check dams is $65,000 and $125,000.

Cost Site 49B: The estimated cost for design, permitting and construction of approximately 3,000 square feet of lawn to meadow conversion is $35,000 and $60,000.

SITE 50: SMALL BATHROOM BUILDING

The small bathroom building located to the northwest of Johns Lake lacks gutters. Stormwater that drains off the sloped roofs has eroded the compacted grass. Due to the compacted grass and the apparent low permeability of the soil on site, runoff from the roof appears to drain downslope towards the main inlet, further eroding the ground.

Photos 102-103. Lack of gutters on bathroom building (left) and dripline from stormwater draining off the building (right)

Recommendation Site 50: The building should be fitted with gutters and downspouts that empty into a downspout planter that contains a porous soil media and native plants.

Cost Site 50A: The estimated cost to design, permit and install approximately 120 LF of gutters, drop tubes and leaders is expected to be between $4,500 and $6,500.

Cost Site 50B: The estimated cost to design, permit, furnish and install two large stormwater planters with plants and media is expected to be between $ 4,000 and $5,500.

SITE 51: LARGE PAVILION

The large pavilion located to the northwest of the lake lacks gutters around a portion of the building. The existing gutters are in poor condition and were observed to be disconnected from the roof on the east side of the building during the site visit. The gutter downspouts on the west side of the building are currently discharging into the ground; however, it is not known where the stormwater is conveyed. The pavilion is located on top of a hill, and there was little grass or other vegetation growing around the building due to the poor soil conditions and extensive bedrock. Runoff from the roof has eroded a shallow gully as the stormwater flows downhill towards the lake.

Photos 104-105. Erosion along the outside of the pavilion from the roof runoff

Recommendation Site 51: The pavilion should be fitted with gutters and downspouts that empty into downspout planters that contains a porous soil media and native plants. This would eliminate the primary cause of the current erosion. This would also involve modifying the downspouts on the west side of the building to discharge directly into a planter. Due to the poor condition of these gutters during the site visit, it is recommended that they are replaced with new gutters. The drainage path on the hill can also be lined with rip-rap to further prevent erosion caused by stormwater that originates between the building and the hill.

Cost Site 51A: The estimated cost to design, permit and install approximately 440 LF of gutters, drop tubes and leaders is expected to be between $13,500 and $18,500.

Cost Site 51B: The estimated cost to design, permit, furnish and install four large stormwater planters with plants and media is expected to be between $ 8,000 and $10,000.

Cost Site 51C: The estimated cost to design, permit, furnish and install rip rap to line approximately 450 SF of eroded area is expected to be between $ 3,000 and $5,000.

SITE 52: MAIN INLET

The main inlet to Johns Lake, located at the northern end, receives stormwater that originates to the east and west of the inlet, along the gravel road. Stormwater from both sides of the inlet has eroded both the gravel road and the compacted grass. The gullies that have formed are incised significantly in proximity to the inlet.

Photos 106-109. Eroded gullies to the west (top) and east (bottom) of the main inlet

Recommendation Site 52: The current eroded gullies on both sides of the inlet should be converted to either rip-rap lined swales or a vegetated swales with check dams, depending on the site constraints relative to the soil conditions. Where space allows, swale widths should be maximized by cutting back bank walls to a shallower slope.

Cost Site 52: The estimated cost for design, permitting and construction of the proposed interventions for approximately 2,500 square feet of vegetated conveyance with check dams or rip rap lining is $175,000 and $200,000.

8.20 HIGH CREST LAKE

High Crest Lake is located at the southern end of a small watershed. The upper half of the watershed is mostly forested while the lower half is mostly residential development. Forested land accounts for approximately 60% of the total watershed area while residential development accounts for approximately 33%. The residential development around the shoreline of the lake is relatively dense. High Crest Drive wraps around the entire lake with residential properties on both sides of the road. Macopin Road traverses the northeast section of the watershed and has some residential development along it. There are a few inlets located around the northern section of the lake but the main inlet is in the small northern cove.

SITE 53: APSHAWA PRESERVE PARKING LOT

The Apshawa Preserve parking area consists of a large, loose gravel parking lot that drains towards a small stream on the southern side of the site. The stream is separated from the parking lot by an open, compacted, grass area with a few trees. Stormwater from the parking lot is conveying gravel from the parking area to the grass area and into the stream. Stormwater appears to be flowing off the parking lot in a few locations and creating small gullies, but there is one larger gully that appears to be the main drainage location. This larger gully is the most eroded close to the receiving stream and gravel from the parking lot was present throughout the gully. The stream traverses the entire southern end of the parking lot and entrance drive and lacks a sufficient riparian buffer along most of that length. Invasive plants, like *Rosa multiflora* were observed growing along the stream.

Photos 110-111. Apshawa Preserve parking lot (left) and gravel deposition in the grass area (right)

Photos 112-113. Extensive gravel accumulation (left) and the eroding gully near the stream (right)

Recommendation Site 53: The first recommendation for this site (Site 48A) is the conversion of areas throughout the grass that currently receive sheet flow to a vegetated filter strip(s).

A second recommendation (Site 48B) involves the conversion of the main large gully to a bioswale that will reduce the erosion that's actively occurring and provide enhanced infiltration and sediment and nutrient sequestration. The other small gullies can also be converted to small, vegetated swales, or potentially the parking lot can be slightly regraded to direct the majority of the drainage from the parking lot to the main bioswale.

A third recommendation (Site 48C) involves the enhancement / establishment of a riparian buffer along the entire drainage stream. This would involve removing and managing the existing invasive plants and replacing them with native vegetation.

Finally, a fourth recommendation (Site 48D) targets the loose gravel parking lot. The loose gravel in the parking area can be stabilized using a gravel stabilization grid system that holds the loose material in place while adding compaction resistance to the subbase layers so that pore space and therefore infiltration capacity is increased. By preventing pulverization of gravel into smaller particles, non-point source pollution in the form of sediments leaving the lot is significantly reduced.

Cost Site 53A: The estimated cost for design, permitting and construction of the an approximately 2,000 square foot vegetated filter strip(s) planting is estimated to be between $30,000 and $100,000 dependent on condition of soils, planting material type, and irrigation requirements.

Cost Site 53B: The approximate cost for design, permitting, and implementation of approximately 600 square feet of bioswale is between $35,000 and $70,000 depending on existing soils, labor and plant material type.

Cost Site 53C: The estimated cost for design, permitting and construction of the proposed riparian plantings and minor regrading encompassing approximately 1,300 SF along the tributary stream is between $35,000 and $80,000.

Cost Site 53D: The estimated cost for design, permitting and implementation of the proposed gravel stabilization grid for the entire 12,000 square foot parking area is between $200,000 and $300,000 dependent on reuse of existing materials and/or need for additional excavation and subdrainage layers.

SITE 54: INLET COVE

The main inlet to High Crest Lake is located in the narrow cove at the northeastern end of the lake. The inlet flows under High Crest Drive and discharges into the cove through two large pipes that diverge from each other under the grass area. There are at least four catch basins on High Crest Drive, along the western half of the cove, that drain directly to the cove via individual pipes. These catch basins receive stormwater runoff from High Crest Drive, but it is believed additional flow may pass through these pipes from stormwater that originates behind the houses. All of these catch basins were significantly filled in with sediment and road grit and there was extensive sediment deposition in the cove where the pipes discharge. There was vegetation growing on the accumulated sediment in front of several of these pipes. The entire shoreline of this cove lacks a vegetated shoreline buffer.


Photos114-115. Lack of shoreline buffer along the inlet cove


Photos 116-117. Sediment deposition at two pipes that discharge into the northeast cove

Recommendation Site 54A: A vegetated shoreline buffer with native vegetation should be implemented along the entire cove shoreline, with particular emphasis on the western shoreline since it is in close proximity to the road. Designated areas along the shoreline can be left open for access to the shoreline for fishing or other recreational activities. A shoreline buffer here would intercept overland stormwater flow that originates on High Crest Drive and would reduce the rate and volume of stormwater that enters the lake and would provide filtration of sediment, nutrients, and other pollutants. The root structures from the vegetation would also strengthen the shoreline, offering additional protection against shoreline erosion.

Recommendation Site 54B: The catch basins should be periodically cleared out to maintain proper drainage. Failing to properly maintain the catch basins can dramatically slow down or completely stop the passage of stormwater which can result in localized flooding issues. If the catch basins are periodically cleared out but are subject to an extensive amount of debris accumulation, simple catch-basin inserts can be installed to prevent the material from clogging the pipes or discharging directly into the lake. These catch basin inserts are effective in removing coarse debris, such as sediment, gravel, road grit, trash, and even oil. However, these catch basin inserts will not remove nutrients such as nitrogen or phosphorus as effectively as a large-scale MTD with filter media. The catch-basin inserts also have much less of a capacity for pollutant accumulation, and thus need to be maintained on a regular basis so they maintain proper functionality. Alternatively, larger MTDs (49C) can be installed in-line with these inlet pipes to provide enhanced sediment and nutrient removal capabilities; these systems need to be cleaned out periodically as well.

Cost Site 54A: The estimated cost for design, permitting and construction of the proposed BMP is estimated to be between $125,000 and $175,000 for approximately 4,000 square feet of riparian aquatic buffer planting at the shoreline.

Cost Site 54B: The approximate cost for design, permitting, and implementation for catch basin inserts is between $5,000 and $10,000 depending on number of locations and type.

Cost Site 54C: The estimated cost for design, permitting and construction of the proposed MTD is estimated to be between $500,000 and $1,000,000.

SITE 55: APSHAWA ELEMENTARY SCHOOL

The Apshawa Elementary School grounds have potential for both reducing non-point source pollutants from entering the lake and for being a nexus of public education about GI. Between the building roof and parking areas, there are approximately 69,000 square feet of impervious cover on this site, contributing runoff that ultimately goes to the lake. The existing on-site stormwater drainage system consists of several storm inlets in the parking lot and associated drives as well as a flat roof with internal drains that presumably empty to the storm system, underground.

The large, depressed grass area in the center of the site presumably holds the septic and leach fields and was not considered for BMP's. The service lot to the east, behind the building contributes runoff to the system, but due to access considerations, no BMPs were considered for that area at this time.

The slope in the parking lot splits at the main entrance to the building with southward flow directed via curbs to inlets in the pavement while the northward side sheet flows into the compacted soil areas off the pavement edges. Where flows concentrate at the bottom of the slope (see Figures 118-121), erosion and incision are visible on the ground. Piles of leaves have been blown into this area and rip rap has been placed downslope of thisarea to dissipate the energy of the water flowing through and undercutting the tree roots and existing curb where the parking lot turns to exit onto Macopin Terrace.

Photos 118-121. (Upper left) Looking north up long slope of parking area in front of school. (Upper right) Edge condition at head of parking stalls. (Lower left) Looking south at bottom of slope. (Lower right) Looking northwest toward Macopin Terrace- severe incising and undermining of curb from uncontrolled storm water drainage flows received from parking area.

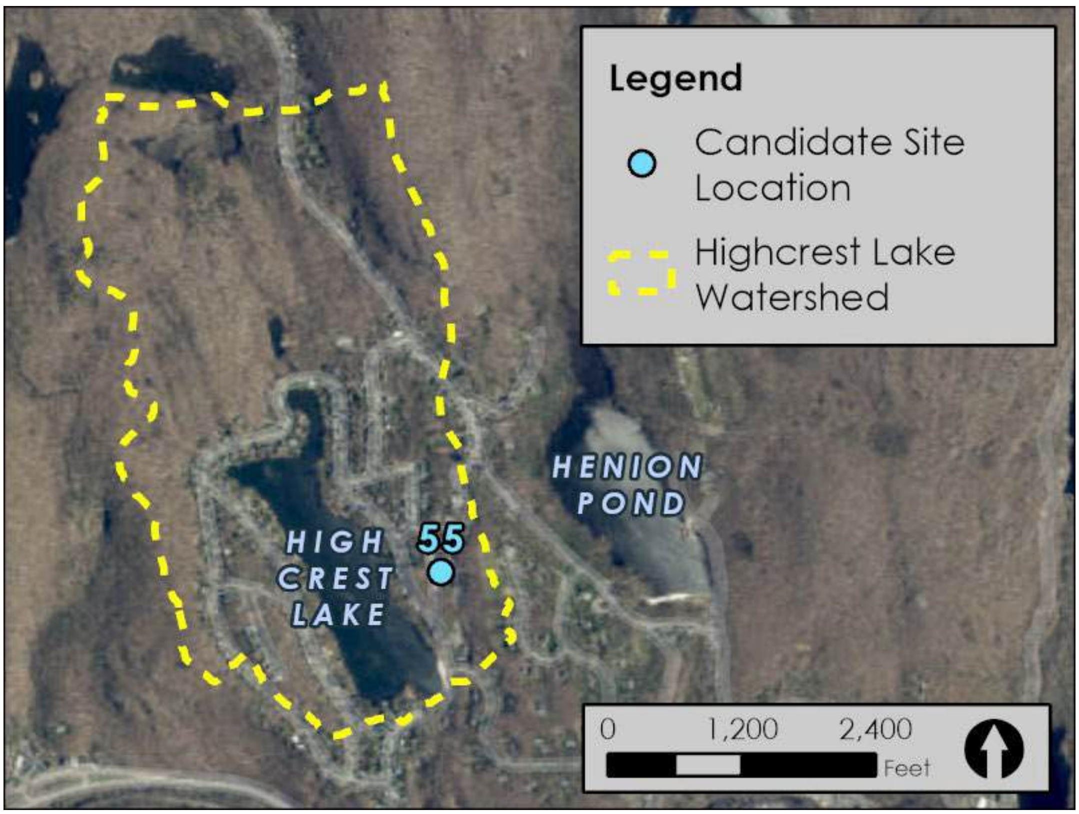
Recommendation Site 55: For this site a series of practices can be installed to reduce negative inputs from being transported off-site and into the storm drainage system.

55A: First, the asphalt sidewalk that runs from High Crest Drive along the front of the school can be converted to a porous pavement system to reduce impervious area and runoff volumes overall. These foot-traffic only areas are ideal candidates for this type of treatment.

55B: Second, given the flat roof and opportunity for creating a pilot project, a green roof retrofit could be considered for the building to reduce overall runoff volume leaving the site and reducing pressure on the stormwater conveyance and treatment system.

55C: Next, starting from the highpoint at the main entrance to the building, portions of the existing asphalt pavement can be converted to a porous pavement system to reduce overall volume of runoff that flows into the area that is currently receiving it and becoming eroded, incised and undermined. As a minimum, the cross walk at the entryway and parking stalls to the north could receive this treatment. Additional study and design would need to be undertaken to ensure the sizing of the practice would be suitable for the amount of runoff volume anticipated from the design storm. Note that additional areas of the parking lot and travel ways on the school property can also be evaluated for similar treatments to reduce overall volume of storm runoff leaving the site, but the areas mentioned above are thought to be the most immediately impactful in terms of sequestering sediment and nutrients from entering the lake.

55D: Finally, the softscape areas at the heads of the parking stalls and continuing down the drive to Macopin Terrace can be converted into a bioretention area and bioswales to direct flows, infiltrate runoff, sequester sediment and nutrients and provide additional landscape enhancements to the existing. It is also recommended that leaves, snow and other landscape related materials are no longer piled in this area as they create a source of nutrients, sediment and/or otherwise create an obstacle in the directing of runoff to a beneficial practice area.



Location of Site 55 in the High Crest Lake Watershed

Cost Site 55: The estimated cost for design, permitting and construction of the proposed BMPs for the above practices is estimated separately to allow for selection of practice and/or phased work as follows:

55A: The estimated cost for design, permitting and construction of the proposed BMP for approximately 5,500 square feet of porous pavement conversion for the sidewalk is between $350,000 and $450,000.

55B: The estimated cost for design, permitting and construction of the proposed BMP for approximately 45,000 square feet of retrofitted green roof is between $1,500,000 and $2,500,000.

55C: The estimated cost for design, permitting and construction of the proposed BMP for approximately 5,000 square feet of porous pavement conversion for the north side of the parking area is between $300,000 and $450,000.

55D: The estimated cost for design, permitting and construction of the proposed BMP for approximately 5,000 square feet of new bioretention area is between $200,000 and $350,000.

SITE 56: HIGH CREST LAKE SHORE FRONT- PICNIC AREA

This portion of the High Crest Lake shorefront supports existing trees that shade passive recreation uses including picnic tables, lawn and small area containing play equipment. The open lawn areas are compacted and do not infiltrate stormwater effectively. Evidence of runoff and transportation of sediment is visible downslope of the pavers and where water drips freely off the shed roof and moves downhill into the lake.

Photos 122-123. Erosion from runoff coming off pavers and running into lake and eroded area around shed (left) Impervious pavers under picnic tables and bare, compacted lawn (right)

Recommendation Site 56: It is recommended to remove and reset the existing pavers on a permeable stone base with stone filled joints that allow water to infiltrate into the ground in lieu of running off the paved area and onto the grassy hill.

The shed should be fitted with gutters, leaders and drop tubes that can empty into a planter containing porous soil media and plants material that will benefit from receiving water from the rooftop but can also withstand periods of drought.

Select areas of the compacted grass hill can be converted to planting beds with amended soil that will increase the ability of the ground to infiltrate and provide opportunities for transpiration of stormwater via native shrubs, grasses and perennials.

Cost Site 56: The estimated cost for design, permitting and construction of the proposed BMPs for approximately 250 square feet of porous paver installation, 40 linear feet of gutter and leader and 600 square feet of new planting beds is between $40,000 and $60,000. It is recommended that these small interventions be completed together and not separated.

SITE 57: HIGHC REST DRIVE ROAD SHOULDER SOUTH OF THE BEACH

The eastern soft shoulder of High Crest Drive slopes sharply down to the waters of High Crest Lake for approximately 160 linear feet, allowing sediment, nutrients, road salts and debris to wash directly into the lake, just above its outlet. The road is pitched toward the lake and there are no intercepting catch basins or inlets

along this length to mitigate the potential inputs to the lake. A small margin of compacted grass and a stone-armored shoreline probably do little to trap particulates.

Photo 124. Evidence of sediment from the road and existing compacted grass and stone shoreline

Recommendation Site 57: For this site, the recommended BMP is to plant a vegetated buffer in lieu of the grassed area along the shoulder to increase the soil's infiltration capability by introducing plants with more robust rooting systems than lawn grass. Plantings here will also increase evapotranspiration of stormwater and sequester nutrients and sediments. Low growing, salt and drought tolerant plantings will serve to maintain traffic sight lines, view of the lake and thrive in harsh road-side conditions. Plantings of this type along shore lines have also been shown to reduce the Canada geese presence due to limited available landing space which also increases traffic safety on this section of road.

Cost Site 57: The estimated cost for design, permitting and construction of the proposed BMP for approximately 1,700 square feet of new aquatic riparian buffer at the shoreline is between $50,000 and $65,000.


GREENDALE DR
SANDLOR TER
CREST LAKE DR
CREST HILL DR
61
60
59
58
FARM
CREST
LAKE
DOREMUS ROAD
LAND OF OAKS DR
OLD HOOP POLE ROAD
WOODRIDGE DR
Legend
Proposed BMP Location
Watershed
0
200
400
Feet

8.21 FARM CREST LAKE

Farm Crest Lake is located directly in the center of an extremely small watershed; the lake extends to the northern and southern borders of the watershed. The eastern half of the watershed contains a few houses and a residential road in addition to forested lane. The western half of the shoreline has a few additional houses and small residential roads. Residential development accounts for approximately 65% of the total watershed area while forested land accounts for approximately 28%.

SITE 58: SOUTHWEST SHORELINE (UPPER LAKE)

The southwest shoreline of the upper lake lacks an aquatic riparian buffer at the shoreline buffer along Doremus Road.


Photo 125-126. Lack of shoreline buffer on Farm Crest Lake

Recommendation Site 58: An aquatic, riparian buffer should be established here with salt tolerant native plantings. The root structures of these native plants will strengthen the shoreline and reduce erosion.

Cost Site 58: The estimated cost for design, permitting and construction of the proposed BMP for approximately 1,000 square feet of new aquatic riparian buffer at the shoreline is between $30,000 and $55,000.

SITE 59: SWALE ALONG DOREMUS ROAD

Stormwater runoff from the three-way intersection of Doremus Road, Cresthill Drive, and Greenhole Drive drains toward the lake along the southwest side of the recreational space. There is a very small drainage ditch that receives direct discharge from a small pipe; there was minor erosion along the ditch. Runoff from the road was also causing a small gully to form next to the small drainage ditch. Sediment and road grit that is conveyed with the stormwater was accumulating in this area.


Photos 127-128. Current conditions along Doremus Road

Recommendation Site 59: The current drainage ditch should be modified and converted into a much wider bioswale. This would also likely involve minor regrading upgradient of the swale to accommodate the stormwater that is currently eroding the land adjacent to the existing ditch. Converting this area to a bioswale would reduce the active erosion next to the current ditch and would allow for increased infiltration of stormwater within the bioswale.

Cost Site 59: The estimated cost for design, permitting and construction of the proposed BMP for approximately 1,700 square feet of new bioswale is between $75,000 and $150,000.

SITE 60: INTERSECTION OF DOREMUS ROAD, CREST HILL DRIVE, AND GREENDALE DRIVE

The grassed area off the pavement at the corner where Doremus Road, Crest Hill Drive and Greendale Drive meet receives sheet flow from the road before it slopes down toward the lake. No storm inlets were seen in this immediate area, so it is presumed based on the existing grade of the road, that some water sheet flows into this area before travelling further downslope to the first inlets. The roads do not have curbs in this location, so sheet flow into the grass verges is expected.


Photos 129-130. Steep slope from Doremus Road toward the shore (left); Compacted lawn sediment deposits from drainage off Doremus Road (right)

Recommendation Site 60: A rain garden or bioretention area can be created in the open area that receives sheet flow from the road. Retaining stormwater runoff in a vegetated area with soil media designed to infiltrate and filter out sediments and nutrients will act to reduce inputs into the lake and enhance groundwater recharge. Reducing sediment and nutrient load from entering the existing stormwater system will help relieve pressure on that system during heavy rainfall events. Native plants in the BMP will take up water via evapotranspiration and keep soils from eroding away while forebays or other sediment traps within the practice will help keep sediment from clogging the soils.

Cost Site 60: The estimated cost for design, permitting and construction of the proposed BMP for approximately 1,800 square feet of rain garden or small bioretention area is between $75,000 and $130,000.

SITE 61: NORTHERN SHORELINE

The grass area off the pavement edge along the lake side of the road is compacted and receives sediment and other detritus from the road that make their way into the lake due to lake of buffer along the road edge and the water's edge.

Photos 131-132. Sediment from the road (left); compacted lawn, leaves in water and lack of shoreline vegetation (right)

Recommendation Site 61: Planting an aquatic riparian buffer starting at the road edge and leading to the water's edge will server to sequester runoff, sediments and nutrients and keep them from entering the water and contributing to filling in the lake and reducing water quality. Planting should be adapted to the transitional nature of the site going from hot and dry to more wet soils toward the water. More robust planting in this area will also discourage geese from landing and contributing nitrogen into the lake through their droppings.

Cost Site 61: The estimated cost for design, permitting and construction of the proposed BMP for approximately 1,600 square feet of aquatic riparian buffer at the shoreline is between $45,000 and $70,000.

8.22 GENERAL RECOMMENDATIONS

Along with the site-specific restoration and BMPs listed for each lake, Princeton Hydro has a list of general recommendations and BMPs that can be implemented anywhere throughout the Township of West Milford to enhance stormwater management and improve water quality. Some of these general recommendations can be implemented as small-scale efforts on residential property. The watersheds of many of the lakes included in this study were extremely small, with little room for BMPs on public or open land. Thus, watershed restoration in these small watersheds will need to come through the form of small-scale and residential BMPs. While some of these small-scale practices can be found in the New Jersey Stormwater BMP Manual some do not. However, they are recommended in the New Jersey Developers' Green Infrastructure Guide and many are also recommended by the EPA.

In addition to stormwater management, the following section will also include general management measures and recommendations for septic systems, streams and riparian zones, and pet waste management.

STORMWATER MANAGEMENT

DOWNSPOUT DISCONNECTION

Downspout disconnection is a simple practice that involves the rerouting of rooftop drainage pipes (gutter downspouts) from draining to an impervious surface that drains directly to the stormwater sewer, to draining rainwater into rain barrels, cisterns, or other permeable areas such as grassy or vegetated areas. It is important to divert the rainwater away from the foundation of a house, especially if there is a basement or crawlspace.

Photo 133. Downspout Disconnection, Source: USEPA

RAINWATER HARVESTING

Rainwater harvesting is one of the easiest and cheapest methods of managing stormwater runoff from impervious roofs. Rainwater harvesting simply involves capturing runoff from the gutter downspout of a roof and temporarily storing it in a container. Harvesting stormwater from the gutter downspout reduces the erosive force that occurs when the downspout drains directly to the ground. The rain barrel overflow can be directed to vegetated areas to allow for infiltration into the soil rather than draining directly to an impervious surface. The harvested rainwater is also an ideal source of irrigation for gardening or lawn maintenance.

For a small roof such as a house, a rain barrel is the ideal container for rainwater harvesting. Rain barrels are typically 55-gallon drums but can be purchased or built to accommodate larger volumes. Additionally, multiple rain barrels can be connected with hoses for increased storage capacity. There are countless resources on how to build and install a rain barrel at home and can cost from around $30 - $300 or more, depending on availability of the materials. Rutgers has a number of websites dedicated to rain barrels, including on how to build one (E329: Rain Barrels Part I: How to Build a Rain Barrel (Rutgers NJAES)).

For commercial rooftops or any rooftop with a large surface area, cisterns and dry wells are superior to rain barrels for rainwater harvesting. Cisterns are used for larger rooftops and can capture and store between 100 and 10,000 gallons of runoff. Drywells are small, subsurface detention basins that collect stormwater runoff from smaller drainage areas. Water collected by drywells slowly infiltrate into the ground to contribute to recharge. Generally, the costs for cisterns and dry wells can range anywhere from $150 - $700+ for units <500 gallons to $500 - $3,000+ for units >500 gallons ($3,000+ for a sub-surface, 800 gallon two-tank unit). Costs will vary greatly depending on size, number of downspouts, above ground or below ground, etc. and do not include design andinstallation.

Photo 134-135. Rain barrel (left) and cistern (right), Sources: CT DEEP (left) and USEPA (right)

DOWNSPOUT PLANTERS

Downspout planters or planter boxes are small structures that contain an engineered soil/gravel mix and native vegetation that enhance stormwater infiltration and nutrient removal. They are essentially small-scale rain gardens and can create the visual appeal of standard landscape planters with an enhanced ability for infiltration and nutrient removal. These systems are placed directly adjacent to a building, similar to a rain-barrel, where rainwater from the roof of a structure flows into the structure through the gutter downspout. Similar to a rain garden, these systems can be designed with an underdrain pipe or they can be designed to infiltrate into the subsoil.

Photo 136. Downspout planter, Source: Phillywatersheds.org

GREEN ROOF

Green roofs are roofing surfaces that are partly or completely covered with vegetation. Green roofs provide stormwater management by slowing down rainfall and by allowing a portion of the precipitation to be returned to the atmosphere through evapotranspiration. Green roofs have been shown to hold a significant amount of the rainfall that reaches their surface in the summer. Green roofs decrease stress on storm sewer systems by retaining and delaying the release of stormwater.

Photo 137. Green Roof, Source: New Jersey Future

A professional company can install a green roof, typically for approximately $10 to $40 per square foot. Note, site specific issues or constraints may result in additional costs in the installation; considerations include roof loading, accessibility for maintenance, the height and the pitch of the roof, and maintenance budgets. Such considerations often necessitate the need for professional installation. An extensive green rooftop is one that is limited to grasses and mosses and has a shallow substrate (< 4").

CURB BUMPOUT

Curb bumpouts are relatively small extensions of the curb that extend into the roadway. These areas are designed in a similar fashion to rain gardens, with a bottom layer of gravel or stone, followed by soil and native plants. They are designed with inlets and/or curb-cuts along the street and/or sidewalk that directs stormwater runoff into the system. In addition to improving stormwater management in the community through enhanced infiltration and filtration of nutrients and other pollutants, they improve the appearance of the community. They can also be strategically placed at intersections to help slow traffic and improve pedestrian safety.

Photo 138. Curb bumpout, Source: Phillywatersheds.org

STORMWATER PLANTER

Stormwater planters are a type of linear bioretention system often used in urban areas. However, they can also be used in residential neighborhoods when space is limited for larger GI practices, such as bioswales. Stormwater planters are rectangular structures, usually with four concrete curbs around the perimeter. They are vegetated structures that are often installed within an existing sidewalk, between the walkway and the road. They are designed to receive stormwater runoff from both the road and the sidewalk through curb cuts and drains. They are similar to curb bumpouts and other bioretention systems in that they incorporate gravel or stone, soil, and native plants to enhance stormwater infiltration and nutrient filtration. Wherever possible, these systems are designed to infiltrate water into the subsoil; however, they can also be designed with an outlet structure that conveys the stormwater back to the existing subsurface stormwater system. The latter type of system is only recommended when the soil is not suitable for proper infiltration.

Photo 139. Stormwater Planter, Source: Philadelphia Water Department

TREE BOXES

Tree boxes are MTDs that incorporate soil and vegetation, thus classifying them as GI. These devices are large concrete boxes that incorporate a specialized soil media and a tree. They are often installed along a curb, similar to a curbside catch basin, and allow for high volume/flow treatment in a compact system. Unlike a standard bioretention system, they do not result in volume reduction, however, they do provide pollutant removal.

Photo 140. Tree Box, Source: Contech

SEPTIC MANAGEMENT

Traditional septic systems consist of a septic tank that receives wastewater which is then discharged to a distribution box and then distributed to the drainage field via perforated conveyance lines. The tanks provide primary treatment that includes the separation of solids that sink from the wastewater and subsequent bacterial decomposition of the solids. Secondary treatment is provided as the wastewater infiltrates the subsurface soils, through adsorption, filtration, oxidation, and other means. There are other types of septic systems that may be present, such as sand-mound systems. These systems consist of a septic tank that receives wastewater which is then discharged to a pump chamber where it is pumped to the sand mound in prescribed doses. Similar to the traditional system, the tanks provide primary treatment that includes the separation of solids that sink from the wastewater and subsequent bacterial decomposition of the solids. Secondary treatment of the effluent is then provided as it discharges to the trench and filters through the sand, then dispersing into the soil. These systems are typically installed in areas of shallow soil depth, high groundwater, or shallow bedrock

SEPTIC SYSTEM FAILURE

Septic systems are an important component of managing wastewater, especially in rural and lake communities where treatment and conveyance infrastructure does not exist. Treatment capacity of these systems can be high when maintained properly. However, septic system failure can be a serious concern, especially for older systems. Some failures can be obvious while others are less so. Failures can result from design, performance, or age, but these often overlap. Common failure types according to EPA are:

- **Hydraulic** – Excessive hydraulic loading to undersized systems, low soil permeability, ponding, poor maintenance, or increasing water use over the design capacity.
- **Organic** – Excessive organic loading from unpumped, sludge-filled tanks results in biomat loss of permeability (a stratum of anaerobic bacteria lining the trenches in the drain field).
- **Depth to Limiting Zone** – Insufficient soil depths, high water tables, and impermeable layers can all diminish pathogen removal and hydraulic performance. Sand mound systems correct for depth to limiting zones by mounding appropriate soil for treatment.
- **System Age** – Systems more than 25 to 30 years old on average. Failure rates in older systems triple. Regular maintenance, e.g., tank pumping and alternating leach fields, can substantially prolong system life.
- **Design Failure** – Inappropriate system design for site characteristics including hydraulic load or restrictions.
- **System Density** – Cumulative effluent load from all systems in watershed or groundwater recharge area exceeds the capacity of the area to accept or properly treat effluent.

SIGNS OF SEPTIC SYSTEM FAILURE

The following are a list of common warning signs of septic system inadequacy/failure that owners can monitor:

- Sewage backs up into the household plumbing
- Untreated sewage emerges at the land surface
- Untreated sewage leaches into the groundwater
- The ground above the absorption area is very spongy
- Sewage odor is noticeable in the house or well water
- Dosing tank alarm light is on
- Dosing pump runs constantly or not at all

Proper septic system management is vital to reduce the potential for failures, prolong the life of the system, and to protect local waterways. At its most basic, septic system management for existing systems must incorporate actions for the following elements:

- Inspection
- Maintenance
- Repair
- Replacement

For the most part, these items will be the responsibility of the system owner. It is important to stress that there are cost savings involved in minimizing repairs or replacement through spending on inspection and maintenance.

INSPECTION

In order to avoid septic system failure, systems must be inspected by trained professionals regularly. Inspections often include, but are not limited to the following elements:

- Check accumulation of sludge, scum, or trash
- Review previous inspections and maintenance
- Piping to and from the box should be assessed for clogs, cracks, and failures
- Assess tank conditions for cracks, rust, baffle integrity, misalignment, and malfunction
- Assess leach field conditions, which may include digging a cross-section

MAINTENANCE AND BMPs

Maintenance is one of the most important factors in the management of septic systems. Without regular maintenance performance suffers and they may not properly treat the effluent leading to excessive nutrient and bacteria loading. The following maintenance tasks and BMPs should be part of the routine operation of all septic systems:

- Septic tanks should be pumped out and inspected every 3 years for full-time residents and every 5 years for part-time residents. For systems that may be undersized, experience heavy use, have exhibited performance problems, are subject to non-flushable wipes, or are nearing the end of their life cycle, pumping frequency may need to be increased. Please refer to the New Jersey Department of Environmental Protection regulations (N.J.A.C. 7:9A) for septic sizing criteria and use relative to bedrooms, occupancy, and treatment volume.
- Maintain inspection records and know the location of the access manhole, inspection ports, and drainfield.
- Practice water conservation and limit, where possible, excessive wastewater generation
- Do not drive and park on the septic as this has the potential to damage septic components and compact soils.
- Divert runoff from impervious areas including roofs and driveways away from the system.
- Limit vegetation on the systems to grass; woody vegetation can damage pipes and tanks.
- Use low-phosphorus or no-phosphorus detergents.
- Septic system additives are not effective and may compound problems or leach organic solvents.
- Do not dispose of non-degradable material such as grease, cigarette butts, or personal hygiene items, do not use garbage disposals as these can overload the system with organic materials, and do not dispose of medicines, solvents, paints, poisons, or excessive household cleaning chemicals.

These maintenance measures can improve performance and increase the longevity of septic systems. Solids pumping is the most important action because if a system is not properly cleaned, sludge will buildup in the system and could either clog pipes and the outlet, or foul the drainfield which could cause flooding of untreated effluent or backup into the structure. A properly maintained septic system will cost far less over the long run.

REPAIRS, REPLACEMENTS, AND NEW CONSTRUCTION

Professional special inspections, inspections during pump outs, and general operator awareness may necessitate system repairs to maintain system efficacy or correct deficiencies. These repairs can be minor or major, and given the severity of the impairment could require outright system replacement. Major repairs and other alterations could require township and/or Lake Association approval, as would replacements. Replacements in particular may make a major difference in pollutant loading to the lakes as replacements systems will adhere to current technical regulations that ensure better treatment of effluent.

STREAMBANK STABILIZATION AND RIPARIAN BUFFER ENHANCEMENTS

Another important set of watershed management measures throughout West Milford involves streambank stabilization and riparian buffer enhancements. While some stream reaches throughout the township were assessed as part of the watershed investigations, there are likely hundreds of miles of streams throughout the township. As such, focus was given to stream reaches in close proximity to the receiving lake and streams that receive major stormwater inflow. Any specific stream reaches that were deemed to be in poor condition during the watershed assessments were included above with a specific site location and recommended management measure. Given the moderate to high grade throughout many of the watersheds, there are likely additional stream sites that could be restored or enhanced through streambank and streambed stabilization as well as riparian buffer enhancements. As such, this section will provide a brief overview of these general stream restoration measures and how they can reduce pollutant loading to the West Milford Lakes.

One of the most important functions of streams is sediment transport, and there are a variety of factors that contribute to erosion and sediment loading in West Milford. One of these main factors is the moderate to high grade throughout portions of the township. Anthropogenic stressors also increase erosion and sediment loading, including high impervious cover and stormwater loading, as well as buffer impairments related to general development patterns.

Stream restoration and riparian buffer enhancements have advanced considerably in recent years. Previously, channel management focused on hard engineering designs meant to lock channels in place, channel "cleaning" exercises to remove substrate and increase flow velocities and straightening. These actions have largely proven futile, are subject to high failure rates, and ultimately do not account for naturalistic stream functions. Many stream restoration efforts today focus on correcting those earlier management activities. This is due to better understanding of riverine dynamics and a different management approach, one that is dependent on the theory of dynamic equilibrium, as well as floodplain connectivity, and improving aquatic habitat value. The major streambank restoration measures that are the most relevant in West Milford include the following:

RIPARIAN BUFFER ENHANCEMENTS

The enhancement, preservation, and protection of riparian buffers are important measures for protecting water quality in the waterbodies throughout West Milford. One of the reasons that riparian buffer enhancement is so important is that the benefits are multi-lateral. For instance, the enhancement of a degraded buffer, one that is characterized by lack of native vegetation including shrubs and trees, soil disturbances, and impervious surfaces among other problems, offers improved canopy coverage and stream shading which reduces stream temperature thereby improving benthic macroinvertebrate and fisheries habitat with resultant improvements in community structure, as well as decreased biological productivity related to periphyton growth thus leading to improvements in both dissolved oxygen and pH. The following list exhibits some of the benefits of riparian buffer enhancement:

- Increased shading and maintenance of lower temperatures
- Decreased algal productivity
- Nutrient removal through vegetative uptake
- Vegetative trapping of solids and other pollutants from the surrounding watershed
- Reduced runoff velocity and increased infiltration and evapotranspiration
- Increased bank stability and decreased erosion and sedimentation
- Functional wildlife habitat and protection of rare species
- Barrier to waterfowl access and decreased coliform loading
- Reduced flood damage
- Improved carbon cycling and allochthonous material deposition
- Reduced invasive vegetation colonization

No Mow Zones - The establishment of no-mow zones is probably the most easily implemented BMP that can improve stream function. The mowing of riparian buffers or the establishment of maintained lawn space is typical in developed watersheds and mowing often continues to the very top of the streambank within feet of the wetted channel. This leads to severe bank instability often characterized by mass wasting and severe undercutting. Besides the erosion and subsequent sediment deposition of the unstable banks much of the function associated with vegetated buffers, including shading, nutrient uptake, and wildlife habitat, among others, is lost.

Riparian Buffer Planting - The next step in riparian buffer enhancement is a more thorough approach focused on the restoration of native vegetation. Crucial to this scheme is the replication of natural riparian vegetation communities which integrate multiple vegetation types including herbaceous plants, shrubs, and trees, and may be structured to match different communities including riparian forests and herbaceous and scrub/shrub wetlands. In addition, these planting plans can be tailored as necessary to provide enhancement of existing but degraded buffers or the complete mitigation of severely degraded or non-existent buffers such as in maintained lawns. The design philosophy of riparian buffer planting is to restore the natural pollutant removal capabilities and stabilizing properties of fully functioning riparian buffers by adapting to site specific conditions such as soil moisture and incorporating those considerations into a three-dimensional plan that prominently features vertical design elements, such as trees, to produce a self-sustaining plant community.

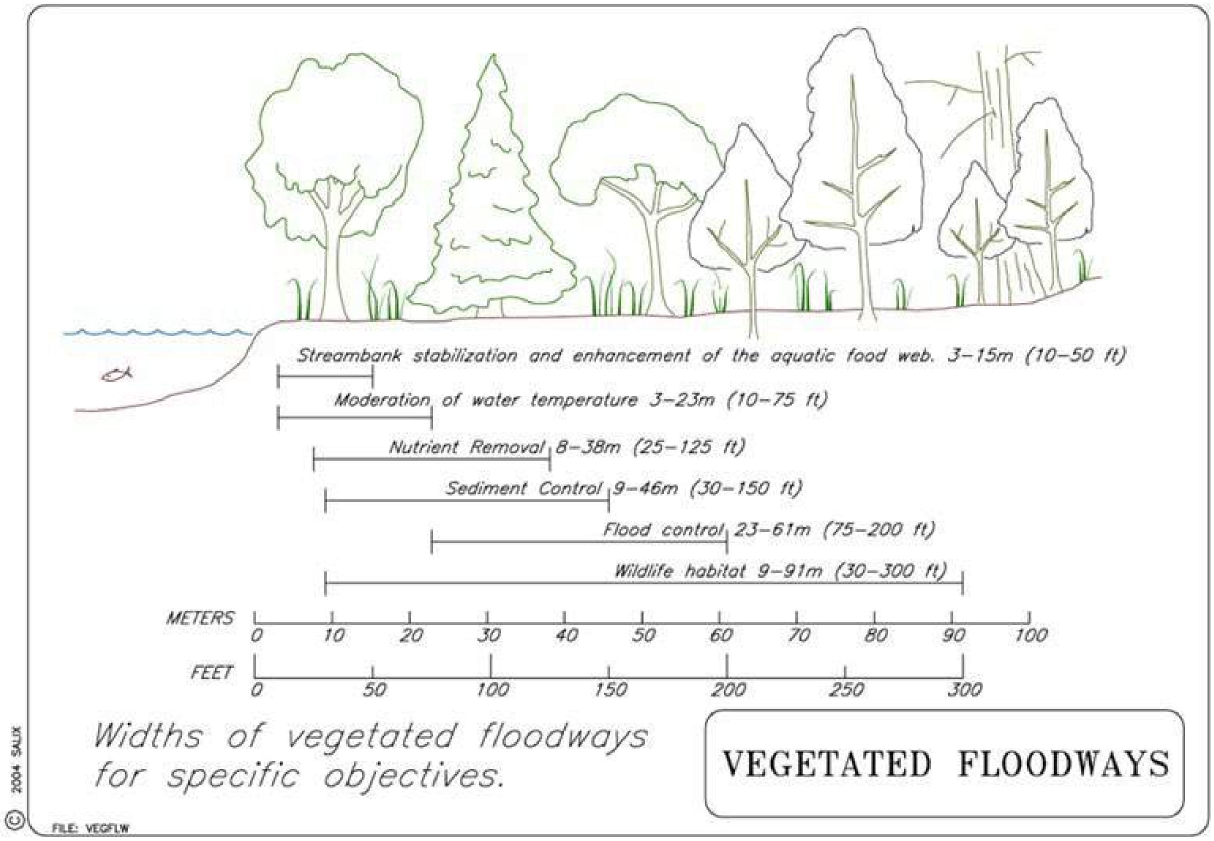


Photo 141: Riparian buffer zones and functional value widths

BANK STABILIZATION

A variety of methods are used to stabilize streambanks ranging from simple projects such as planting to more complex methods such as grading and potentially the placement of rock for toe protection or grade controls. The choice of method depends on a variety of factors including site hydraulics, stream order, erosion severity, channel incision, floodplain connectivity, and proximity to structures. Most stream stabilization and restoration projects rely heavily on a vegetative component. As with riparian buffer enhancement, vegetation serves a variety of functions the most important of which is the stabilization of the bank through the rooting.

GRADE CONTROL

In-stream grade control is also another important component of bed and bank stabilization. While erosion is mostly thought of as a problem with the banks, channel incision includes both horizontal (bank) and vertical (bed) erosion. The erosion of bed materials results in entrenchment or a hydraulic disconnect of the channel with the floodplain. Since the stream no longer is able to leave its banks all the flow is forced through the incised channel resulting in even greater erosion due to low flow area which yields increased velocities. Under these conditions a typical type of erosional process that develops is the head cut, an erosional feature in the bed that migrates upstream. Grade controls therefore mitigate these processes and could include several types of engineered features such as rock riffles, step pools, and cross vanes or V-weirs. Grade control measures are also frequently used when stream channels have been extensively reshaped or when impoundments have been removed to prevent the formation of head cuts and to align flows in the center of the channel. Another use of grade control structures is to elevate the entire channel of severely incised streams to restore floodplain connectivity.

PET WASTE MANAGEMENT

The key to this group of watershed management involves widespread implementation followed by consistent enforcement. As such, it is important to highlight primary elements of a successful pet waste management plan. Areas throughout West Milford that should be targeted for pet waste and wildlife management include public areas such as parks, beaches, and other recreational areas. Since they are public places, people may not always be equipped with the proper waste disposal items, such as small bags. Incorporating cultural practices like this also raises the general awareness of surface water protection and environmental stewardship by getting the community involved.

- Education and Outreach – As a program that is dependent on individual pet owners, education and outreach is key to the success. Educational elements should address public health and water quality impacts. Outreach can be done through multiple means including educational brochures, public meetings and committee formation, signage, and media campaigns including press releases and website publishing.
- Investigation – Identifying and prioritizing problem areas is important for managing the problem and will direct where waste management tools should be employed. Researching pet owner behavior through surveys and field studies can also be utilized.
- Waste Management – Providing waste receptacles and bags in public spaces encourages proper waste disposal.
- Public Policy – Leash laws, pet waste ordinance, and policy regarding animals in public spaces should be implemented with reasonable enforcement mechanisms.

FERTILIZER MANAGEMENT

It should be noted that the New Jersey legislature has passed new rules regulating fertilizer composition and usage. More information of this law, which went into effect in January 2010, can be obtained by downloading copies of the bill (S-2554/A-2290). The most significant feature of the law is that it bans phosphorus from over the counter fertilizers (the types of products sold at most big box retail stores). The legislation also limits the amount of nitrogen (0.7 lbs/1,000 ft2) in the fertilizer and specifies that at least 20% of the nitrogen must be in a time release formula. The legislation also restricts the timing of fertilizer application (no fertilizer applications between November 15 and March 1). Although the passage of this legislation may have significantly reduced fertilizer related loading to lakes, the Township should continue promote the voluntary measures discussed below.

The primary developed land use in most watersheds of New Jersey is the single family, residential lot, with some of those located in close proximity to the lake(s). The majority of the land area in the typical residential development within these watersheds is thus devoted to turf cover. Research has widely documented that lawns and turf areas can be major contributors of nutrients and sediment loads (Center for Watershed Protection, 2003). The propensity for lawn areas to contribute nutrients is directly related to the management and fertilizer application provided by the homeowner and therefore this is a behavior issue. Studies have shown that the majority of fertilizer application (75%) is done by homeowners. Furthermore, studies have also shown that the majority (50-70%) of fertilizers (homeowner and lawn care providers) apply fertilizer in excess of the lawn requirements. Proper fertilization application rates and types (if necessary at all) can only be determined through soil tests, however public surveys and research have indicated that less than 10% of home owners have ever had any soil tests conducted to assess the fertilizer requirement of their lawn. Unfortunately, many homeowners base their fertilizer application rates on information from commercial sources (fertilizer packaging labels, sales personnel, lawn care companies and other purveyors of fertilizer) (Center for Watershed Protection, 2005).

Fertilizer applications must also be timed properly to account for plant needs and to anticipate rainfall events. For example, nutrients are most needed in the spring and fall, not throughout the summer. Also, rain induced fertilizer losses are greatest immediately following an application because the material has neither become adsorbed by the soil nor taken up by the plants. Fertilizer uptake and retention is promoted by proper soil pH. Although soil pH can have a significant bearing on the ability of soils to retain nutrients, such testing is also not commonly conducted by property owners. The application of lime, especially in areas of acidic soils, can improve phosphorus uptake and retention. Other non-chemical lawn care treatments such as de-thatching and aeration are also rarely conducted (Watershed Protection, 1994). Urban soils, even those associated with lawns, can become compacted due to site clearing and grading practices and function similar to impervious areas in respect to the generation of storm water runoff (Schueler, 1995). Aerating lawns helps promote better infiltration and the generation of less runoff and therefore less export of nutrients.

Public Education is the main pathway to address these behavior issues related to NPS pollution. Homeowner behavioral changes that can have a significant impact on the NPS pollution related to lawn and turf area management include proper fertilizer application and reduced total turf areas. The reduction of turf areas is addressed in the following section. By applying only the necessary quantity and proper type of fertilizer necessary for optimum plant growth, the amount of nutrients that can potentially be mobilized and transported to surface and groundwater resources is minimized. Use of non-phosphorus fertilizers or slow-release nitrogen fertilizers also decreases the loading to receiving waters. The effectiveness of fertilizer management is dependent upon cumulative effects within a watershed and requires commitment on an area-wide basis.

The most effective public education techniques related to lawn care are those that illustrate the benefits of proper and educated lawn care behavior. Educational techniques should inform the residents that proper lawn management techniques can have direct financial benefits while still provide a desirable or potentially improved lawn.

Specific educational techniques that could be implemented by the Township include media awareness campaigns including the distribution of outreach materials related to proper lawn care techniques. These techniques should be focused (geographically) and timed to during the periods of peak fertilizer application (spring and fall). The outreach materials should include resources where homeowners can get their soil tested to determine proper fertilizer requirements. Programs for free or reduced cost soil tests will greatly increase public participation. The Public Education techniques should also focus on fertilizer retailers and attempt to provide informational brochures at retail locations during periods of high fertilizer sales. Specifically, the Township and any other pertinent stakeholders should conduct the public education campaign that informs all the residents of the benefits of fertilizer and pesticide management, stressing the low-cost alternatives and environmental benefits of such techniques. Residents should be educated about conducting soil pH and nutrient testing before applying any lawn care product to their lawn. They should also be informed about the benefits of liming, aeration, thatch control, and other non-chemical lawn care measures.

9.0 REGULATORY EVALUATION

The recommendations above are varied in type and location. Some of them, depending on the site and will require permits and approvals from the State of New Jersey. Below is a discussion of the expected site studies (e.g., wetland delineations, flood hazard verifications), permits (e.g., freshwater wetlands) and approvals that maybe required for some of the proposed projects. Following the descriptions is a table that summarizes the anticipated requirements for each of project categories recommended above. Please note that the permits and approvals are only required when a proposed activity would disturb or impact the regulated resource (e.g., placing fill in a freshwater wetland). Therefore, the requirement to obtain a permit (or approval) is heavily dependent on the existing site conditions and how the proposed activity is installed or constructed. Without site specific investigation and conceptual designs, at minimum, this evaluation can only be generic in nature.

Wetland Delineation

The proposed projects may require a delineation of the project areas' freshwater wetlands and state open waters in accordance with the Federal Manual for Identifying and Delineating Jurisdictional Wetlands of 1989 and the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (Version 2.0). Wetland delineations are based on an examination of the vegetation, soils, and hydrology found on the site. State open Waters are delineated by the ordinary highwater mark. The wetlands and state open waters would be identified by sequentially numbered, colored survey flagging. Subsequent to the delineation, a professional land surveyor licensed in New Jersey would need to survey the boundary flags in support of a wetland delineation plan (described below). In support of a Letter of Interpretation (LOI) – Line Verification (see below), all requisite data related to the required soil borings, plant inventory, and site hydrology would be collected during this effort and incorporated into the Letter of Interpretation – Line Verification application submitted to the New Jersey Department of Environmental Protection (NJDEP) Division of Land Resource Protection (DLRP) to request its concurrence on the boundaries delineated herein.

NJDEP Letter of Interpretation – Line Verification Application

A Letter of Interpretation (LOI)- Line Verification in compliance with N.J.A.C. 7:7A-4.5 may be required for the proposed projects. The LOI is a process through which an applicant requests that the NJDEP DLRP review a wetland delineation and concur with the delineated boundaries of freshwater wetlands and state open waters on the site. The submittal includes an application, site mapping (e.g., USGS, Aerial, Soils, mapped wetlands), a database search for threatened and endangered species, a wetland delineation report, a photograph log and map, and a wetland delineation map signed by a professional land surveyor licensed in New Jersey.

Fee: $1,000 plus $100 per acre or fraction thereof associated with the block(s), lot(s), or project area that are the subject of the LOI application.

Recording Verification with County Clerk and NJDEP

Subsequent to receipt of the LOI, the NJDEP DLRP requires that all LOIs be recorded with the county in which the LOI was issued. The recording must include the approval and expiration date of the LOI; a metes and bounds description of the wetland boundary approved under the LOI (prepared by the surveyor); the width and location of any transition area approved under the LOI; and the following statement: "The State of New Jersey has determined that all or a portion of this lot lies in a freshwater wetland and/or transition area. Certain activities in wetlands and transition areas are regulated by the New Jersey Department of Environmental Protection and some activities may be prohibited on this Site or may first require a freshwater wetland permit. Contact the DLRP at (609) 777-0454 or http://www.nj.gov/dep/landuse for more information prior to any construction onsite."

Recording Fee: $45 first sheet, $10 each additional sheet.

Flood Hazard Area Verification

A Flood Hazard Area (FHA) Verification, in compliance with N.J.A.C 7:13-5, may be required for the proposed projects, dependent on existing FEMA and state flood studies. The verification provides the NJDEP DLRP official determination of the extent of the flood hazard areas (i.e., floodway and flood fringe) and design flood elevation, and riparian zone limits. The submittal includes an application form, site mapping (e.g., USGS, Aerial, Soils), an engineering report, a photographic log and map, a database search for threatened and endangered species, and a Flood Hazard Area Verification Plan that represents the extent of the proposed flood hazard area (floodway, flood fringe,) and riparian zone. This plan would also include a metes and bounds description of the proposed flood hazard area and is required to be signed by a professional engineer licensed in the state of New Jersey.

Fee: Dependent on FEMA and state flood studies.

Recording Verification with County Clerk and NJDEP

Subsequent to receipt of an approved flood hazard verification, the NJDEP-DLRP requires that all verifications be recorded with the county in which the verification was issued. The recording must include the following information : (1) the NJDEP file number for the verification; (2) the approval and expiration dates of the verification; (3) a metes and bounds description of any flood hazard area limit and/or floodway limit approved under the verification; (4) the flood hazard area design flood elevation approved under the verification; (5) the width and location of any riparian zone approved under the verification; and (6) the statement described at N.J.A.C. 7:13-5.6(a)6.

Fee: $45 first sheet, and $10 for each additional sheet.

Pre-application Meeting

Prior to the submission of the required applications (described below) pre-application meeting(s) with the NJDEP-DLRP is recommended. The purpose of the meeting would be to introduce the proposed project to the agencies along with the anticipated permitting pathway to seek (1) their initial comments on the proposed project, and (2) get agency buy-in on the proposed permitting pathway. This offers the presiding agencies and design team the opportunity to clarify potential design conflicts as it relates to the required permit approvals and to identify any potential concerns related to the issuance of the requisite permits to implement the proposed project. It is also an opportunity for the agencies to provide recommendations related to streamlining the review process based on the proposed design.

Fee: No fee

Highlands Water Protection and Planning Act

The Highlands Water Protection and Planning Act and its implementing rules found at N.J.A.C. 7:38, identify the Highlands as an essential source of drinking water for half of the residents of New Jersey. West Milford Township is located within the Highlands Preservation Area. If any of the proposed projects are a Major Highlands development in the Preservation Area, it must first obtain a Highlands Preservation Area Approval (HPAA) or a Highlands Applicability Determination (HAD) for an exemption determination. Major Highlands Developments are defined in N.J.A.C. 7:38-1.4 and include, but are not limited to, the disturbance of one acre or more of land or a cumulative increase in impervious surface by one-quarter acre or more; any activity in the Preservation Area, that results in the disturbance of one- quarter acre or more of forested areas; any capital or other project of a state or local government unit, in the

Preservation Area, that requires an environmental land use or water permit or that results in the disturbance or one acre or more of land or a cumulative increase in impervious surface by one-quarter acre or more.

Freshwater Wetlands Protection Act

Freshwater wetlands, their associated transition areas, and state open waters are regulated under the Freshwater

Wetlands Protection Act and its implementing rules in N.J.A.C. 7:7A. Further, all waterbodies and wetlands within the Highlands Preservation Area are considered "Highlands open waters" as defined in N.J.A.C. 7:38-1.4. The distinguishing factor is that all wetlands, springs, streams (perennial and intermittent), and bodies of surface water (natural or artificial) have a 300-foot buffer adjacent to their upland boundaries per N.J.A.C. 7:38-3.6. Any project that would disturb Highlands open waters or the 300-foot buffer would require review and authorization under the Freshwater Wetlands Protection Act or one of the two Highlands General Permits; General Permit 1 – Habitat Creation and Enhancement Activities or General Permit 2 – Bank Stabilization.

Recording Verification with County Clerk and NJDEP:

Subsequent to receipt of an approved freshwater wetlands permit, the NJDEP-DLRP requires that all permits be recorded with the county in which the verification was issued. The recording must include the following information : (1) the NJDEP file number for the permit; (2) the approval and expiration dates of the permit; (3) a metes and bounds description of any flood hazard area limit and/or floodway limit approved under the verification; (4) the flood hazard area design flood elevation approved under the verification; (5) the width and location of any riparian zone approved under the verification; and (6) the statement described at N.J.A.C. 7:13-5.6(a)6.

Fee: $45 for the first sheet and $10 for each additional sheet.

Rare, Threatened, and Endangered Species & Habitat

All of the proposed projects would require an evaluation of the potential effects on rare, threatened, and endangered species and their habitats. The first step is a data request sent to the NJDEP Natural Heritage Program (NHP). The request is a single-page form and requires a site map (USGS topographic map). The review time is 30 days, and the fee is $70. In return, the NHP will provide a list of species observed on-site and in the vicinity. It is then the responsibility of the applicant to determine the effects of the project on the identified species and their habitats. NJDEP biologists in the Threatened and Endangered Species unit then review the assessment and either accept the determinations or provide comments and recommendations on the proposed activities.

Clean Water Act (CWA) Section 401 Water Quality Certification:

Under the CWA, states have the authority to grant, deny, or waive certification of proposed federal licenses or permits that may discharge into or fill waters of the United States and/or navigable waters. As such, during the federal permitting process listed above, the state of New Jersey will also review the project and determine if it is consistent with Section 401 of the Federal Clean Water Act in accordance with N.J.A.C. 7:7A and the Surface Water Quality Standards provided in N.J.A.C. 7:9B. The NJDEP DLRP would conduct this review during the Freshwater Wetlands Protection Ac Permit process described above.

Fee: No fee.

Flood Hazard Area Control Act Permit:

The New Jersey Flood Hazard Area Control Act, N.J.S.A. 58:16A-50 et seq. are implemented via the Flood Hazard Area (FHA) Control Act Rules at N.J.A.C 7:13. The proposed projects may require approval(s) under these rules for proposed disturbance to the floodway, flood fringe and riparian zone of regulated waters, as define in N.J.A.C 7:13-1.2.

The NJDEP DLRP has several permit pathways, including permits-by-rule, permits-by-certification, general permits, and individual permits. It is recommended that the specific permitting pathway be discussed and agreed upon with DLRP, via a pre-application meeting, prior to the preparation and submission of any permit application.

Fee: The permit fees are dependent on the activities proposed and the subsequent permit pathways.

Soil Erosion and Sediment Control Plan Certification:

The New Jersey Soil Erosion and Sediment Control Act (N.J.S.A. 4:24-39 et seq.) stipulates that any project that proposes 5,000 square feet of land disturbance or greater requires certification from the presiding Soil Conservation District. This certification includes a review of the proposed earth disturbance activities and proposed Erosion and Sediment Control Best Management Practice (ESC-BMP) measures to be implemented to minimize erosion and the associated potential for pollution to water resources to the maximum extent practicable. The implementation and maintenance of ESC-BMPs are required to minimize the potential for accelerated erosion and sedimentation. Some of the proposed projects may exceed 5,000 square feet of earth disturbance and are proximate to waterbodies. Therefore, approval from the Hudson Essex Passaic Soil Conservation District (HEPSCD) may be required.

The required submission would include a completed HEPSCD application form and checklist, a completed requisite plan set, and a project drainage report supporting stability and erosion control calculations.

Fee: Fees are dependent on disturbance. Please refer to the fee schedule here: https://hepsoilnj.org/fee-schedule-effective-july-1-2023/

New Jersey Pollution Discharge Elimination System (NJPDES) Permits:

5G3-Construction Activity

Certain construction activities that disturb greater than one acre of land within New Jersey require a 5G3-Construction Activity Stormwater approval from NJDEP. Examples of earth disturbance activities include but are not limited to, commercial and residential development, timber harvesting, utility line installation, and road maintenance and drainage improvements. If any of the projects exceed the one-acre of earth disturbance threshold, it would trigger the requirement to procure this approval.

Fee: Projects with an area of disturbance of less than five (5) acres require a $450 dollar fee. Projects with an area of disturbance greater than or equal to five (5) acres require a $650 fee.

Pesticide Application Discharge (PGP)

This is a general permit that authorizes the application of biological or chemical pesticides in surface waters of the state (e.g., lakes and ponds). Products used to treat aquatic invasive species require this permit.

Local and other permits

Discussed above, are permits and approvals that are required under state laws. However, there are additional permits and approvals that may be required on a case-by-case basis for the proposed projects. We recommend that an assessment of other required permits and approvals be conducted prior to commencing design on any of these projects. For instance, the township, Passaic counties, and the New Jersey Department of Transportation have ownership and rights for the roads and rights-of-way they maintain. Activities that will obstruct or require "opening" the roadway (i.e., installation of MTDs) would require a road opening or encroachment permit from the roadway owner. Further, the MTDs, if installed on a county-owned storm drain, would require a Storm Drain Connection Permit, from Passaic County.

Table 254. Regulatory Evaluation Summary

Activity	Wetland Delineation	Letter of Interpretation	Flood Hazard Area Verification	Pre-Application Meeting	Highlands Preservation Area Approval/Highlands Applicability Determination	Freshwater Wetlands Protection Act Permit	Rare, Threatened, and Endangered Species & Habitat Evaluation	CWA Section 401 Certification	Flood Hazard Area Control Act Permit	Soil Erosion and Sediment Control Plan Certification	NJDPES 5G-3 Permit	NJPDES PGP Permit	Other Permits and Approvals
Watershed Based Activities													
Shoreline and Bank Stabilization	Recommended	As needed	Site-Dependent	Case-by-Case	HAD minimum	Required	Required	Required	Required	Required	Site Dependent	not required	Site-Dependent
Riparian Zone Enhancement	Recommended	As needed	Site-Dependent	Case-by-Case	HAD minimum	Site Dependent	Required	Site Dependent	Required	Required	Site Dependent	not required	Site-Dependent
Defined and Stabilized Access Points	Site-Dependent	As needed	Site-Dependent	Case-by-Case	HAD minimum	Site Dependent	Site Dependent	Site Dependent	Site Dependent	Site Dependent	Site Dependent	not required	Site-Dependent (but likely required)
Rain Gardens, vegetated swales & Bio-retention Systems	Site-Dependent	As needed	Site-Dependent	Case-by-Case	HAD minimum	Site Dependent	Site Dependent	Site Dependent	Site Dependent	Site Dependent	Site Dependent	not required	not required
Ditch Expansion	Site-Dependent	As needed	Site-Dependent	Case-by-Case	HAD minimum	Site Dependent	Site Dependent	Site Dependent	Site Dependent	Site Dependent	Site Dependent	not required	not required
Porous Pavement, Asphalt Apron	Site-Dependent	Not Needed	Site-Dependent	Not needed	not required	Site Dependent[1]	Site Dependent	Site Dependent	Not Needed[2]	Site Dependent	Site Dependent	not required	Site-Dependent
Terrestrial Invasive Species Management	Site-Dependent (but recommended)	Not Needed	Site-Dependent (but unlikely)	Not needed	HAD recommended	Site Dependent[3]	Site Dependent	Site Dependent	Site Dependent[4]	Site Dependent (but unlikely)	Site Dependent (but unlikely)	not required	Site-Dependent (but unlikely)
Lawn conversions	Site-Dependent	Not Needed	Site-Dependent (but unlikely)	Not needed	HAD recommended	Site Dependent	Site Dependent	Site Dependent	Site Dependent	Site Dependent (but unlikely)	Site Dependent (but unlikely)	not required	Site-Dependent (but unlikely)
Installation of Manufactured Treatment Device	Site-Dependent (but recommended)	Not Needed	Site-Dependent	Case-by-Case	HAD recommended	Site Dependent	Site Dependent	Site Dependent	Site Dependent	Site Dependent (but unlikely)	Site Dependent (but unlikely)	not required	Site-Dependent
In-Lake Based Activities													
Aeration	As needed at staging, stockpiling, and access points	As needed at staging, stockpiling, and access points	Site-Dependent for upland infrastructure	Case-by-Case	HAD minimum	Site Dependent	Recommended	Site Dependent	Site Dependent	Site Dependent	Unlikely	not required	Site-Dependent (but unlikely)
Biochar	Not Needed	Not Needed	Not Needed	Recommended	HAD recommended	Site Dependent	Not Needed	Site Dependent	Site Dependent	Not needed	Not needed	not required	Site-Dependent (but unlikely)
Dredging	As needed at staging, stockpiling, and access points	As needed at staging, stockpiling, and access points	Site Dependent	Case-by-Case	HAD minimum	Required	Required	Required	Site Dependent	Required	Site Dependent	not required	Site-Dependent
Floating Wetland Islands	Not Needed	Not Needed	Not Needed	Not Needed	HAD recommended	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	not required	not required
Mechanical Aquatic Vegetation Management	Not Needed	Not Needed	Not Needed	Not Needed	HAD recommended	Site Dependent[5]	Site Dependent	Site Dependent	Not needed	Not needed	Not needed	not required	not required
Aquatic Invasive Species Management (i.e., Herbicides)	Not Needed	Not Needed	Not Needed	Not Needed	HAD recommended	Site Dependent[6]	Site Dependent	Site Dependent	Not needed	Not needed	Required	Treatment method and site dependent	Required
Nutrient Inactivation and/or Sequestration (i.e., alum treatment)[6]	Not Needed	Not Needed	Not Needed	Recommended	HAD recommended	Maybe Required	Site Dependent	Site Dependent	Not Required	Not Required	Not Required	not required	not required
EutroSORB Bags	Site-Dependent	Not Needed	Not Needed	Recommended	HAD recommended	Maybe Required	Site Dependent	Site Dependent	Not Required	Not Required	Not Required	not required	not required

[1] A Freshwater wetlands Permit is required if repaving is located within a transition area. General permit 26 (NJAC 7:7A-7.26) maybe applicable if the conditions are met.

[2] A Flood Hazard Area permit is required if the work is located within the Flood Hazard Aras. Permits by rule 1-3 (NJAC 7:13-7.1-7.3) may apply if the conditions are met.

[3] A Freshwater Wetlands Permit is required if pesticide is applied in wetlands or transition areas. General Permit 27 (NJAC 7:7A-7.27) maybe applicable if the conditions are met.

[4] A Flood Hazard Area permit is required if the treatment is located within a riparian zone. Permit-by-rule 14 (NJAC 7:13-9.14) may apply if the conditions can be met.

[5] Mechanical removal that disturbs the lake bottom requires a Freshwater Wetlands permit.

[6] In discussions with NJDEP staff, the application of alum does not require any permits. However, details about applications and water quality data must be submitted for each instance.

10.0 REFERENCES

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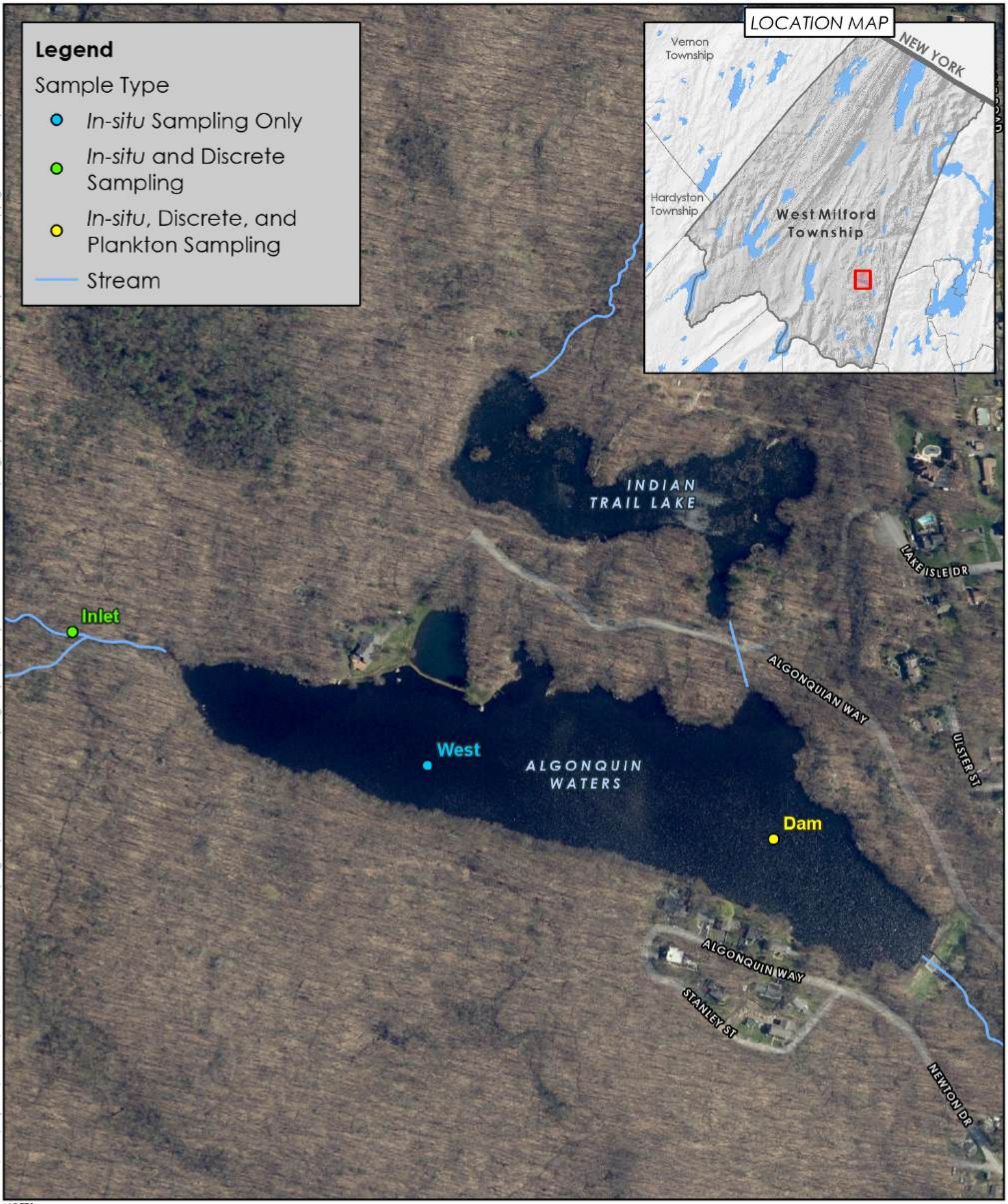
APPENDIX I – WATER QUALITY SAMPLING MAPS



NOTES:
1. Lake sampling points are approximate. Samples collected by Princeton Hydro.
2. Waterbodies obtained from the United States Geological Survey (USGS) National Hydrography Dataset (NHD).
3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

ALGONQUIN WATERS SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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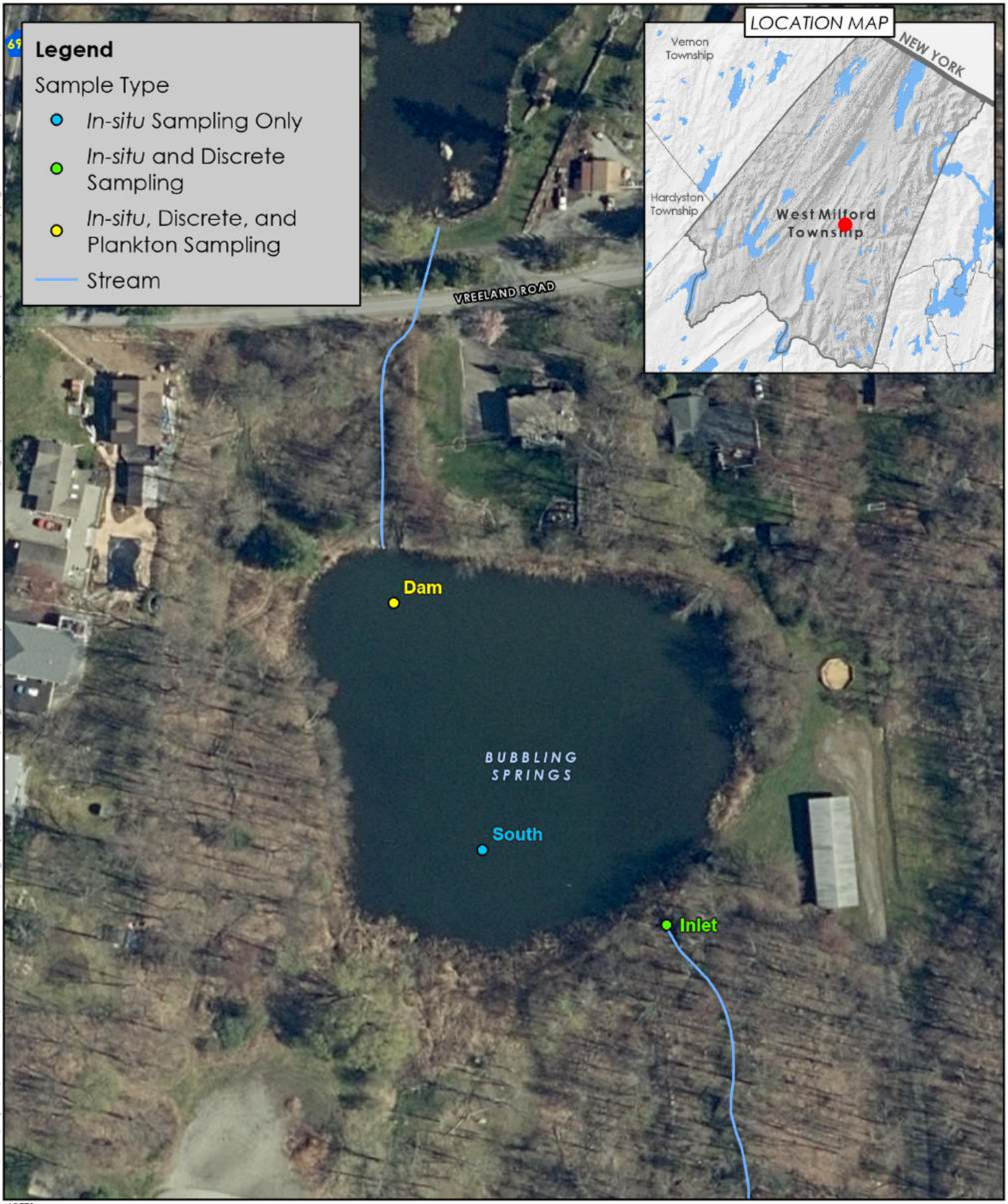

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 50 100 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

BUBBLING SPRINGS POND SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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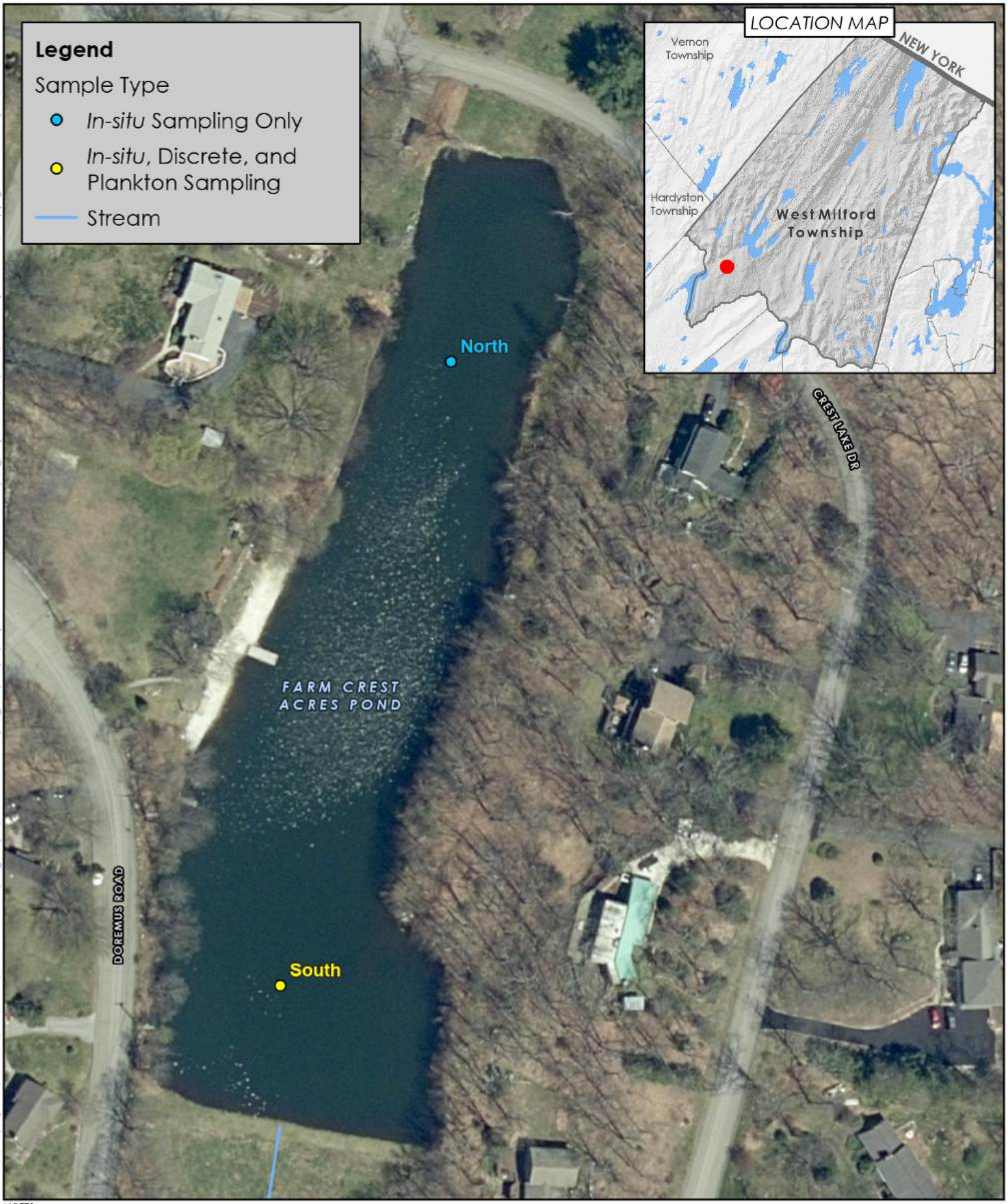

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 50 100 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

FARM CREST ACRES POND SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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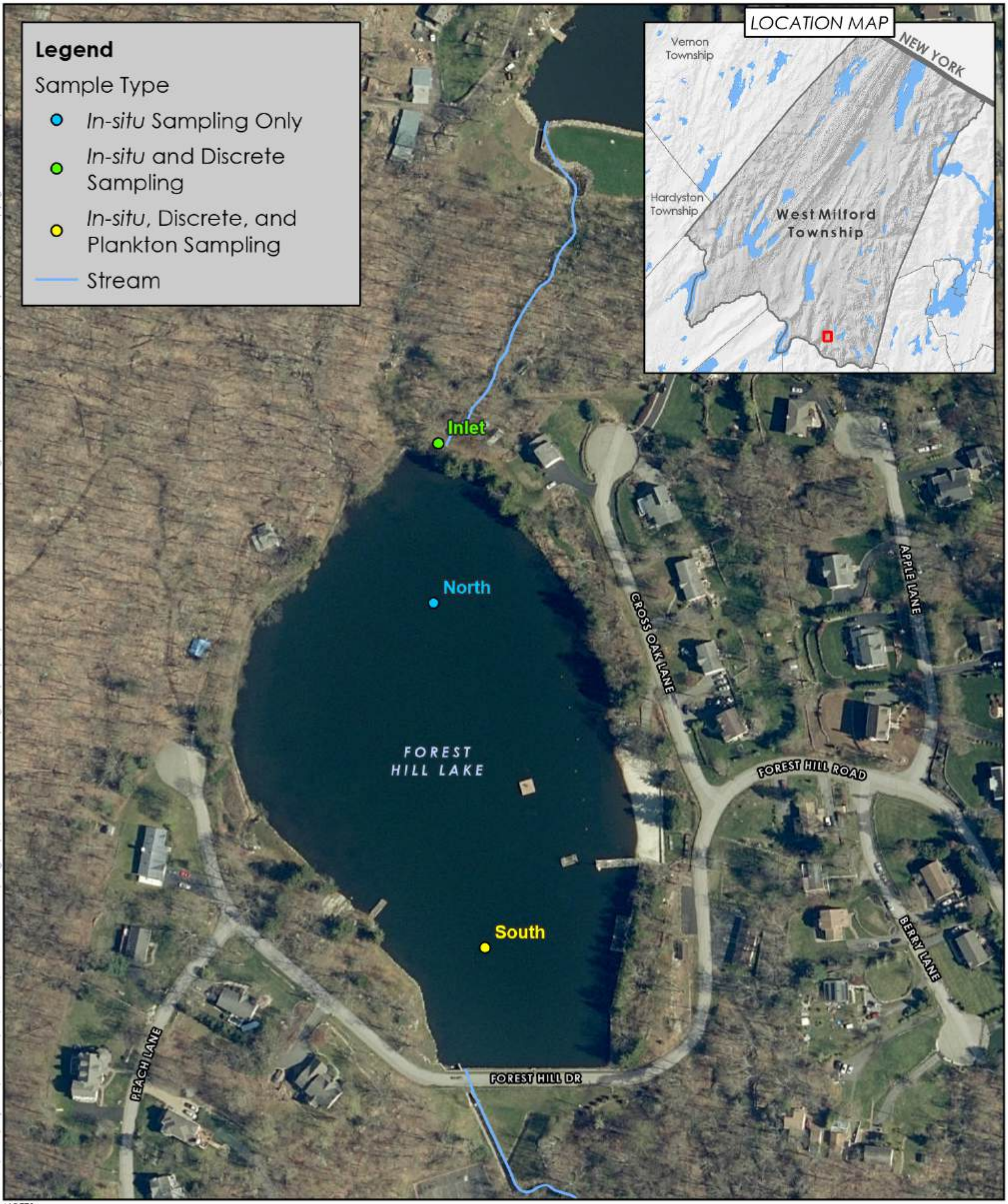

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 100 200 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

FOREST HILL LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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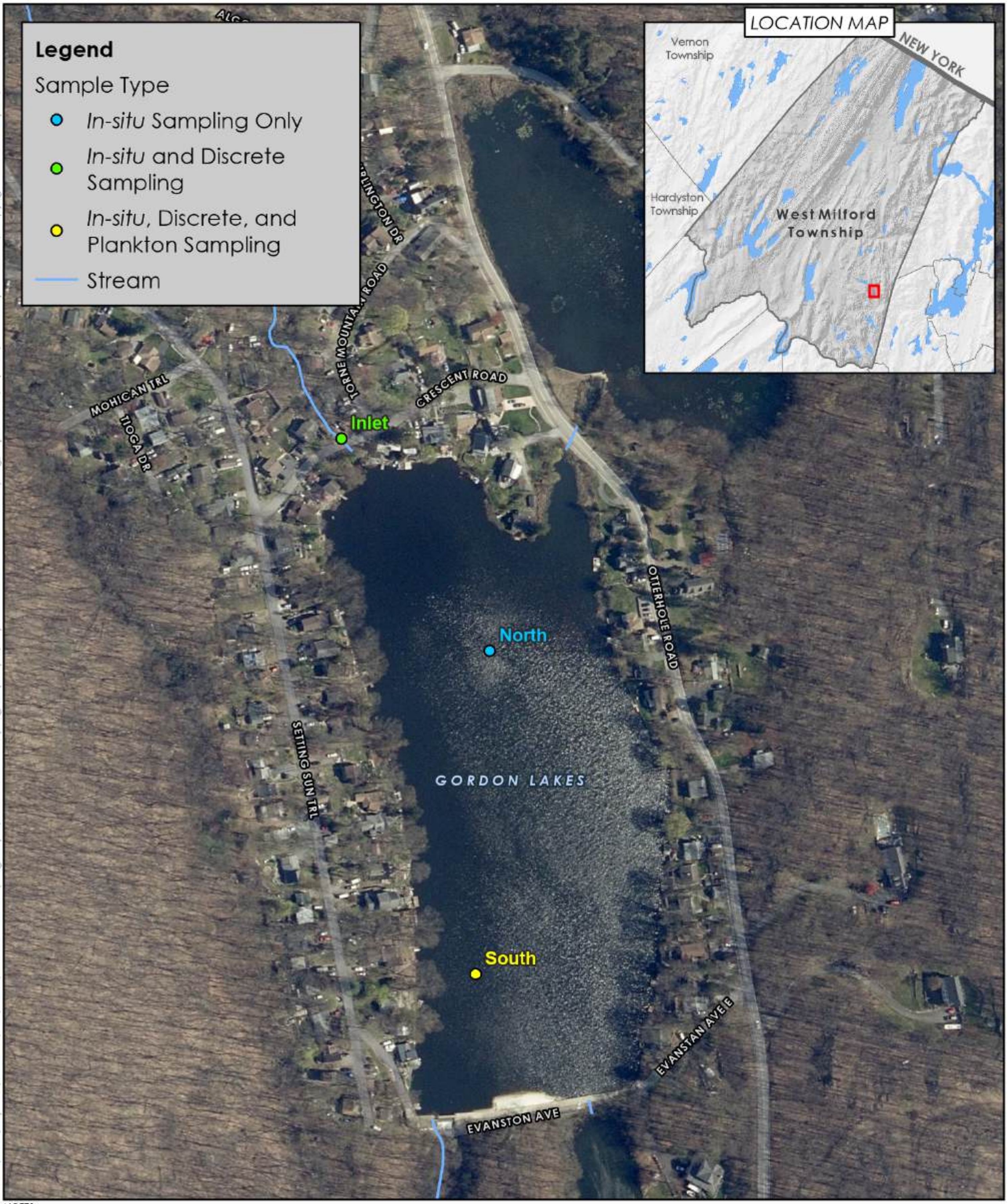

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0 125 250 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

GORDON LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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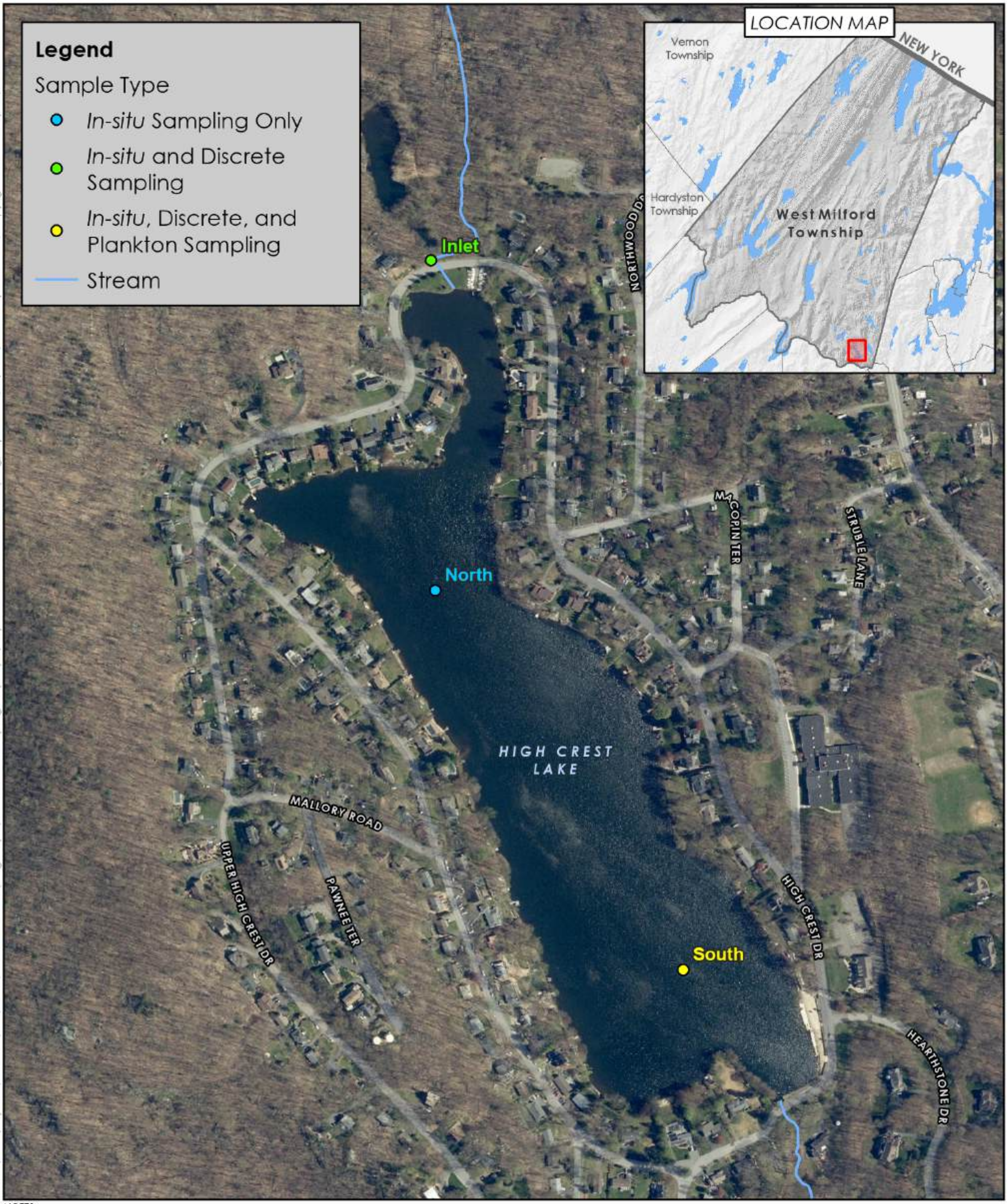

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NOTES:
1. Lake sampling points are approximate. Samples collected by Princeton Hydro.
2. Waterbodies obtained from the United States Geological Survey (USGS) National Hydrography Dataset (NHD).
3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

HIGH CREST LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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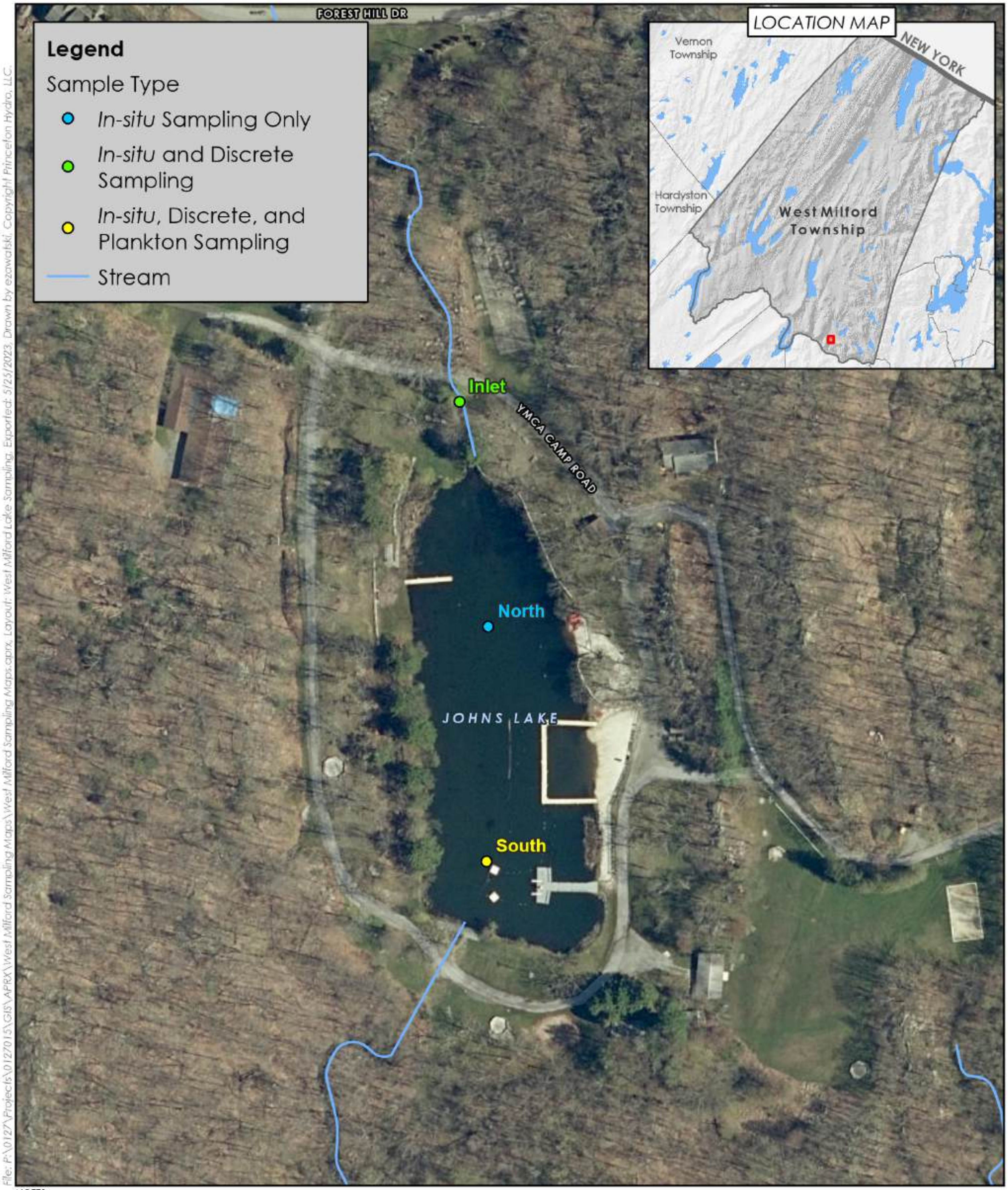

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 75 150 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

JOHNS LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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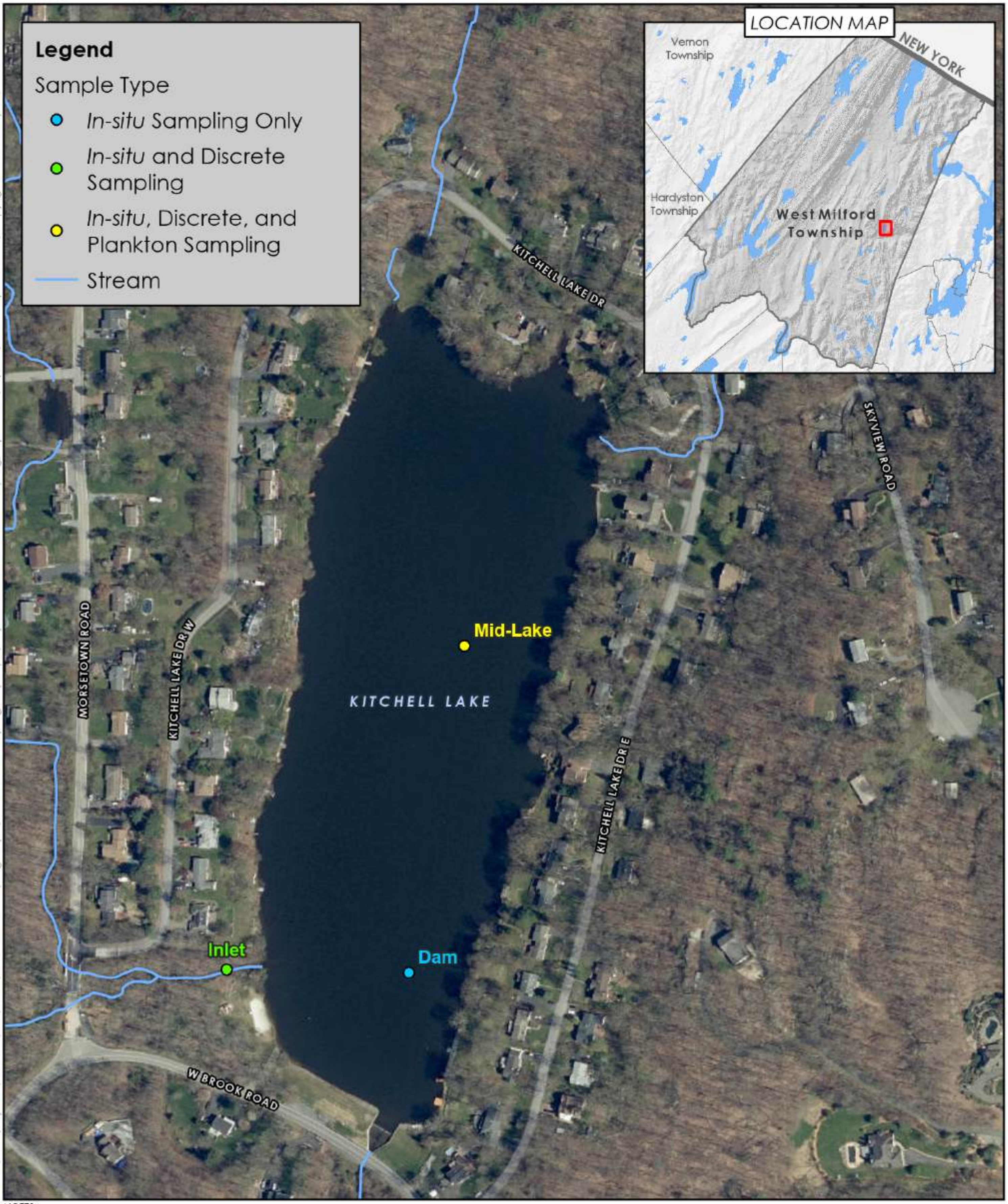

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 150 300 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

KITCHELL LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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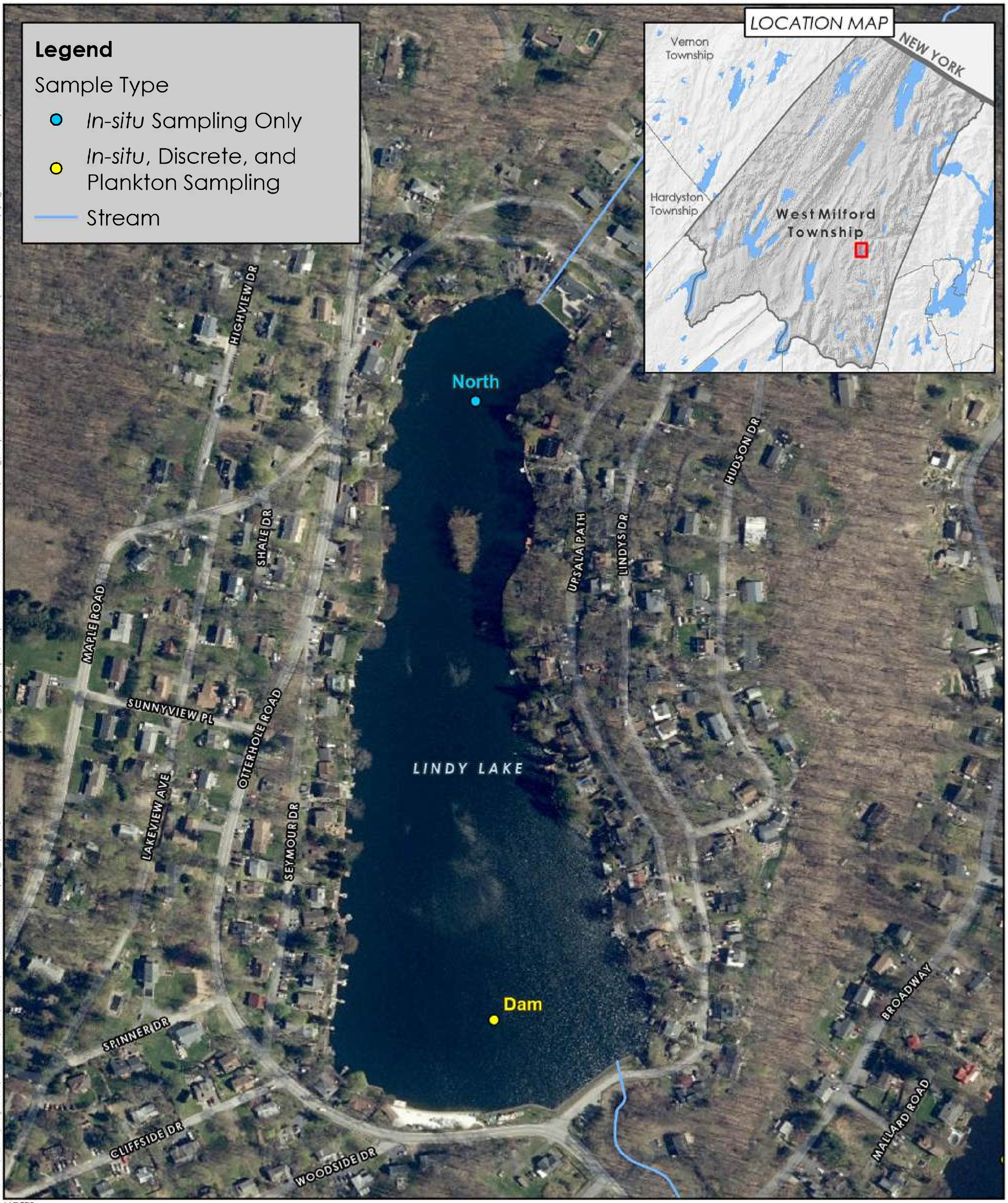

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 150 300 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

LINDY'S LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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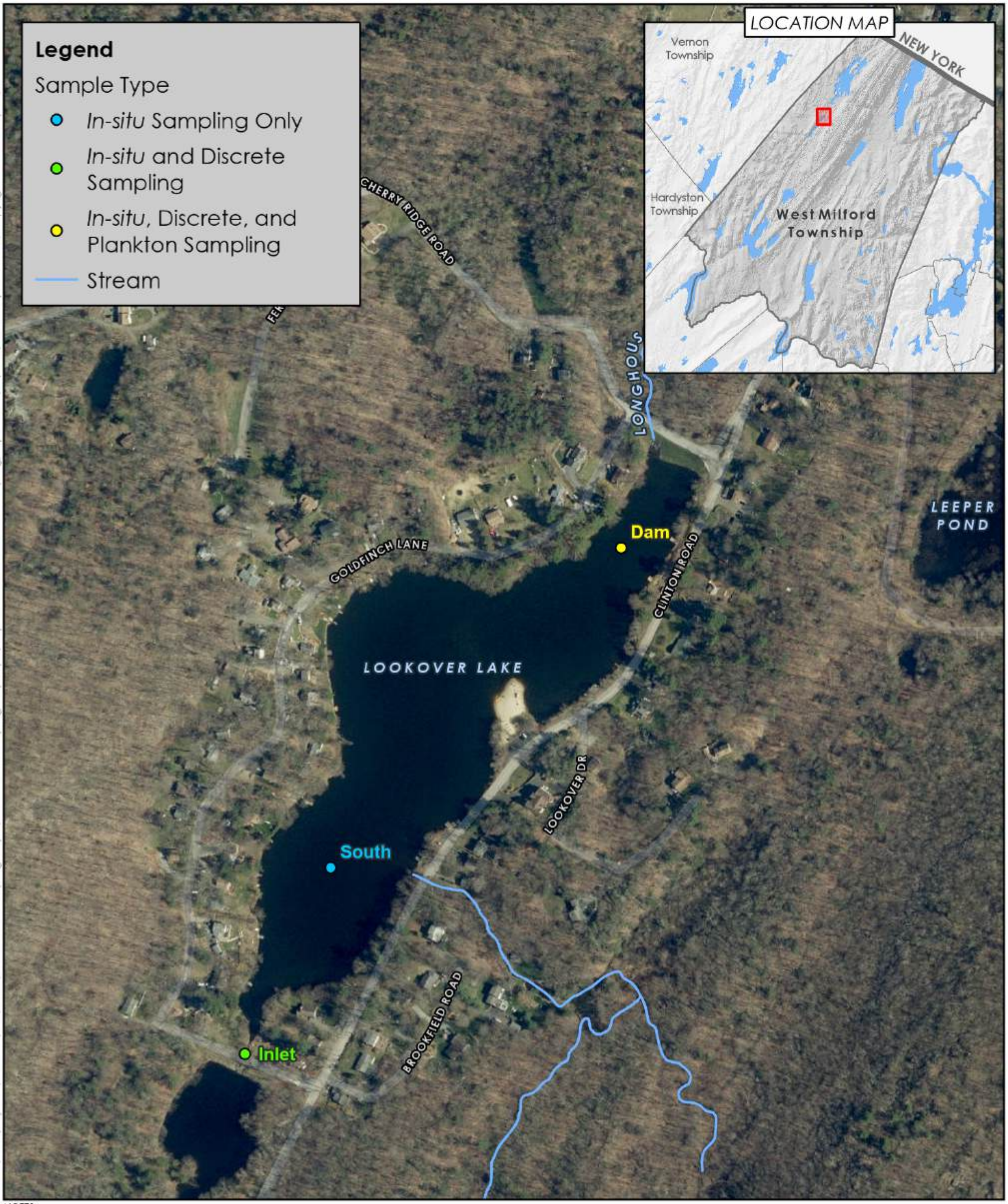

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0 175 350 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

LOOKOVER LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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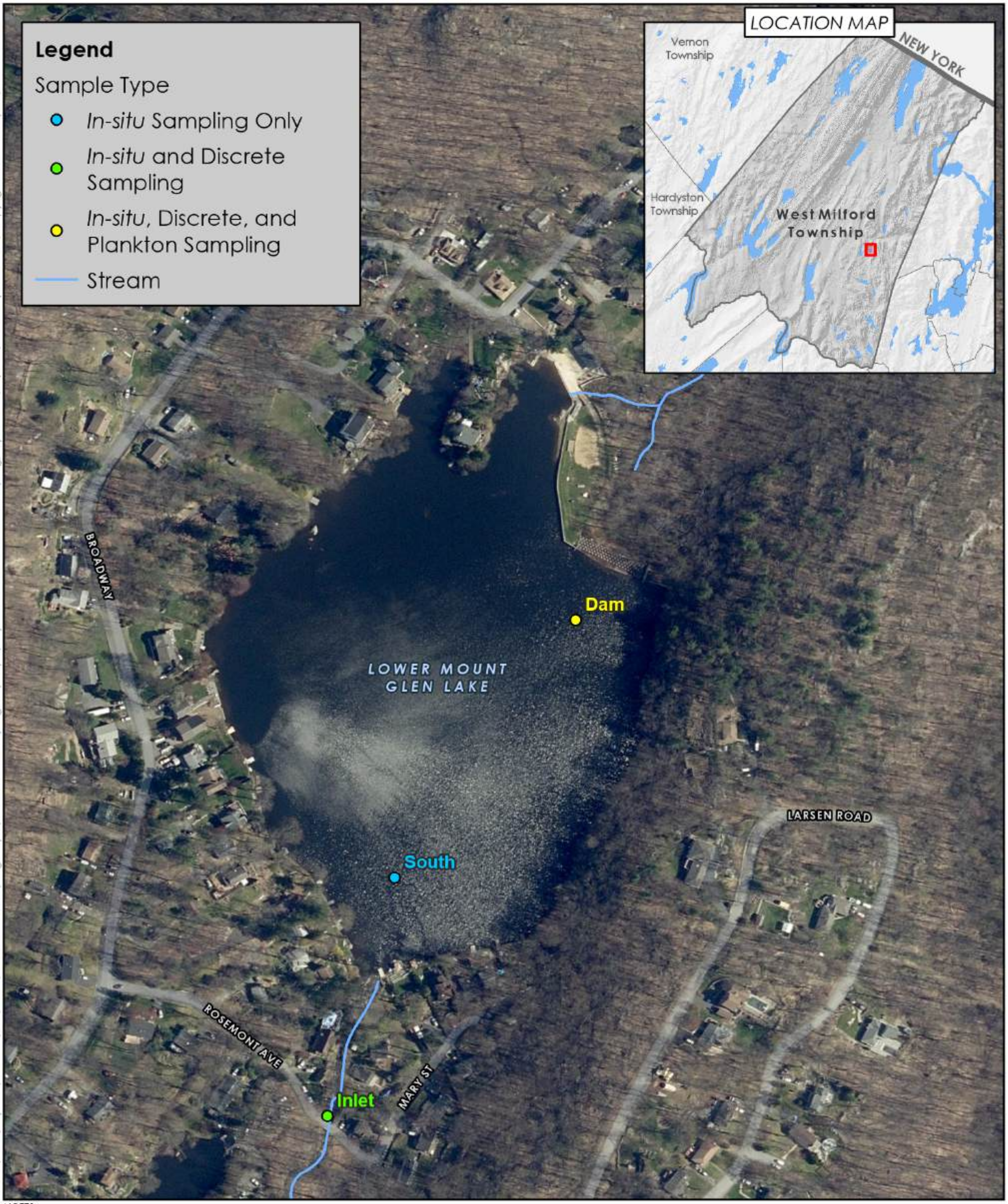

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 125 250 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

LOWER MOUNT GLEN LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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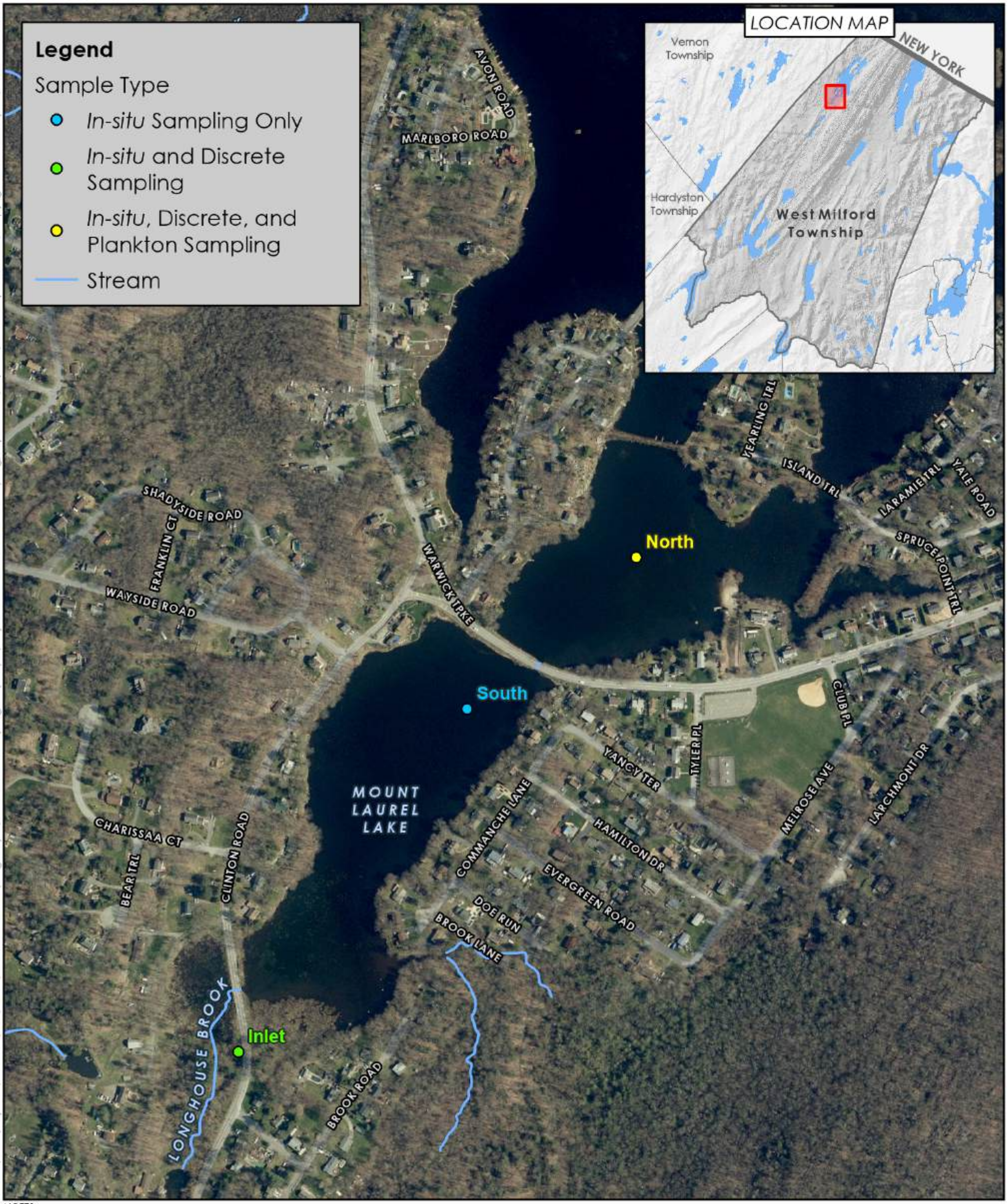

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 250 500 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

MOUNT LAUREL LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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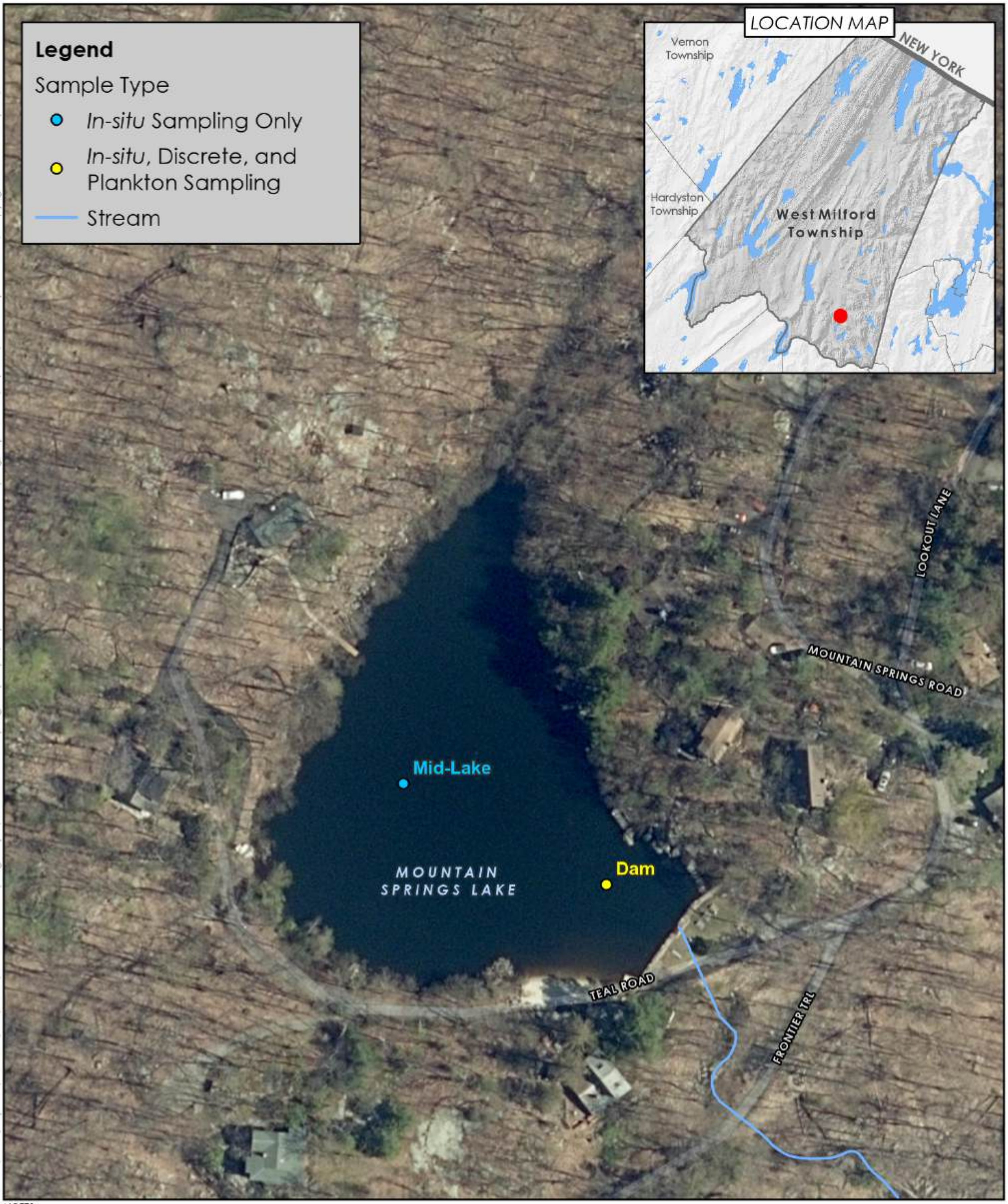

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 50 100 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

MOUNTAIN SPRINGS LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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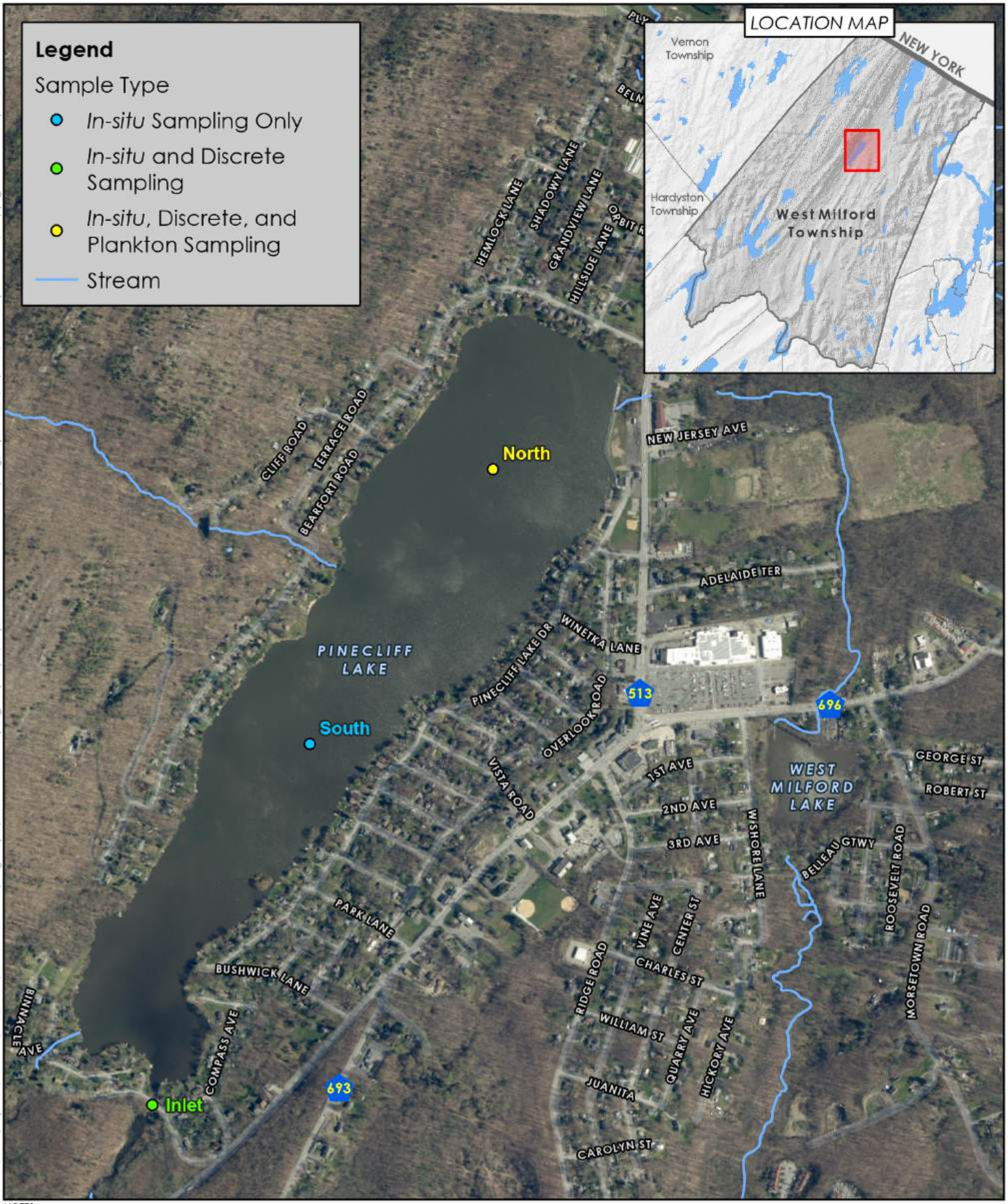

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2. Waterbodies obtained from the United States Geological Survey (USGS) National Hydrography Dataset (NHD).
3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 450 900 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

PINECLIFF LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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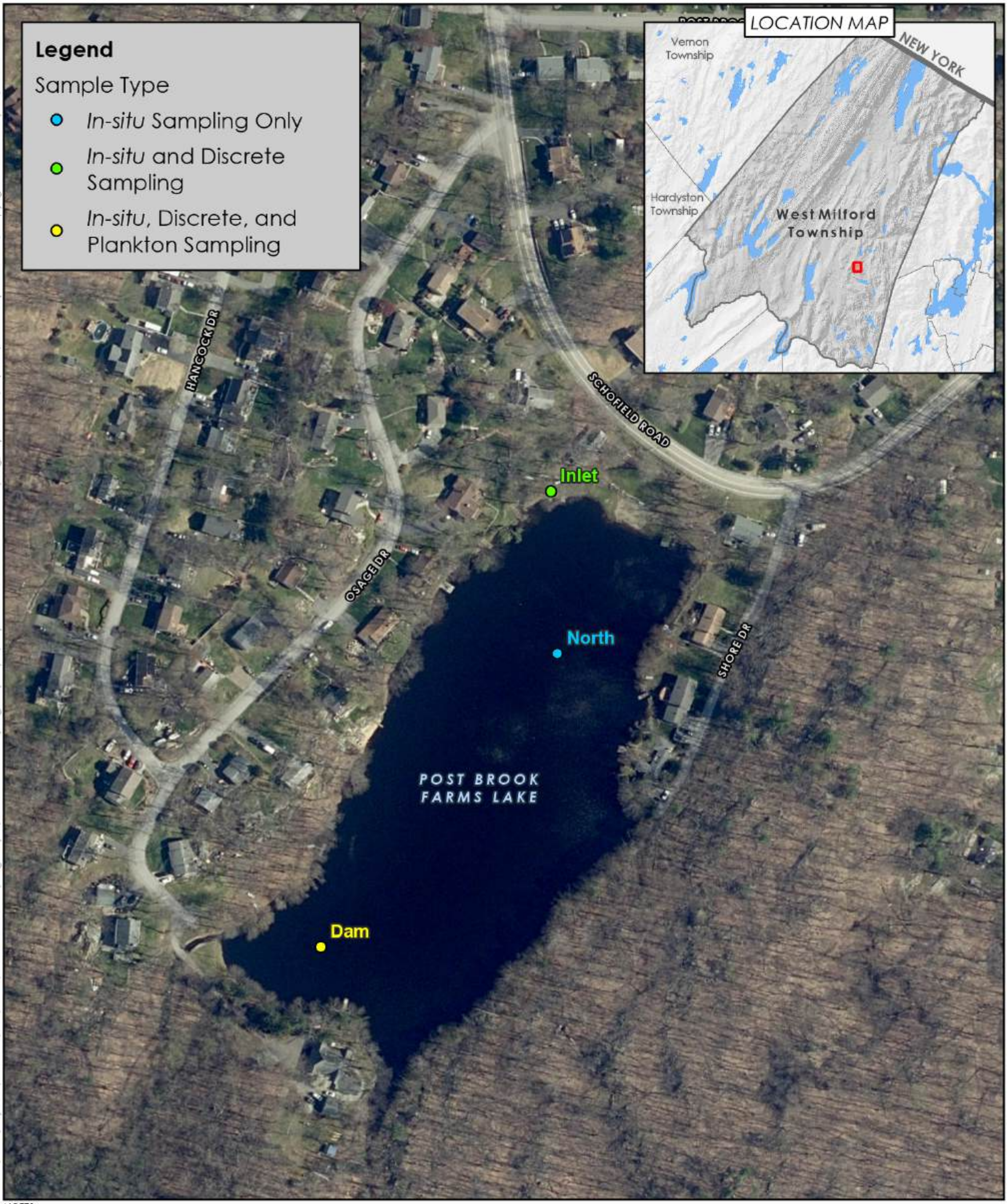

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2. Waterbodies obtained from the United States Geological Survey (USGS) National Hydrography Dataset (NHD).
3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 100 200 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

POST BROOK FARMS LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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NOTES:
1. Lake sampling points are approximate. Samples collected by Princeton Hydro.
2. Waterbodies obtained from the United States Geological Survey (USGS) National Hydrography Dataset (NHD).
3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 100 200 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

SHADY LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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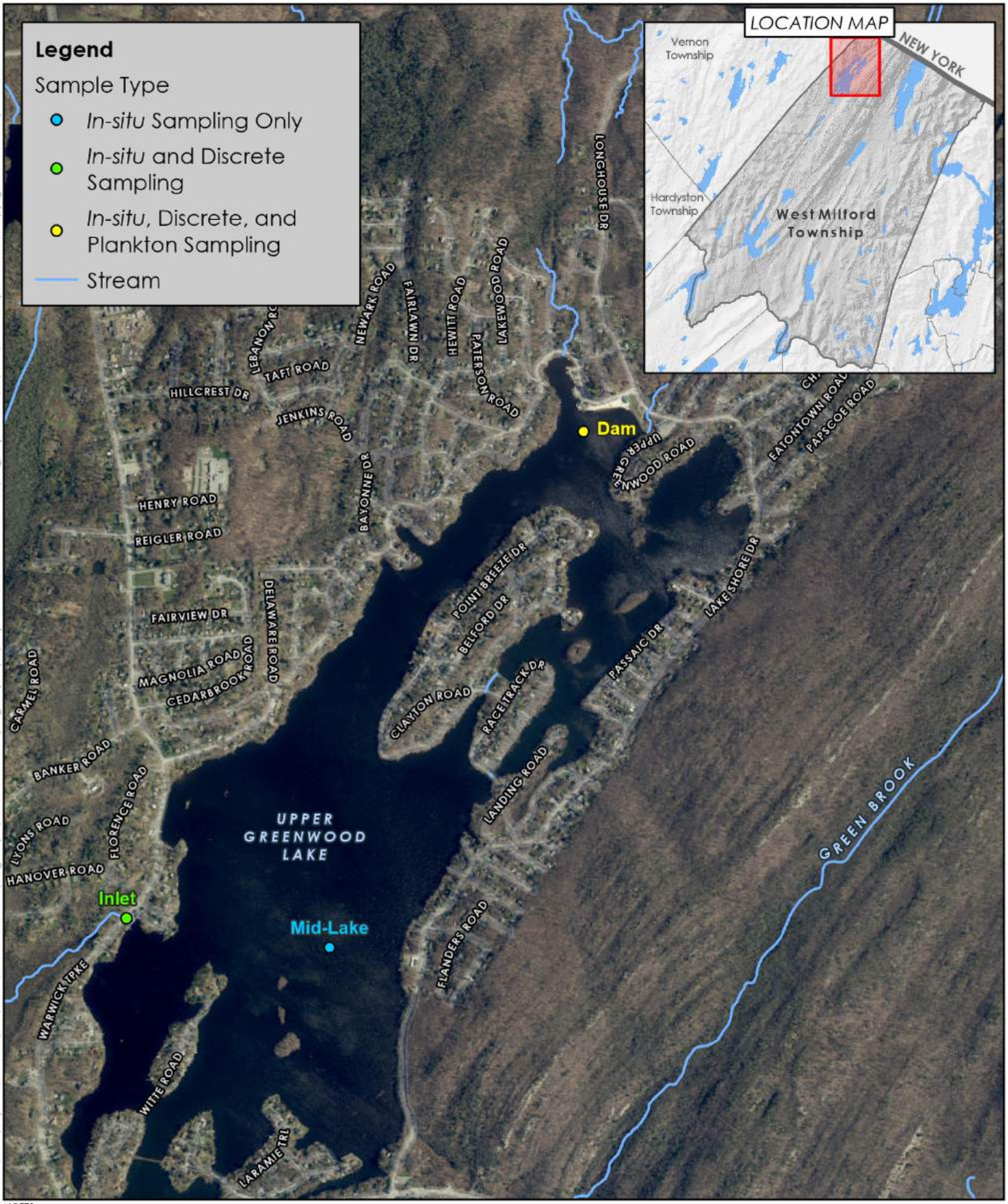

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 650 1,300 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

UPPER GREENWOOD LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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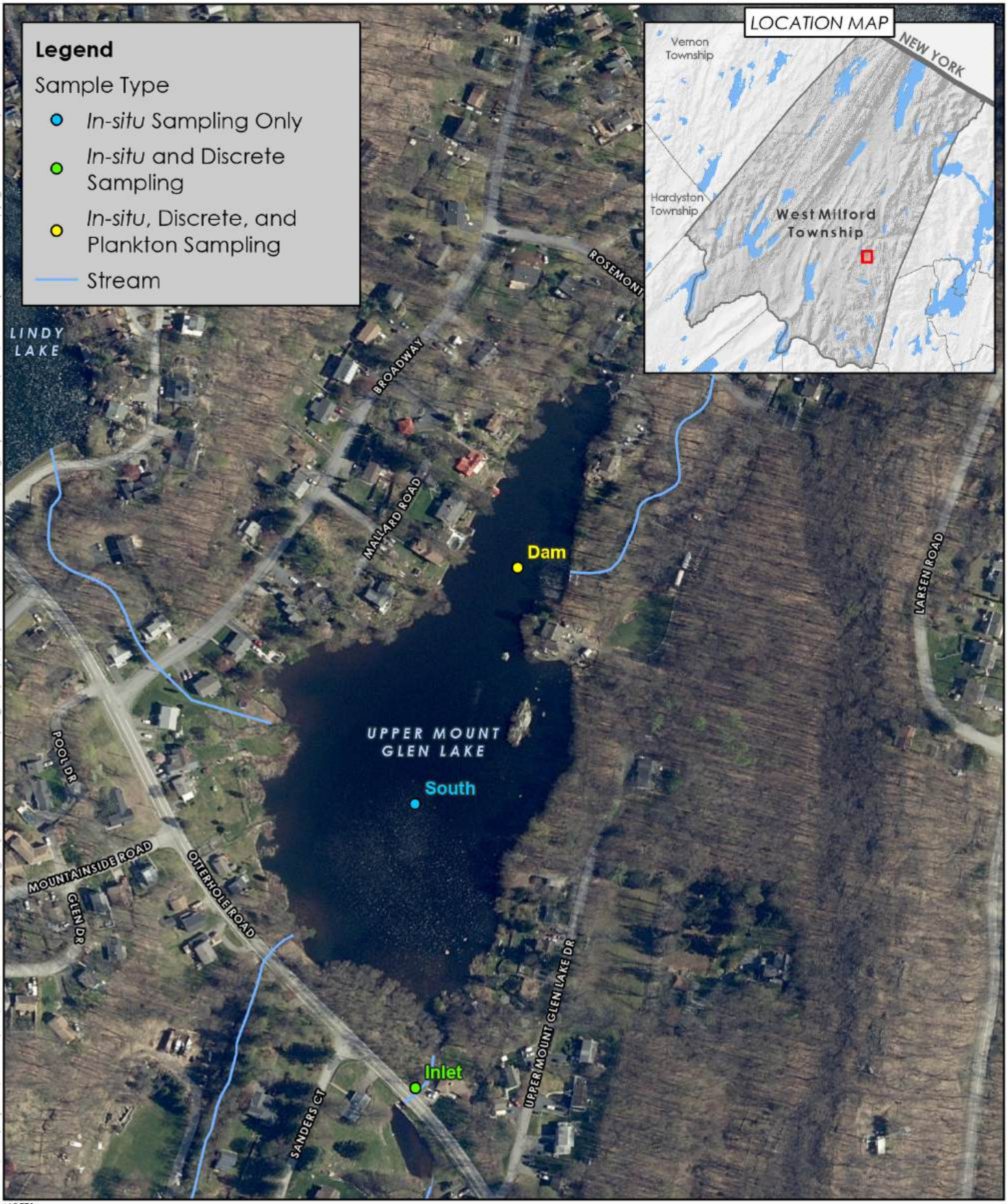

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 125 250 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

UPPER MOUNT GLEN LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

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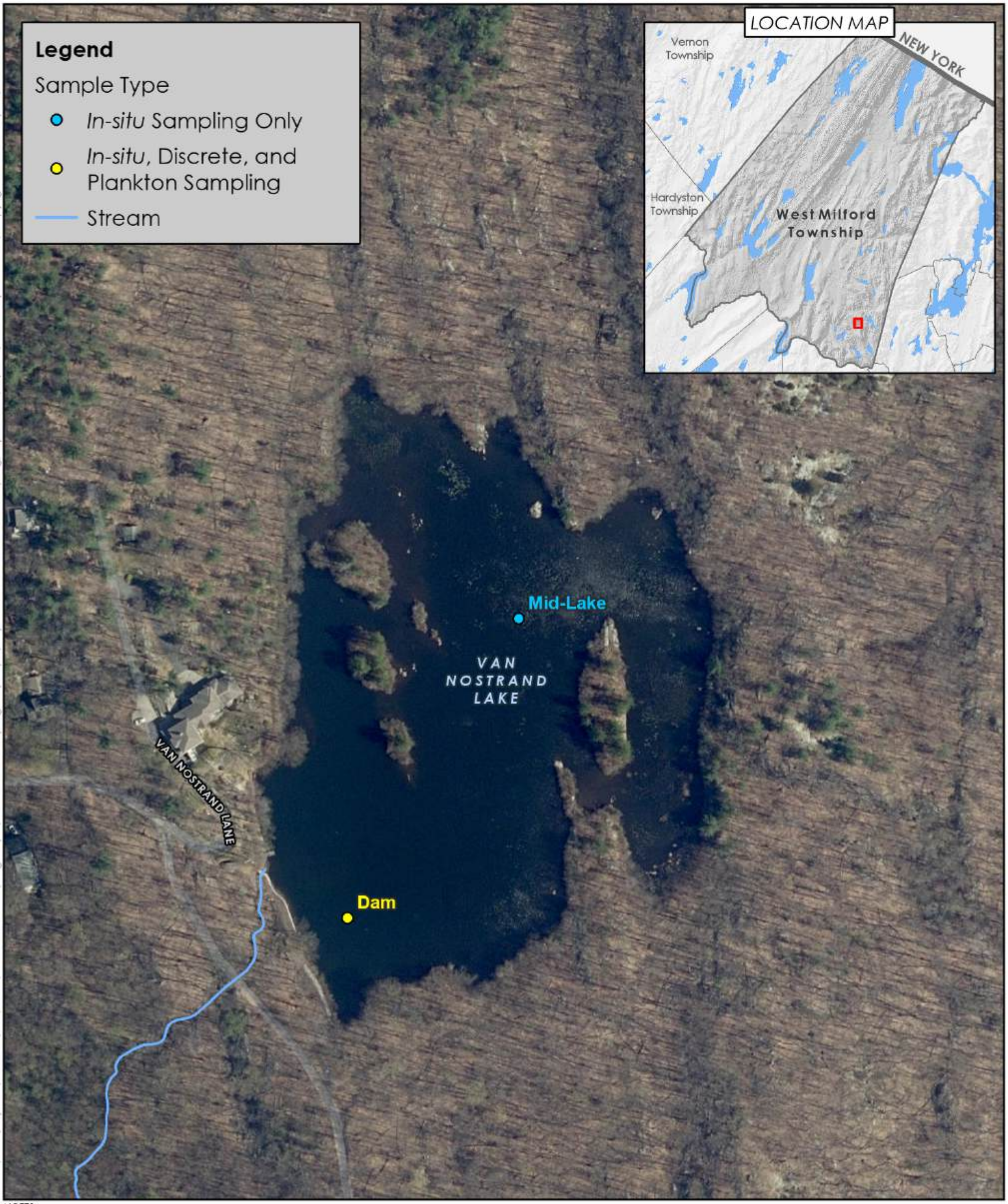

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3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

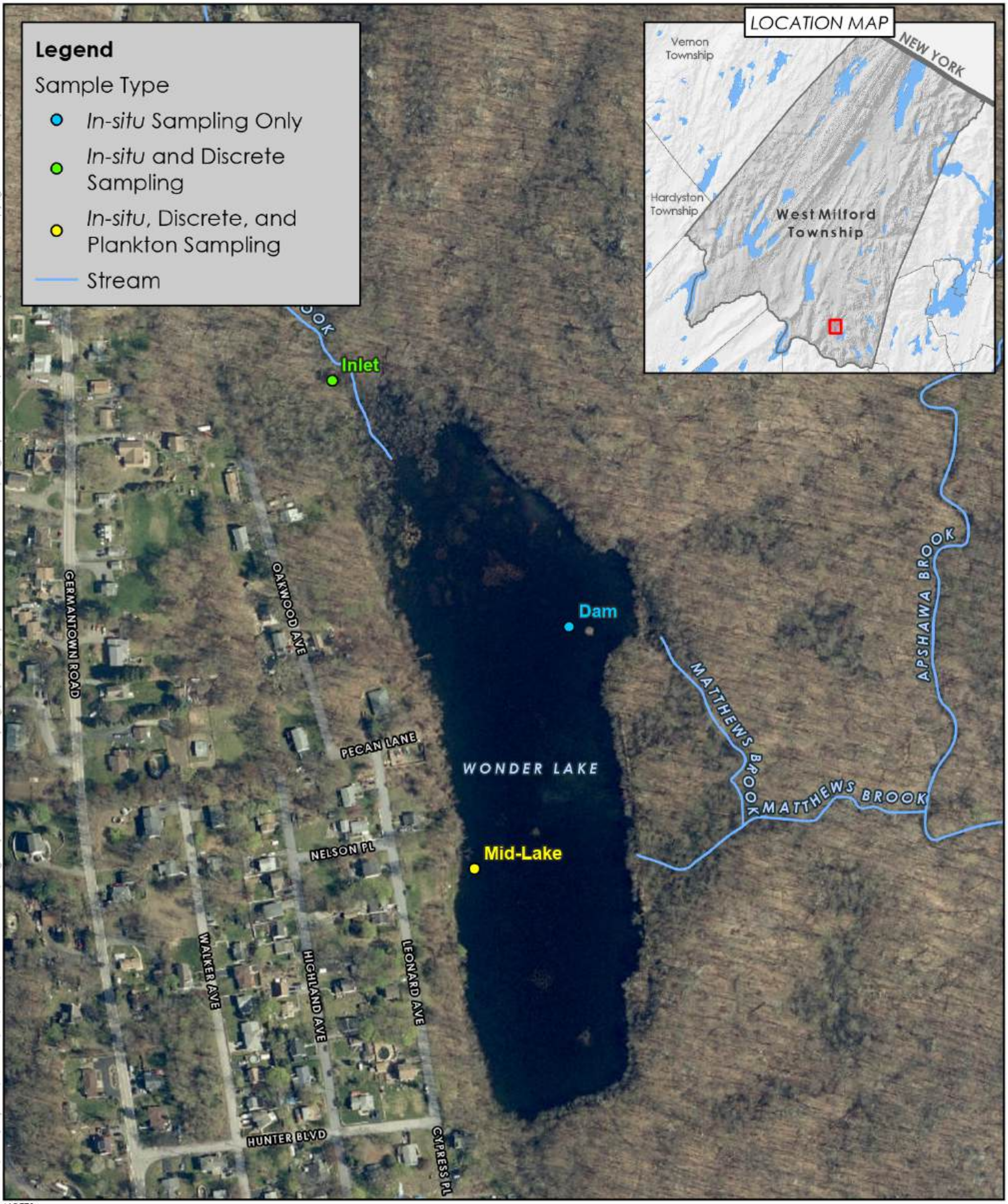
0 100 200 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

VAN NOSTRAND LAKE SAMPLING LOCATIONS

WEST MILFORD LAKE SAMPLING
WEST MILFORD TOWNSHIP
PASSAIC COUNTY, NEW JERSEY

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING
www.PrincetonHydro.com



NOTES:
1. Lake sampling points are approximate. Samples collected by Princeton Hydro.
2. Waterbodies obtained from the United States Geological Survey (USGS) National Hydrography Dataset (NHD).
3. 2020 orthoimagery obtained from the NJ Geographic Information Network (NJGIN) Open Data portal: https://njgin.nj.gov/

0 150 300 Feet

Spatial Reference: NAD 1983 2011 StatePlane New Jersey FIPS 2900 Ft US

WONDER LAKE SAMPLING LOCATIONS

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APPENDIX II – IN-SITU DATA

In-situ Monitoring for West Milford Streams 2022

Date	Lake	Temperature	Dissolved Oxygen		Specific Conductance	pH
		°C	mg/L	% Sat.	µS/cm	S.U.
5/3/2021	High Crest	12.45	8.99	86.30	241.51	7.08
	Gordan	13.46	9.16	90.90	114.60	7.13
	Upper Mt. Glen	12.96	9.1	89.33	167.40	7.02
	Lower Mt. Glen	16.05	8.77	92.02	425.72	7.64
	Kitchell	13.27	9.94	98.00	393.30	7.68
	Forest Hill Lake	14.97	9.56	96.82	194.93	7.68
	Johns Lake	15.4	8.39	85.94	318.61	7.43
	Wonder	14.47	7.05	71.09	436.19	6.97
5/20/2021	Algonquin Waters	14.54	7.12	70.12	150.52	6.36
	Post Brook Farm	14.14	8.97	89.08	124.46	7.63
	Bubbling Springs	20.77	8.41	95.40	494.77	7.51
	Pinecliff	19.94	9.76	107.72	373.54	7.81
	Upper Greenwood	18.04	6.89	74.86	136.25	6.76
	Mt. Laurel	20.51	9.68	109.76	287.81	7.43
	Lookover	22.57	7.99	94.48	176.95	7.3
10/20/2021	Lookover	16.03	8.63	90.84	133.14	7.39
	Mt. Laurel	13.1	8.5	83.76	310.09	7.13
	Upper Greenwood	13.47	7.62	75.68	677.15	7.28
	Pinecliff	13.66	9.54	93.71	415.37	7.51
	Bubbling Springs	13.19	9.41	92.51	498.41	7.22
	Kitchell	14.05	8.84	87.93	405.76	7.5
	Upper Mt. Glen	14.32	8.33	83.88	261.15	7.12
	Lower Mt. Glen	14.71	8.18	83.88	532.00	7.12
	Gordan	15.01	8.22	83.52	118.68	7.53
10/22/2021	Highcrest Inlet	15.15	7.57	77.01	305.36	7.1
	Algonquin Waters	14.23	1.29	12.33	174.58	6.81
	Post Brook Farms	14.92	8.68	89.12	126.90	7.57
	Wonder Lake	15.12	5.62	55.50	284.22	6.95
	Forest Hill Lake	16.95	8.4	89.04	181.39	7.39
	Johns Lake	15.44	6.14	62.40	461.58	7.16

No Inlet/Not accessib

Van Nostrand
Carpi
Lindys
Farm Crest
Shady Lake
Mt. Springs

In-Situ Monitoring for West Milford Lakes 5/16/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
Van Nostrand - Dam	2	2.0+	0.0	21.30	21.45	7.94	93.25	7.65
			0.5	20.94	21.68	7.44	86.45	7.45
			1.0	18.90	20.77	8.79	99.74	7.46
			1.5	17.22	21.35	8.13	87.88	7.22
Van Nostrand - Mid-Lake	1.9	1.9+	0.0	21.99	20.68	8.49	100.44	7.37
			0.5	21.22	20.41	8.72	102.93	7.30
			1.0	18.99	20.41	9.23	103.78	7.27
			1.5	17.26	20.94	7.81	79.32	6.98
Lindy's Lake - North	1.3	1.2	0.0	22.43	814.12	9.99	120.33	8.78
			0.5	22.16	811.76	9.87	117.65	8.78
			1.0	21.13	810.53	8.54	99.90	8.48
Lindy's Lake - South	7.3	1.5	0.0	21.73	809.73	10.29	122.39	8.93
			1.0	19.41	803.30	12.20	139.80	9.17
			2.0	15.97	782.78	12.86	135.54	9.26
			3.0	13.27	788.42	12.13	120.77	8.85
			4.0	11.25	798.90	3.46	28.93	7.79
			5.0	9.50	793.90	0.90	5.55	7.50
			6.0	8.07	812.45	0.03	0.02	7.22
			7.0	7.30	825.28	0.00	0.00	7.22
Post Brook Farms - Dam	2.5	1.2	0.0	21.42	344.09	7.80	92.47	7.84
			0.5	20.60	345.92	7.87	91.72	7.72
			1.0	16.59	341.52	9.12	97.84	7.68
			1.5	13.96	340.35	8.30	83.57	7.35
			2.0	12.58	343.36	5.81	56.55	7.00
Post Brook Farms - Beach	2.1	1.2	0.0	22.37	347.78	8.10	97.43	7.42
			0.5	21.95	346.49	7.67	91.90	7.44
			1.0	17.55	338.05	8.91	97.92	7.53
			1.5	14.14	341.19	7.65	75.22	7.43

In-Situ Monitoring for West Milford Lakes 5/17/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
Lake Lookover - South	**1.6**	**1.6+**	0.0	19.94	268.98	8.51	97.78	7.55
			0.5	19.83	268.38	8.51	97.68	7.36
			1.0	19.56	270.09	8.63	98.47	7.30
			1.5	19.35	273.12	7.81	88.34	7.10
Lake Lookover - Dam	**2.5**	**2.5+**	0.0	20.16	272.72	8.97	103.67	7.23
			0.5	20.16	273.00	8.96	103.15	7.28
			1.0	20.11	273.35	8.87	102.20	7.31
			1.5	19.93	273.33	8.92	102.94	7.32
			2.0	17.85	269.59	10.40	115.42	7.45
Mt. Laurel Lake - Upper	**1.9**	**1.6**	0.0	20.57	371.01	8.22	96.01	7.30
			0.5	20.58	371.04	8.22	95.93	7.31
			1.0	20.52	374.00	8.30	96.85	7.35
			1.5	20.05	387.98	8.35	95.71	7.39
Mt. Laurel Lake - Lower	**2.0**	**2.0+**	0.0	20.09	415.99	10.19	117.59	8.13
			0.5	20.07	422.38	10.17	117.38	8.14
			1.0	19.64	426.80	10.07	114.64	8.00
			1.5	18.90	426.44	10.72	123.44	8.09
Upper Greenwood - South	**1.8**	**1.2**	0.0	19.69	507.21	8.79	110.79	7.67
			0.5	19.84	506.11	8.74	110.74	7.64
			1.0	19.88	505.11	8.73	100.23	7.63
			1.5	19.88	505.07	8.73	100.47	7.63
Upper Greenwood - Dam	**2.7**	**1.6**	0.0	21.18	526.08	9.41	110.76	7.95
			0.5	21.17	526.07	9.39	110.56	7.96
			1.0	21.12	525.38	9.39	110.96	7.94
			1.5	20.94	524.08	9.35	109.90	7.97
			2.0	20.77	524.16	9.15	106.89	7.86
			2.5	20.75	524.59	9.16	106.49	7.81
Pinecliff - South	**2.0**	**1.5**	0.0	20.50	419.38	9.38	107.15	7.91
			0.5	20.48	419.47	9.37	107.30	7.91
			1.0	20.44	419.19	9.35	107.30	7.90
			1.5	19.86	419.31	9.05	101.30	7.83
Pinecliff - North	**2.8**	**1.5**	0.0	20.88	415.16	9.52	109.61	8.09
			1.0	20.86	414.76	9.50	109.46	8.11
			2.0	20.82	415.19	9.47	109.11	8.09
			2.5	20.71	414.38	9.45	108.36	8.06
Lake Kitchell - North	**1.0**	**2.5**	0.0	21.24	523.13	9.66	112.94	7.79
			0.5	21.26	519.24	9.61	112.98	7.78
			1.0	20.89	483.74	9.86	114.82	7.72
			1.5	19.99	478.81	9.94	113.63	7.68
			2.0	19.56	478.75	8.92	99.42	7.54
Lake Kitchell - South	**0.9**	**2.5**	0.0	21.21	433.30	10.13	118.43	7.81
			0.5	21.23	433.48	10.16	118.69	7.81
			1.0	21.19	433.74	10.12	118.15	7.81
			1.5	20.83	434.68	10.15	117.60	7.81
			2.0	20.39	436.54	10.30	118.30	7.81

In-Situ Monitoring for West Milford Lakes 5/20/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
High Crest Lake - South	4.9	2.3	0.0	18.79	280.48	10.65	116.87	8.40
			1.0	18.74	280.16	10.64	116.56	8.45
			2.0	18.69	280.26	10.54	115.20	8.40
			3.0	17.33	277.70	10.16	108.07	8.13
			4.0	14.96	279.62	3.86	37.83	7.68
			4.5	14.08	282.97	0.96	9.45	7.18
High Crest Lake - North	3.1	2.2	0.0	18.79	280.93	10.85	118.97	8.42
			1.0	18.75	280.24	10.77	117.84	8.45
			2.0	18.63	280.77	10.49	114.55	8.30
			3.0	17.88	281.11	7.22	77.71	7.81
Forest Hill Lake - South	4.0	1.5	0.0	19.54	196.16	10.58	118.06	8.43
			1.0	19.27	195.93	10.53	116.90	8.43
			2.0	19.06	195.83	9.96	110.64	8.25
			3.0	18.04	194.52	7.08	74.90	7.81
			3.5	16.35	198.03	2.93	30.34	7.46
Forest Hill Lake - North	2.8	1.5	0.0	19.81	197.18	10.37	116.29	8.40
			0.5	19.41	196.90	10.44	116.07	8.45
			1.0	19.24	196.70	10.32	114.47	8.39
			1.5	19.18	196.98	10.21	113.20	8.33
			2.0	19.11	197.53	10.00	110.50	8.25
			2.5	19.07	198.28	9.97	110.21	8.19
Johns Lake - South	2.2	1.1	0.0	19.58	261.81	9.15	103.64	7.93
			0.5	18.93	265.01	9.89	108.82	7.91
			1.0	18.46	267.21	8.30	89.78	7.71
			1.5	17.82	260.73	8.88	96.13	7.63
			2.0	15.67	256.60	5.13	51.42	7.30
Johns Lake - North	1.5	1.4	0.0	18.86	257.56	8.87	96.97	7.55
			0.5	18.71	258.69	8.50	93.94	7.52
			1.0	18.32	261.48	7.38	79.83	7.40
Lower Gordan Lake -North	1.6	1.6+	0.0	18.86	159.44	10.27	114.35	7.87
			0.5	18.84	159.41	10.26	113.75	7.90
			1.0	18.85	159.41	10.29	114.00	7.85
			1.5	18.83	159.49	10.42	115.46	7.96
Lower Gordan Lake - South	2.8	2.8+	0.0	18.56	160.46	10.08	111.81	7.81
			0.5	18.49	160.11	10.36	113.92	7.84
			1.0	18.40	155.91	10.33	113.26	7.88
			1.5	18.28	158.81	10.30	112.58	7.80
			2.0	18.12	163.36	10.23	111.00	7.75
			2.5	17.44	159.60	12.34	135.55	8.71
Shady Lake - Dam	1.9	1.4	0.0	19.64	526.35	7.34	82.72	9.03
			0.5	19.51	525.82	7.46	83.87	9.08
			1.0	19.46	524.59	7.52	84.71	9.08
			1.5	19.32	525.29	7.76	87.08	9.13
Shady Lake - Mid-lake	1.6	1.4	0.0	19.46	524.97	8.01	89.71	8.96
			0.5	19.50	522.61	7.94	89.13	9.03
			1.0	19.35	522.69	8.00	89.71	9.05
			1.5	18.86	519.82	8.23	91.41	9.02

In-Situ Monitoring for West Milford Lakes 5/24/2022								
Station	**Depth (m)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
	Total	**Secchi**	**Sample**	**°C**	**µS/cm**	**mg/L**	**% Sat.**	**S.U.**
Upper Mt. Glen - Dam	**1.4**	**1.2**	0.0	21.33	423.68	7.78	90.06	7.58
			0.5	21.45	422.92	7.74	89.57	7.59
			1.0	21.06	421.73	6.41	73.84	7.48
Upper Mt. Glen - North	**0.6**	**0.5***	0.0	20.74	417.33	8.75	99.68	7.67
			0.5	20.07	395.27	8.32	93.50	7.65
Lower Mt. Glen - South	**2.8**	**2.8+**	0.0	21.50	366.79	7.89	91.60	7.54
			1.0	21.52	366.86	7.86	90.68	7.57
			2.0	19.32	356.21	7.91	87.66	7.53
			2.5	17.07	351.92	8.64	91.01	7.48
Lower Mt. Glen - Dam	**3.9**	**2.8**	0.0	21.36	367.22	8.03	92.63	7.52
			1.0	21.41	366.57	7.74	89.53	7.53
			2.0	19.29	354.85	8.12	89.51	7.54
			3.0	16.03	347.66	8.24	83.98	7.52
			3.5	14.08	352.93	7.09	70.24	7.19
Farm Crest Acres - South	**3.5**	**2.1**	0.0	20.90	537.43	8.69	99.99	7.33
			1.0	20.70	536.03	8.70	99.67	7.26
			2.0	17.53	556.48	6.75	72.18	7.05
			3.0	14.82	572.51	0.67	6.11	6.67
Farm Crest Acres - North	**1.7**	**1.7+**	0.0	20.88	537.50	8.78	100.83	7.26
			0.5	20.86	536.63	8.78	100.40	7.25
			1.0	20.84	536.65	8.79	100.88	7.25
			1.5	20.47	521.70	8.58	97.45	7.17

*secchi covered by plants

In-Situ Monitoring for West Milford Lakes 6/1/2022								
Station	**Depth (m)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
	Total	**Secchi**	**Sample**	**°C**	**µS/cm**	**mg/L**	**% Sat.**	**S.U.**
Algonquin Waters - Dam	**3.7**	**1.9**	0.0	23.07	108.27	8.42	101.17	7.71
			1.0	23.01	112.19	8.81	106.01	7.65
			2.0	20.16	105.97	9.18	104.70	7.60
			3.0	15.32	102.60	10.01	103.22	7.64
			3.5	14.28	103.24	9.36	93.16	7.57
Algonquin Waters - West	**3.0**	**2.0**	0.0	22.48	108.68	8.64	102.86	7.53
			1.0	23.70	100.49	8.25	100.49	7.51
			2.0	19.76	106.63	9.47	106.63	7.56
			2.5	18.01	114.63	10.55	114.63	7.57
Bubbling Springs - Dam	**1.9**	**1.9+**	0.0	23.38	532.95	11.49	139.70	7.76
			0.5	23.44	533.37	11.40	138.25	7.81
			1.0	23.08	526.85	15.30	184.50	8.29
			1.5	22.05	507.70	15.71	186.27	8.48
Bubbling Springs - South	**1.6**	**1.6+**	0.0	23.13	535.55	11.84	143.03	8.15
			0.5	23.36	534.72	11.87	143.88	8.14
			1.0	23.05	528.73	14.24	172.30	8.41
			1.5	21.91	527.55	11.16	134.65	8.00
Mt. Springs - Dam	**2.5**	**2.0**	0.0	23.16	86.69	7.75	93.38	7.87
			0.5	23.08	86.50	8.36	100.61	7.69
			1.0	22.47	86.18	9.98	118.51	7.63
			1.5	21.53	86.42	10.46	122.63	7.62
			2.0	20.32	92.75	9.42	106.98	7.48
Mt. Springs - Mid-Lake	**2.4**	**2.0**	0.0	23.01	86.75	7.61	91.75	7.48
			0.5	23.14	86.70	7.39	90.17	7.41
			1.0	22.70	86.32	9.66	115.02	7.43
			1.5	21.40	88.26	10.01	116.94	7.38
			2.0	19.94	95.45	8.73	98.70	7.23

*secchi covered by plants

In-Situ Monitoring for West Milford Lakes 6/20/22								
Station	**Depth (m)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
	Total	**Secchi**	**Sample**	**°C**	**µS/cm**	**mg/L**	**% Sat.**	**S.U.**
Wonder Lake - Dam	**0.9**	**0.9+**	0.0	19.51	251.16	1.89	20.38	6.69
			0.5	18.67	245.44	0.92	8.84	6.58
Wonder Lake - Mid-lake	**1.7**	**1.3**	0.0	20.63	316.47	5.47	60.89	6.82
			0.5	20.03	316.16	5.52	60.86	6.79
			1.0	19.61	319.52	4.30	47.97	6.69
			1.5	19.50	320.44	2.34	25.79	6.63

*secchi covered by plants

In-Situ Monitoring for West Milford Lakes 7/25/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
Van Nostrand - Dam	1.9	1.4	0.0	26.78	19.97	2.82	36.79	6.79
			0.5	27.15	20.31	1.67	21.59	6.44
			1.0	25.73	32.29	0.04	0.46	6.13
			1.5	24.40	37.37	0.01	0.10	5.99
Van Nostrand - Mid-Lake	1.7	1.5	0.0	27.25	18.56	2.28	29.66	5.94
			1.0	26.10	22.44	0.20	2.50	5.80
			1.5	24.87	36.07	0.06	0.59	5.70
High Crest - Dam	4.9	2.0	0.0	29.20	306.34	8.53	114.06	8.44
			1.0	29.21	306.15	8.34	111.47	8.55
			2.0	29.11	305.68	7.77	105.72	8.32
			3.0	27.74	299.72	3.50	45.04	7.71
			4.0	23.78	305.35	0.16	1.81	7.19
			4.5	21.92	353.81	0.02	0.18	6.73
High Crest - North	2.8	2.0	0.0	29.25	308.38	8.29	110.90	8.44
			1.0	29.31	308.22	8.11	108.47	8.41
			2.0	29.10	308.22	7.23	94.04	7.98
			2.5	29.02	309.31	4.30	56.29	7.57
Mt. Springs - Dam	2.0	1.6	0.0	27.96	95.39	5.97	78.76	7.33
			0.5	27.98	95.32	5.91	78.87	7.29
			1.0	27.97	95.23	6.01	79.47	7.18
			1.5	27.74	96.00	4.31	56.67	6.96
			1.8	26.66	100.54	1.05	9.13	6.66
Mt. Springs - Mid-Lake	2.1	1.7	0.0	27.86	95.29	6.44	85.20	6.98
			0.5	27.96	95.12	6.38	84.56	6.39
			1.0	27.93	95.26	6.23	81.35	7.01
			2.0	27.71	112.04	0.27	112.06	6.61
Forest Hill - South	3.8	1.0	0.0	29.21	252.34	7.99	107.16	7.72
			1.0	29.28	252.03	7.20	93.78	7.67
			2.0	29.21	251.68	6.40	85.98	7.57
			3.0	28.06	259.44	0.58	7.54	7.14
			3.5	25.43	287.76	0.04	0.29	7.01
Forest Hill - North	2.7	1.0	0.0	29.31	252.27	8.38	112.51	8.03
			1.0	29.24	252.29	7.59	101.13	7.85
			2.0	29.22	252.54	7.30	97.81	7.73
			2.5	29.11	256.93	5.88	78.49	7.54
Johns Lake - South	2	1.1	0.0	29.78	355.98	6.74	91.26	7.44
			0.5	29.21	356.5	6.57	88.00	7.43
			1.0	28.95	355.92	5.49	73.17	7.27
			1.5	28.53	357	3.05	39.42	7.09
Johns Lake - North	1.7	1	0.0	29.39	358.17	7.05	94.72	7.44
			0.5	29.46	357.66	7.08	94.9	7.47
			1.0	28.93	357.75	6.76	90.51	7.46
			1.5	28.57	373.69	6.01	72.64	7.29

In-Situ Monitoring for West Milford Lakes 7/26/2022								
Station	**Depth (m)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
	Total	**Secchi**	**Sample**	**°C**	**µS/cm**	**mg/L**	**% Sat.**	**S.U.**
Wonder Lake - Dam	**0.8**	**0.8+**	0.0	23.98	293.01	3.29	33.52	7.15
			0.5	23.94	288.17	0.96	9.14	6.80
Wonder Lake - West	**1.7**	**1.2**	0.0	25.52	349.53	0.67	8.19	6.78
			0.5	25.35	352.97	0.52	2.22	6.69
			1.0	24.29	372.68	0.12	1.16	6.49
			1.5	21.67	539.84	0.00	0.00	6.57
Bubbling Springs - Dam	**1.8**	**1.2**	0.0	27.62	684.67	9.17	119.13	7.75
			0.5	27.10	682.88	9.19	119.24	7.82
			1.0	26.85	677.59	11.02	146.73	8.11
			1.5	26.46	682.02	6.75	91.03	7.55
Bubbling Springs - near inlet	**1.5**	**1.1**	0.0	27.69	686.96	9.30	120.91	7.88
			0.5	27.52	681.71	9.98	142.55	8.05
			1.0	27.01	684.96	10.19	131.89	8.05
Pinecliff Lake - South	**2.1**	**0.6**	0.0	28.27	377.18	9.98	130.26	8.95
			0.5	28.09	375.15	9.50	124.58	8.86
			1.0	27.72	376.35	8.67	111.99	8.34
			1.5	26.57	382.09	7.09	79.15	8.04
			2.0	26.40	384.04	5.06	62.95	7.83
Pinecliff Lake - North	**3.0**	**0.5**	0.0	28.30	379.67	9.59	125.50	8.90
			1.0	27.58	379.64	6.93	89.73	8.25
			2.0	27.51	380.95	5.74	73.36	7.91
			2.5	27.13	381.07	4.74	58.84	7.54
Upper Greenwood - South	**1.8**	**1.8+**	0.0	27.34	380.38	7.24	94.89	7.86
			0.5	27.36	380.24	7.22	94.54	7.76
			1.0	27.28	379.76	7.1	92.51	7.64
			1.5	27.04	378.53	6.92	89.88	7.5
Upper Greenwood - North	**2.7**	**2.1**	0.0	28.31	397.36	7.35	97.81	7.72
			0.5	28.33	396.67	7.3	97.4	7.64
			1.0	28.35	396.34	7.3	97.34	7.57
			1.5	28.18	393.82	7.21	95.78	7.5
			2.0	27.84	384.55	7.18	95.9	7.51
			2.5	27.75	384.92	7.96	105.31	7.63

In-Situ Monitoring for West Milford Lakes 8/1/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
Shady Lake - Dam	**1.9**	**1.3**	0.0	25.58	534.06	3.33	42.10	7.41
			0.5	26.21	533.84	2.99	37.83	7.35
			1.0	26.24	534.07	2.82	35.76	7.31
			1.5	26.23	533.55	2.63	33.39	7.29
Shady Lake - Mid-Lake	**1.4**	**1.1***	0.0	25.98	531.92	5.69	72.19	7.53
			0.5	26.09	531.78	5.56	70.63	7.46
			1.0	26.07	531.97	5.50	69.84	7.43
Lower Gordan Lake - North	**2.3**	**0.7**	0.0	26.09	202.43	7.34	93.41	7.61
			0.5	26.09	202.44	7.35	93.29	7.60
			1.0	26.04	202.19	7.19	91.09	7.58
			1.5	25.80	202.04	3.57	43.02	7.20
			2.0	25.77	206.14	1.81	21.48	6.95
Lower Gordan Lake - Dam	**2.9**	**0.9**	0.0	25.87	202.56	7.53	95.21	7.59
			1.0	26.08	202.40	7.33	93.05	7.58
			2.0	25.16	212.28	1.22	12.23	7.03
			2.5	22.95	285.34	0.05	0.54	6.84
Algonquin Waters - Dam	**3.5**	**2.0**	0.0	26.47	113.92	7.46	95.94	6.74
			1.0	26.53	113.78	7.41	95.15	6.82
			2.0	26.28	114.23	5.99	75.48	6.79
			3.0	24.85	144.33	0.86	9.35	6.42
Algonquin Waters - West	**2.9**	**1.8**	0.0	26.16	108.42	7.65	97.98	7.29
			1.0	26.41	113.55	7.60	97.44	7.34
			2.0	26.37	113.39	7.38	94.45	7.27
			2.5	26.18	113.68	6.84	86.68	7.11
Post Brook Farms - Dam	**2.7**	**1.2**	0.0	25.85	375.24	9.88	125.95	8.27
			1.0	25.91	374.53	9.08	115.32	8.12
			2.0	24.59	376.39	0.44	4.79	7.08
			2.5	22.29	446.13	0.08	0.88	6.68
Post Brook Farms - North	**2**	**1.2**	0.0	25.54	376.43	9.48	120.37	8.24
			0.5	25.95	375.87	9.41	119.32	8.30
			1.0	25.95	374.79	8.42	102.06	7.99
			1.5	25.64	376.56	3.86	42.61	7.30
Kitchell Lake - mid-lake/north	**2.4**	**0.9**	0.0	26.86	339.03	7.91	101.55	8
			0.5	27.01	337.31	6.84	88.37	7.66
			1.0	27.01	337.34	6.49	82.93	7.57
			1.5	26.95	337.19	6.59	85.23	7.54
			2.0	26.91	337.09	6.48	82.99	7.51
Kitchell Lake - Dam	**2.4**	**0.9**	0.0	26.75	338.98	8.07	103.49	7.79
			0.5	27.05	338.06	7.95	102.42	7.77
			1.0	26.95	337.71	7.19	91.73	7.6
			1.5	26.92	335.53	6.87	88.61	7.51
			2.0	26.87	337.67	6.73	85.86	7.43

*Secchi covered by plants

In-Situ Monitoring for West Milford Lakes 8/2/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
Upper Mt. Glen - Dam	1.2	0.5	0.0	24.45	566.69	5.86	71.45	7.51
			0.5	24.40	567.30	5.77	71.57	7.45
			1.0	24.04	567.49	4.47	54.60	7.32
Upper Mt. Glen - Midlake	1.0	0.5	0.0	24.32	575.83	6.06	75.02	7.52
			0.5	24.08	570.56	4.57	53.23	7.36
Lower Mt. Glen - South	1.3	2.6	0.0	26.29	413.60	8.68	111.59	8.54
			1.0	25.96	413.07	8.59	109.52	8.52
			2.0	25.58	419.43	6.77	82.05	7.90
			2.5	24.99	420.62	4.85	58.20	7.42
Lower Mt. Glen - Dam	1.3	4.2	0.0	26.27	413.17	8.75	112.53	8.59
			1.0	26.00	413.28	8.58	109.23	8.49
			2.0	25.60	409.96	7.83	95.11	7.91
			3.0	21.38	415.14	0.41	4.26	6.98
			4.0	18.05	562.82	0.06	0.75	6.85
Lindy's Lake - North	1.3	1.2	0.0	26.31	868.20	6.62	85.48	8.08
			0.5	25.66	869.57	6.47	82.57	8.13
			1.0	25.36	867.55	6.33	80.63	8.10
Lindy's Lake - Dam	6.7	1.2	0.0	26.73	869.50	6.79	88.15	8.33
			1.0	25.86	850.20	5.70	72.55	8.10
			2.0	24.94	861.17	4.69	58.65	7.81
			3.0	17.99	805.25	0.35	2.63	7.28
			4.0	14.67	796.83	0.01	0.08	7.06
			5.0	11.14	797.01	0.00	0.00	6.90
			6.0	8.96	822.95	0.00	0.00	6.70
			6.5	8.37	837.78	0.00	0.00	6.64
Farm Crest Acres - South	3.9	1.8	0.0	26.45	536.99	6.69	86.26	7.63
			1.0	25.31	534.7	6.11	77.4	7.55
			2.0	24.98	535	6.16	77.4	7.41
			3.0	23.96	546.53	0.34	2.69	6.65
			3.5	20.58	818.58	0.01	0.13	6.56
Farm Crest Acres - North	1.8	1.6	0.0	26.01	537.93	7.25	92.92	7.59
			0.5	25.54	535.33	6.88	87.44	7.59
			1.0	25.31	534.38	6.78	86.09	7.56
			1.5	24.99	533.66	6.93	87.07	7.52

In-Situ Monitoring for West Milford Lakes 8/3/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
Lake Lookover - South	**1.5**	**1.2**	0.0	26.57	240.97	6.71	86.72	7.61
			0.5	25.90	245.70	6.02	73.84	7.38
			1.0	25.44	245.01	5.38	67.22	7.24
Lake Lookover - North	**2.3**	**1.2**	0.0	26.42	232.73	6.01	77.31	7.31
			1.0	25.60	238.38	5.79	73.39	7.18
			2.0	25.10	238.33	4.35	54.33	7.01
Upper Mt. Laurel (South)	**1.4**	**1.3**	0.0	26.81	358.30	4.67	60.48	7.20
			0.5	25.94	360.99	4.18	53.27	7.08
			1.0	25.38	358.99	3.90	48.95	6.97
Lower Mt. Laurel (North)	**1.5**	**1.8**	0.0	27.31	358.07	8.61	112.56	7.92
			1.0	26.29	358.15	8.22	106.15	7.72
			1.5	25.98	359.79	5.51	74.71	7.21

In-Situ Monitoring for West Milford Lakes 7/25/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
Van Nostrand Lake - Midlake	1.5	1.5+	0.0	13.13	18.89	2.18	20.82	5.23
			0.5	13.03	18.92	2.09	20.23	4.86
			1.0	13.05	18.70	2.09	20.26	4.87
Van Nostrand Lake - Dam	1.7	1.7+	0.0	12.52	18.70	7.72	74.17	5.07
			0.5	12.58	18.67	7.61	72.96	5.17
			1.0	12.57	18.57	7.65	73.44	5.20
			1.5	12.55	18.56	7.70	74.11	5.27
High Crest Lake - South	4.5	1.4	0.0	15.68	314.74	9.28	94.22	6.91
			1.0	15.87	314.55	9.24	94.28	7.27
			2.0	15.91	314.64	9.22	94.24	7.43
			3.0	15.88	314.42	9.23	94.61	7.54
			4.0	15.89	314.48	9.22	94.22	7.60
High Crest Lake - North	2.3	1.5	0.0	15.31	322.44	9.48	95.92	7.55
			0.5	15.55	315.38	9.41	95.18	7.67
			1.0	15.56	314.96	9.39	95.36	7.73
			1.5	15.59	314.83	9.33	95.41	7.78
			2.0	15.14	314.95	9.23	92.61	7.79
Mt. Springs Lake - Midlake	1.5	1.5+	0.0	14.33	91.91	7.45	74.45	7.31
			0.5	14.36	91.64	7.43	74.17	7.25
			1.0	14.34	91.63	7.55	75.59	7.16
Mt. Springs Lake - Dam	2.2	2.2+	0.0	14.16	91.76	7.74	77.06	6.99
			0.5	14.20	91.70	7.71	76.87	6.94
			1.0	14.21	91.64	7.70	76.83	6.96
			1.5	14.20	91.64	7.71	76.88	6.93
			2.0	14.19	91.65	7.71	77.05	6.92
Forest Hill Lake - Dam	3.9	1.1	0.0	16.02	281.11	9.93	102.14	8.37
			1.0	16.10	280.74	9.86	101.85	8.51
			2.0	16.14	280.39	9.83	101.40	8.54
			3.0	16.11	280.84	9.80	100.83	8.59
			3.5	16.11	281.31	9.76	99.78	8.51
Forest Hill Lake - North	2.5	1.2	0.0	15.71	284.05	9.92	101.17	8.38
			0.5	15.99	282.89	9.78	100.32	8.48
			1.0	16.00	283.04	9.72	99.49	8.49
			1.5	15.99	283.21	9.61	98.60	8.47
			2.0	15.99	282.95	9.57	98.58	8.48
Johns Lake - Dam	1.8	1.8+	0.0	14.17	407.01	9.13	90.14	7.8
			0.5	14.18	406.88	9.14	90.01	7.81
			1.0	14.19	406.83	9.13	90.09	7.81
			1.5	14.2	406.87	9.13	90.32	7.8
Johns Lake - North	1.5	1.5+	0.0	14.12	408.99	8.83	87.25	7.64
			0.5	14.2	408.63	8.77	86.76	7.66
			1.0	14.22	408.59	8.73	86.31	7.69

In-Situ Monitoring for West Milford Lakes 7/25/2022								
Station	**Depth (m)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
	Total	**Secchi**	**Sample**	**°C**	**µS/cm**	**mg/L**	**% Sat.**	**S.U.**
Pinecliff - South	**2.3**	**0.9**	0.0	11.50	396.66	10.03	93.41	7.84
			0.5	11.29	398.16	9.96	92.75	7.68
			1.0	11.27	398.07	9.96	92.97	7.58
			1.5	11.25	398.07	9.96	92.49	7.50
			2.0	11.24	398.05	9.93	92.29	7.47
Pinecliff - North	**2.9**	**0.5**	0.0	11.79	395.58	9.37	88.29	7.39
			1.0	11.82	395.81	9.32	87.82	7.37
			2.0	11.78	396.25	9.26	87.27	7.34
			2.5	11.77	396.47	9.24	87.26	7.34
Upper Greenwood - Midlake	**1.8**	**1.8+**	0.0	10.78	376.30	10.33	96.61	7.67
			0.5	10.75	376.66	10.30	96.59	7.57
			1.0	10.74	376.59	10.29	96.44	7.54
			1.5	10.74	376.75	10.30	96.46	7.51
Upper Greenwood - Dam	**2.8**	**2.8+**	0.0	12.11	379.80	9.69	93.61	7.53
			1.0	12.12	379.61	9.66	93.19	7.50
			2.0	12.13	379.54	9.63	93.19	7.49
			2.5	12.13	379.52	9.62	93.28	7.50
Lake Lookover - North	**1.5**	**1.5+**	0.0	11.13	234.04	10.07	95.16	7.46
			1.0	11.04	231.55	10.11	95.48	7.42
Lake Lookover - Dam	**2.0**	**2.0+**	0.0	11.80	236.23	9.75	93.26	7.43
			1.0	11.78	236.39	9.69	92.82	7.43
			1.5	11.69	236.75	9.71	93.02	7.32
Wonder Lake - Dam	**0.5**	**0.5+**	0.0	11.27	237.58	7.56	71.16	6.95
			0.4	11.22	240.30	7.61	70.58	6.87
Wonder Lake - Midlake	**2.0**	**1.9**	0.0	11.76	300.17	8.40	78.85	7.11
			0.5	11.31	303.78	7.20	66.95	7.02
			1.0	11.09	308.44	7.05	65.79	6.96
			1.5	10.94	308.63	6.71	62.40	6.88

In-Situ Monitoring for West Milford Lakes 7/25/2022								
Station	Depth (m)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	µS/cm	mg/L	% Sat.	S.U.
Shady Lake - Dam	2.0	2.0+	0.0	11.83	477.45	9.86	93.79	7.67
			0.5	11.77	477.31	10.09	96.06	7.52
			1.0	11.69	476.93	9.85	93.45	7.44
			1.5	11.66	477.60	9.35	93.40	7.41
Shady Lake - Mid	1.4	1.4+	0.0	11.74	452.83	9.92	94.34	7.46
			0.5	11.58	453.13	10.07	95.96	7.43
			1.0	11.51	451.84	10.27	97.06	7.43
Gordan Lake - North	2.3	1.0	0.0	12.42	217.66	10.35	99.87	7.72
			1.0	11.96	218.62	10.36	98.66	7.60
			2.0	11.86	219.12	10.13	96.40	7.51
Gordan Lake - Dam	2.8	0.8	0.0	12.58	217.49	10.51	101.47	7.47
			1.0	12.07	217.37	10.32	98.56	7.49
			2.0	11.96	217.61	10.08	95.92	7.46
			2.5	11.94	217.64	10.07	95.93	7.42
Algonquin Waters - West	2.8	2.5	0.0	14.41	111.11	9.47	95.51	7.84
			1.0	13.27	111.50	9.64	94.91	7.70
			2.0	13.04	110.85	9.79	96.37	7.50
			2.5	12.82	112.19	9.99	97.40	7.36
Algonquin Waters - Dam	3.6	2.4	0.0	13.91	110.77	9.57	95.53	7.58
			1.0	13.41	110.91	9.62	94.93	7.56
			2.0	13.17	110.99	9.75	95.49	7.47
			3.0	13.04	111.99	9.54	93.47	7.39
Post Brook Farms - Dam	2.5	1.4	0.0	13.13	365.53	8.98	88.38	7.58
			1.0	12.33	362.97	8.95	86.77	7.45
			2.0	12.14	363.86	8.72	83.98	7.29
Post Brook Farms - North	2.2	1.3	0.0	13.39	367.83	9.50	93.54	7.44
			1.0	12.35	366.45	8.96	86.48	7.47
			2.0	12.17	365.26	8.77	83.99	7.42
Kitchell Lake - Mid-lake	1.7	0.9	0	14.68	304.1	11.15	112.13	7.77
			1	12.15	201.41	11.21	107.53	7.87
Kitchell Lake - Dam	1.7	0.8	0	19.70	304.10	11.15	112.13	7.77
			1	12.29	301.41	11.21	107.53	7.87

In-Situ Monitoring for West Milford Lakes 7/25/2022								
Station	**Depth (m)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
	Total	**Secchi**	**Sample**	**°C**	**µS/cm**	**mg/L**	**% Sat.**	**S.U.**
Upper Mt. Glen - Dam	**1.5**	**1.2**	0.0	13.02	383.88	6.25	60.35	7.40
			0.5	12.73	384.34	6.15	59.36	7.25
			1.0	12.68	384.15	6.09	58.24	7.14
Upper Mt. Glen - Midlake	**0.8**	**0.8+**	0.0	12.59	398.61	6.95	62.18	7.12
			0.5	12.22	391.92	5.33	50.29	6.95
Lower Mt. Glen - South	**2.5**	**2.4**	0.0	13.77	431.84	7.95	75.28	7.44
			0.5	13.50	431.95	6.28	61.60	7.30
			1.0	13.42	432.06	6.29	61.68	7.24
			1.5	13.36	431.99	6.31	61.68	7.19
			2.0	13.29	432.18	6.28	61.42	7.15
Lower Mt. Glen - Dam	**3.7**	**2.7**	0.0	13.73	432.35	7.00	67.73	7.17
			1.0	13.58	431.74	6.69	65.61	7.14
			2.0	13.41	431.96	6.67	65.38	7.12
			3.0	13.36	432.19	6.68	65.34	7.10
			3.5	13.34	432.49	6.67	65.20	7.07
Lindy's Lake - North	**1.2**	**1.2+**	0.0	13.87	823.64	9.70	96.23	7.93
			0.5	13.37	828.81	9.94	97.86	7.93
			1.0	13.33	863.11	9.99	98.22	7.86
Lindy's Lake - Dam	**5.8**	**2.0**	0.0	14.00	836.51	9.41	93.45	7.83
			1.0	13.57	835.82	9.05	89.29	7.75
			2.0	13.41	835.46	8.75	86.13	7.68
			3.0	13.17	833.68	7.16	68.29	7.51
			4.0	12.94	832.79	5.56	53.10	7.38
			5.0	12.51	832.13	1.53	11.02	7.17
			5.5	12.81	831.07	0.35	2.92	7.06
Bubbling Springs - Dam	**1.8**	**1.8+**	0.0	14.48	599.17	10.33	108.95	7.91
			0.5	14.07	600.09	10.88	109.20	7.87
			1.0	13.34	598.07	11.16	109.53	7.91
			1.5	13.19	598.39	11.39	111.50	7.90
Bubbling Springs - Near-inlet	**1.4**	**1.4+**	0.0	14.03	597.80	10.92	108.99	7.96
			0.5	13.61	598.18	11.07	109.06	7.93
			1.0	13.46	597.68	11.06	108.76	7.90
Farm Crest Acres - Dam	**3.5**	**3.4**	0.0	13.75	493.03	10.29	101.88	8.14
			1.0	13.26	493.22	10.15	99.29	7.98
			2.0	13.07	493.98	10.16	99.1	7.79
			3.0	12.99	494.4	10.08	98.08	7.71
Farm Crest Acres - North	**1.8**	**1.8+**	0.0	14.54	494.41	10.41	105.15	7.76
			0.5	14.5	493.92	10.38	104.53	7.78
			1.0	13.88	492.83	10.53	104.93	7.89
			1.5	13.59	491.09	12.77	127.65	8.8

In-Situ Monitoring for West Milford Lakes 10.13.22								
Station	**Depth (m)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**
	Total	**Secchi**	**Sample**	**°C**	**µS/cm**	**mg/L**	**% Sat.**	**S.U.**
Mt. Laurel Lake - North*	**1.3**	**1.3+**	0.0	14.37	378.26	10.24	104.27	7.95
			1.0	13.89	383.02	10.37	104.88	7.88
Mt. Laurel Lake - South/Upper	**1.6**	**1.6+**	0.0	13.91	368.80	9.87	99.30	7.60
			0.5	13.70	369.84	9.83	98.62	7.47
			1.0	13.67	369.09	9.77	98.00	7.36
			1.5	13.71	368.81	9.61	96.53	7.25

*Northern portion was sampled from Warwick Turnpike Bridge

APPENDIX III – DISCRETE LABORATORY DATA

Discrete Monitoring Data for West Milford Lake Inlets - 2021					
Date	**Station**	**NO3-N (mg/L)**	**SRP (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
May-21	Algonquin	0.25	0.028	0.03	12
	Post Brook Farms	4.63	0.049	0.05	7
	Bubbling Springs	1.01	ND <0.002	0.04	14
	Pinecliff	0.92	0.020	0.05	5
	Upper Greenwood (Sawmill)	0.05	0.004	0.02	ND <2
	Mt Laurel	0.38	ND <0.002	0.02	2
	Lake Lookover	0.07	ND <0.002	0.02	ND <2
	High Crest	0.17	ND <0.002	0.01	ND <2
	Gordon	0.22	0.002	0.02	5
	Upper Mt Glen	0.48	0.004	0.02	2
	Lower Mt Glen	0.44	0.002	0.02	2
	Kitchell	0.26	0.002	0.02	2
	Van Nostrand	Access not granted			
	Mt. Springs	No Flowing Inlet			
	Farm Crest	No Flowing Inlet			
	Carpi	Access not granted			
	Shady	Inlet w/non-measureable flow			
	Lindy's	No Flowing Inlet			
	Forest Hill	0.22	ND <0.002	0.04	ND <2
	Johns	1.11	0.002	0.03	ND <2
	Wonder	0.10	0.004	0.03	12
September-21	Algonquin	0.12	0.026	0.14	18
	Post Brook Farms	3.70	0.047	0.07	13
	Bubbling Springs	0.95	ND <0.002	0.01	ND <2
	Pinecliff	0.97	0.017	0.03	ND <2
	Upper Greenwood (Sawmill)	0.07	0.011	0.04	2
	Mt Laurel	0.41	0.002	0.01	ND <2
	Lake Lookover	0.01	ND <0.002	0.02	2
	High Crest	0.11	ND <0.002	0.02	9
	Gordon	0.21	ND <0.002	0.02	5
	Upper Mt Glen	0.13	0.062	0.09	2
	Lower Mt Glen	0.20	0.004	0.01	3
	Kitchell	0.05	0.015	0.02	ND <2
	Van Nostrand	Access not granted			
	Mt. Springs	No Flowing Inlet			
	Farm Crest	No Flowing Inlet			
	Carpi	Access not granted			
	Shady	Inlet w/non-measureable flow			
	Lindy's	No Flowing Inlet			
	Forest Hill	0.07	0.002	0.05	18
	Johns	2.70	0.004	0.02	8
	Wonder	0.03	0.004	0.02	7
NJDEP Surface Water Quality Standard		**N/A**	**N/A**	**0.10**	**25**

Discrete Monitoring Data for West Milford Lakes - 2022													
Date	Station	TP		SRP		Chl A		NO3-N		NH3-N		TSS	
		S (mg/L)	D (mg/L)	S (mg/L)	D (mg/L)	S (ug/L)	D (ug/L)	S (mg/L)	D (mg/L)	S (mg/L)	D (mg/L)	S (mg/L)	D (mg/L)
	High Crest Lake	0.02	0.04	ND <0.002	ND <0.002	4.9	9.3	0.05	0.05	0.01	0.13	ND <2	6
	Algonquin Waters	0.01	0.01	ND <0.002	ND <0.002	3.9	4.6	0.06	0.04	0.01	ND <0.01	ND <2	ND <2
	Lake Lookover	0.01	0.01	ND <0.002	ND <0.002	2.7	3.6	0.05	0.05	0.05	0.14	ND <2	ND <2
	Kitchell Lake	0.02	0.02	0.004	ND <0.002	2.4	9.8	0.10	0.05	0.14	0.05	2	ND <2
	Lindy's Lake	0.02	0.05	ND <0.002	ND <0.002	7.8	7.2	0.10	0.11	0.01	0.07	ND <2	ND <2
	Mt. Laurel Lake	0.01	0.01	ND <0.002	ND <0.002	1.1	1.3	0.07	0.09	ND <0.01	ND <0.01	ND <2	2
	Shady Lake	0.03	0.04	0.002	0.002	2.5	4.9	0.07	0.08	0.28	0.35	3	2
	Wonder Lake	0.01	0.02	0.002	ND <0.002	1.5	1.8	0.06	0.06	ND <0.01	ND <0.01	ND <2	ND <2
	Mt. Glen Lake (Upper)	0.04	0.05	0.002	0.003	1.3	1.3	0.14	0.13	0.02	0.02	ND <2	ND <2
	Mt. Glen Lake (Lower)	0.02	0.02	ND <0.002	ND <0.002	1.4	3.9	0.45	0.43	0.02	0.04	ND <2	ND <2
May-22	Carpi Lake	NO ACCESS GRANTED											
	Pinecliff Lake	0.02	0.03	ND <0.002	0.004	2.2	2.4	0.08	0.10	0.14	0.14	3	2
	Van Nostrand Lake	0.02	0.02	ND <0.002	ND <0.002	ND <0.6	1.0	0.02	0.02	0.03	0.37	3	ND <2
	Upper Greenwood Lake	0.02	0.02	ND <0.002	ND <0.002	7.7	10.0	0.07	0.09	0.05	0.14	ND <2	ND <2
	Post Brook Farms	0.02	0.02	ND <0.002	ND <0.002	3.1	4.1	0.63	0.68	0.05	0.05	ND <2	ND <2
	Farm Crest Acres	0.01	0.02	0.002	ND <0.002	4.0	2.3	0.25	0.20	0.05	0.13	ND <2	ND <2
	Mt. Springs Lake	0.01	0.02	ND <0.002	ND <0.002	6.4	9.0	0.04	0.07	ND <0.01	ND <0.01	ND <2	ND <2
	Forest Hill Park	0.03	0.02	ND <0.002	ND <0.002	14.0	6.7	0.02	0.02	ND <0.01	ND <0.01	5	ND <2
	Johns Lake	0.03	0.04	ND <0.002	ND <0.002	4.5	6.9	0.20	0.17	0.13	0.35	7	4
	Gordon Lake	0.02	0.02	ND <0.002	ND <0.002	7.0	1.4	0.03	0.03	0.35	0.35	3	2
	Bubbling Springs Lake	0.01	0.02	ND <0.002	ND <0.002	0.8	0.6	0.76	0.76	0.02	0.02	2	2
	High Crest Lake	0.01	0.08	ND <0.002	ND <0.002	2.1	53.0	0.02	0.36	0.01	0.42	2	10
	Algonquin Waters	0.01	0.02	ND <0.002	ND <0.002	3.9	21.0	0.04	0.17	0.05	0.35	ND <2	9
	Lake Lookover	0.01	0.01	ND <0.002	ND <0.002	3.3	4.1	0.06	0.06	0.01	0.01	2	10
	Kitchell Lake	0.04	0.03	ND <0.002	ND <0.002	22.0	15.0	0.03	0.04	0.01	0.03	6	4
	Lindy's Lake	0.02	0.26	ND <0.002	ND <0.002	6.8	8.0	ND <0.01	0.02	0.05	0.03	ND <2	ND <2
	Mt. Laurel Lake	0.01	0.03	ND <0.002	ND <0.002	5.8	6.4	0.04	0.04	0.01	0.05	3	ND <2
	Shady Lake	0.04	0.04	ND <0.002	ND <0.002	13.0	15.0	0.05	0.05	0.02	0.05	9	6
	Wonder Lake	0.02	0.04	ND <0.002	ND <0.002	7.8	25.0	0.05	0.11	ND <0.01	0.02	7	15
	Mt. Glen Lake (Upper)	0.09	0.10	0.002	ND <0.002	48.0	55.0	0.03	0.03	0.05	0.06	19	13
	Mt. Glen Lake (Lower)	0.02	0.10	ND <0.002	ND <0.002	17.0	230.0	ND <0.01	0.27	0.02	0.03	5	80
July-22	Carpi Lake	NO ACCESS GRANTED											
	Pinecliff Lake	0.05	0.10	ND <0.002	ND <0.002	51.0	41.0	0.06	0.11	0.01	0.01	15	38
	Van Nostrand Lake	0.01	0.01	ND <0.002	ND <0.002	3.6	4.1	0.06	0.15	ND <0.01	ND <0.01	ND <2	10
	Upper Greenwood Lake	0.02	0.01	ND <0.002	ND <0.002	3.6	5.1	0.02	0.03	ND <0.01	ND <0.01	2	4
	Post Brook Farms	0.04	0.07	ND <0.002	0.002	25.0	66.0	0.08	0.15	0.05	0.13	ND <2	9
	Farm Crest Acres	0.01	0.13	ND <0.002	ND <0.002	4.0	390.0	ND <0.01	0.37	0.05	0.05	2	150
	Mt. Springs Lake	0.02	0.02	ND <0.002	ND <0.002	3.2	4.1	0.04	0.05	0.01	ND<0.01	ND <2	ND <2
	Forest Hill Park	0.04	0.05	ND <0.002	ND <0.002	7.7	36.0	0.03	0.13	0.02	0.35	ND <2	10
	Johns Lake	0.04	0.04	ND <0.002	ND <0.002	9.4	18.0	0.13	0.07	0.13	0.35	ND <2	ND <2
	Gordon Lake	0.04	0.03	ND <0.002	ND <0.002	22.0	44.0	0.05	0.24	0.02	0.04	11	4
	Bubbling Springs Lake	0.02	0.04	ND <0.002	ND <0.002	3.0	17.0	0.07	0.13	0.01	0.05	5	8
	High Crest Lake	0.02	0.02	0.005	0.003	16.0	17.0	0.04	0.03	0.08	0.16	5	2
	Algonquin Waters	ND <0.01	0.01	ND <0.002	ND <0.002	8.7	9.8	0.04	0.03	0.02	0.02	2	ND <2
	Lake Lookover	0.01	ND <0.01	ND <0.002	ND <0.002	1.5	1.1	0.07	0.07	0.02	0.02	2	4
	Kitchell Lake	0.02	0.03	ND <0.002	ND <0.002	27.0	29.0	0.10	0.11	0.16	0.08	5	7
	Lindy's Lake	0.01	0.04	ND <0.002	0.002	5.5	7.1	0.09	0.07	ND <0.01	0.01	ND <2	ND <2
	Mt. Laurel Lake	ND <0.01	ND <0.01	ND <0.002	ND <0.002	6.1	5.1	0.04	0.13	0.04	0.60	ND <2	2
	Shady Lake	0.01	0.01	ND <0.002	ND <0.002	5.9	5.0	0.09	0.09	0.02	ND <0.01	3	ND <2
	Wonder Lake	ND <0.01	0.01	ND <0.002	ND <0.002	2.8	3.0	0.06	0.06	0.04	0.16	5	ND <2
	Mt. Glen Lake (Upper)	0.02	0.02	ND <0.002	ND <0.002	7.5	7.8	0.36	0.35	0.11	0.22	ND <2	ND <2
	Mt. Glen Lake (Lower)	0.01	0.01	ND <0.002	ND <0.002	3.3	2.8	0.21	0.22	0.60	0.53	2	ND <2
September-22	Carpi Lake	NO ACCESS GRANTED											
	Pinecliff Lake	0.07	0.07	ND <0.002	ND <0.002	44.0	43.0	0.19	0.19	0.04	0.08	31	36
	Van Nostrand Lake	0.01	0.01	ND <0.002	ND <0.002	4.6	2.5	0.08	0.08	0.16	0.18	ND <2	ND <2
	Upper Greenwood Lake	0.01	0.01	ND <0.002	ND <0.002	2.4	2.4	0.06	0.05	0.01	0.02	8	10
	Post Brook Farms	0.04	0.03	ND <0.002	0.005	16.0	19.0	0.15	0.15	0.08	0.16	ND <2	ND <2
	Farm Crest Acres	0.01	0.01	ND <0.002	ND <0.002	1.3	2.3	0.04	0.04	0.16	0.22	ND <2	ND <2
	Mt. Springs Lake	0.01	0.01	0.002	0.009	4.0	1.9	0.03	0.04	0.08	0.16	4	ND <2
	Forest Hill Park	0.02	0.02	0.003	0.004	14.0	16.0	0.04	0.05	0.08	0.09	8	9
	Johns Lake	0.01	0.02	ND <0.002	0.018	2.3	2.4	0.08	0.08	0.04	0.04	ND <2	ND <2
	Gordon Lake	0.02	0.02	ND <0.002	0.007	37.0	30.0	0.12	0.09	0.02	0.04	9	2
	Bubbling Springs Lake	0.02	0.01	ND <0.002	ND <0.002	1.7	1.5	0.43	0.41	ND <0.01	0.60	ND <2	ND <2
NJDEP Surface Water Quality Standard		**0.05**	**0.05**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**Temp/pH specific**		**25**	**25**

APPENDIX IV – PLANKTON DATA

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes	Sampling Date: 5/16/2022
Site 1: Van Nostrand Lake	Site 2: Lindy's Lake
Site 3: Post Brook Farms	Site 4:
Site 5:	

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4
Asterionella			R	
Aulacoseira				
Cocconeis				
Cyclotella				
Cymatopleura				
Cymbella				
Denticula				
Fragilaria			R	
Frustulia				
Gyrosigma				
Melosira			R	
Nedium				
Stauroneis				
Stephanodiscus		R		
Sururekka				
Synedra		C		
Tabellaria	R			
Pinnularia				
Navicula				
Mastogloia				
Chrysophyta (Golden Algae)				
Dinobryon				
Chromulina				
Mallomonas				
Synurophytes				
Chrysosphaerella	P			
Unknown filaments				

Chlorophyta (Green Algae)	1	2	3	4
Actinastrum				
Ankistrodesmus				
Chlamydomonas				
Botryococcus				
Chlorella		C		
Coelastrum				
Eudorina	C			
Gloeocystis				
Dictyosphaerium				
Hydrodictyon				
Monoraphidium				
Mougeotia		R		
Microspora				
Ochromonas				
Oedogonium				
Oocystis				
Scenedesmus		R		
Spirogya				
Treubaria				
Pediastrum				
Volvox				
Zygnema				
Sphaerocystis				
Ulothrix				
Desmids (Green Algae)				
Micrasterias				
Staurastrum				
Spondylosium				
Closterium				
Desmidium				
Staurodesmus				

Cyanophyta (Blue-Green Algae)	1	2	3	4
Dolichospermum (formerly Anabaena)				
Amphanizomen				
Aphanocapsa				
Chroococcus				
Cylindrospermum				
Lyngbya				
Microcystis			P	
Nostoc				
Pseudoanabaena	R			
Oscillatoria				
Coelosphaerium				
Spirulina				
Aphanothece				
Euglenophyta (Euglenoids)				
Colacium				
Phacus				
Euglena sp				
Trachelomonas		C	C	
Pyrrhophyta (Dinoflagellates)				
Ceratium			C	
Peridinium				
Gymnodinium		P		
Cryptomonads				
Chroomonas				

Zooplankton

Cladocera (Water Fleas)	1	2	3	4
Bosmina sp.			P	
Daphnia sp.	C	P	A	
Eubosmina sp.				
Chydorus	R			
Diaphniosoma				
Ceriodaphnia				
Leptodora kindti				
Scapholeberis mucronata				
Bosmina longirostris				
Diaphnosoma brachyurum				
Diaphanosoma birgei				

Copecoda (Copepods)	1	2	3	4
Cyclops sp.				
Dipatomus (H)				
Nauplii	C	C	A	
Skistodiaptomus sp.				
Microcyclops sp	P	C		
Limnocalanus macrurus				
Leptodiaptomus sp.				
Unknown Cyclopod				
Unknown Calanoid				
Mesocyclops				
Diacyclops				
Tropocyclops				

Rotifera (Rotifers)	1	2	3	4
Keratella sp.	A	C	R	
Kellicottia sp.	C	R	R	
Asplanchna sp.		A	R	
Polyarthra	P	P		
Hexarthra mira				
Conochilus	A			
Tricocerca				
Bipalpus				
Arthropoda (Arthropods)				
Chaoborus punctipennis				
Ostracoda			R	

Sites:	1	2	3	4		
Total Phytoplankton Genera	4	7	6	0	0	0
Total Zooplankton Genera	8	7	7	0	0	0

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)

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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 5/17/2022**

Site 1: Upper Greenwood | **Site 2: Mt. Laurel Lake** | **Site 3: Kitchell Lake** | **Site 4: Pinecliff Lake** | **Site 5: Lake Lookover**

Phytoplankton

Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**
Asterionella			P	R	
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Denticula					
Fragilaria	P		R	R	
Frustulia					
Gyrosigma					
Melosira		R	P	R	
Nedium					
Stauroneis					
Stephanodiscus					
Sururekka					
Synedra		R			
Tabellaria	R				
Pinnularia		R			
Navicula					
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon	B	A	P	A	B
Chromulina					
Mallomonas	R				
Synurophytes					
Chrysosphaerella					P
Unknown filaments					

Chlorophyta (Green Algae)	**1**	**2**	**3**	**4**	**5**
Actinastrum					
Ankistrodesmus					
Chlamydomonas				P	
Botryococcus					
Chlorella					
Coelastrum					
Eudorina					
Gloeocystis			B		
Dictyosphaerium					
Hydrodictyon					
Monoraphidium					
Mougeotia					
Microspora					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya	R				
Treubaria					
Pediastrum			P	C	
Volvox					
Zygnema					
Sphaerocystis				P	
Ulothrix					
Desmids (Green Algae)					
Micrasterias					
Staurastrum		R			
Spondylosium					
Closterium	R				
Desmidium					P
Staurodesmus			R	R	

Cyanophyta (Blue-Green Algae)	**1**	**2**	**3**	**4**	**5**
Dolichospermum (formerly Anabaena)	P				
Amphanizomen					
Aphanocapsa		R		R	P
Chroococcus					
Cylindrospermum					
Lyngbya					
Microcystis	C				
Nostoc					
Pseudoanabaena	A				
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Euglenophyta (Euglenoids)					
Colacium					
Phacus					
Euglena sp			R		
Trachelomonas		P	R		
Pyrrhophyta (Dinoflagellates)					
Ceratium	R	R	P		
Peridinium					
Gymnodinium					
Cryptomonads					
Chroomonas					

Zooplankton

Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**
Bosmina sp.	R	C	C	C	R
Daphnia sp.		P	R	C	
Eubosmina sp.					
Chydorus	P			P	
Diaphniosoma					R
Ceriodaphnia		R	R		
Leptodora kindti					
Scapholeberis mucronata					
Bosmina longirostris					
Diaphnosoma brachyurum					
Diaphanosoma birgei					

Copecoda (Copepods)	**1**	**2**	**3**	**4**	**5**
Cyclops sp.					
Dipatomus (H)					
Nauplii	C	C	P	C	P
Skistodiaptomus sp.		P			
Microcyclops sp		P	R	P	P
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid				P	P
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	**1**	**2**	**3**	**4**	**5**
Keratella sp.	C	C	P		P
Kellicottia sp.		R	R		
Asplanchna sp.	A	P	P	A	P
Polyarthra		R			R
Hexarthra mira					
Conochilus	A	C	C	P	A
Pompholyx			A		
Bipalpus					
Arthropoda (Arthropods)					
Chaoborus punctipennis					
Ostracoda					
Chironomidae		R			

Sites:	**1**	**2**	**3**	**4**		
Total Phytoplankton Genera	10	8	10	10	4	0
Total Zooplankton Genera	6	11	10	8	9	0

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
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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes — **Sampling Date: 5/20/2022**

Site 1: Forest Hill Lake | **Site 2: Gordan Lake** | **Site 3: High Crest Lake** | **Site 4: Shady Lake** | **Site 5: Johns Lake**

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4	5
Asterionella	A	P	A		P
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Denticula					
Fragilaria	C		P	C	P
Frustulia					
Gyrosigma					
Melosira	A	R			
Nedium					
Stauroneis					
Stephanodiscus					
Sururekka					
Synedra		R		A	P
Tabellaria	R	R	R	R	R
Pinnularia					C
Navicula					
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon	R				
Chromulina					
Mallomonas					
Ochromonas		A			
Synurophytes					
Chrysosphaerella					
Unknown filaments					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus					
Chlamydomonas					
Botryococcus					
Chlorella					
Coelastrum					
Eudorina					
Gloeocystis	R				
Dictyosphaerium					
Hydrodictyon					
Monoraphidium					
Mougeotia					
Microspora					
Ochromonas					
Oedogonium					
Oocystis			C		
Scenedesmus					
Spirogya	R	P		A	A
Treubaria					
Pediastrum	R		P		
Volvox					
Zygnema					
Sphaerocystis			P	P	
Ulothrix					
Desmids (Green Algae)					
Micrasterias					
Staurastrum					
Spondylosium					
Closterium					
Desmidium					
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)		P		R	
Amphanizomen					
Aphanocapsa	P	P		P	
Chroococcus					
Cylindrospermum					
Lyngbya		R	R		
Microcystis					
Nostoc					
Pseudoanabaena		R			
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Euglenophyta (Euglenoids)					
Colacium					
Phacus					
Euglena sp					
Trachelomonas	P			R	
Pyrrhophyta (Dinoflagellates)					
Ceratium			P		
Peridinium					
Gymnodinium					
Cryptomonads					
Chroomonas					

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.	A		P	A	
Daphnia sp.	R	C	A	R	
Eubosmina sp.					
Chydorus				R	R
Diaphniosoma		R			
Ceriodaphnia				R	
Leptodora kindti					
Pleuroxus				R	
Leydigia	R				
Diaphnosoma brachyurum					
Diaphanosoma birgei					

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.					
Dipatomus (H)					
Nauplii					R
Skistodiaptomus sp.					
Microcyclops sp	C	P	R	P	
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid		P			
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	1	2	3	4	5
Keratella sp.	C		C	R	R
Kellicottia sp.		R			
Asplanchna sp.	C	R			
Polyarthra	C				R
Hexarthra mira					
Conochilus		P			
Tricocerca					
Filinia			R		
Arthropoda (Arthropods)					
Chaoborus punctipennis					
Ostracoda	R				
Chironomidae				R	

Sites:	1	2	3	4		
Total Phytoplankton Genera	10	10	8	8	6	0
Total Zooplankton Genera	8	7	4	7	4	0

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
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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 6/1/22**

Site 1: Bubbling Springs | **Site 2: Algonquin Waters** | **Site 3: Mt. Springs Lake**

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4	5
Asterionella			R		
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Denticula					
Fragilaria	R				
Frustulia					
Gyrosigma					
Melosira		P			
Nedium					
Stauroneis					
Stephanodiscus	P				
Sururekka					
Synedra		A	R		
Tabellaria		P			
Pinnularia					
Navicula					
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon	C		C		
Chromulina					
Mallomonas					
Ochromonas					
Synurophytes					
Chrysosphaerella					
Unknown filaments					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus					
Chlamydomonas		R			
Botryococcus					
Chlorella					
Coelastrum					
Eudorina					
Gloeocystis					
Dictyosphaerium					
Hydrodictyon					
Monoraphidium					
Mougeotia					
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya					
Treubaria					
Pediastrum		R			
Volvox					
Zygnema					
Sphaerocystis					
Ulothrix					
Desmids (Green Algae)					
Micrasterias					
Staurastrum					
Spondylosium					
Closterium					
Desmidium					
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)	R	A			
Amphanizomen					
Aphanocapsa					
Chroococcus					
Cylindrospermum					
Lyngbya					
Microcystis		P	A		
Nostoc					
Pseudoanabaena					
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Euglenophyta (Euglenoids)					
Colacium					
Phacus					
Euglena sp	R				
Trachelomonas	R		C		
Pyrrhophyta (Dinoflagellates)					
Ceratium	A		C		
Peridinium					
Gymnodinium					
Cryptomonads					
Chroomonas					

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.	C	R	P		
Daphnia sp.	C	C	P		
Eubosmina sp.					
Chydorus					
Diaphniosoma	R		P		
Ceriodaphnia					
Leptodora kindti			R		
Pleuroxus					
Leydigia					
Diaphnosoma brachyurum					
Diaphanosoma birgei					

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.					
Dipatomus (H)					
Nauplii		C	P		
Skistodiaptomus sp.					
Microcyclops sp	R	C	P		
Limnocalanus macrurus					
Leptodiaptomus sp.	A		C		
Unknown Cyclopod					
Unknown Calanoid		A			
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	1	2	3	4	5
Keratella sp.		A	P		
Kellicottia sp.		C	R		
Asplanchna sp.	P	P	R		
Polyarthra	R		R		
Hexarthra mira					
Conochilus			C		
Tricocerca		P			
Filinia					
Arthropoda (Arthropods)					
Chaoborus punctipennis					
Ostracoda					
Chironomidae					

Sites:	1	2	3	4		
Total Phytoplankton Genera	7	7	6	0	0	0
Total Zooplankton Genera	7	9	12	0	0	0

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)

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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 6/1/22**

Site 1: Wonder Lake

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4	5
Asterionella					
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Denticula					
Fragilaria					
Frustulia					
Gyrosigma					
Melosira	R				
Nedium					
Stauroneis					
Stephanodiscus					
Sururekka					
Synedra					
Tabellaria					
Pinnularia					
Navicula					
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon	C				
Chromulina					
Mallomonas					
Ochromonas					
Synurophytes					
Chrysosphaerella	P				
Unknown filaments					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus					
Chlamydomonas					
Botryococcus					
Chlorella					
Coelastrum					
Eudorina					
Gloeocystis					
Dictyosphaerium					
Hydrodictyon					
Monoraphidium					
Mougeotia					
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya					
Treubaria					
Pediastrum					
Volvox					
Zygnema					
Sphaerocystis	R				
Ulothrix					
Desmids (Green Algae)					
Micrasterias					
Staurastrum					
Spondylosium					
Closterium					
Spinoclosterium	R				
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)					
Amphanizomen					
Aphanocapsa					
Chroococcus					
Cylindrospermum					
Lyngbya					
Microcystis					
Nostoc					
Pseudoanabaena	P				
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Euglenophyta (Euglenoids)					
Colacium					
Phacus	R				
Euglena sp					
Trachelomonas					
Pyrrhophyta (Dinoflagellates)					
Ceratium					
Peridinium					
Gymnodinium					
Cryptomonads					
Chroomonas					

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.	C				
Daphnia sp.	R				
Eubosmina sp.					
Chydorus					
Diaphniosoma					
Ceriodaphnia					
Leptodora kindti					
Pleuroxus					
Leydigia					
Diaphnosoma brachyurum					
Diaphanosoma birgei					

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.					
Dipatomus (H)					
Nauplii	P				
Skistodiaptomus sp.					
Microcyclops sp	P				
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid					
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	1	2	3	4	5
Keratella sp.					
Kellicottia sp.					
Asplanchna sp.					
Polyarthra					
Hexarthra mira					
Conochilus					
Tricocerca					
Filinia					
Arthropoda (Arthropods)					
Chaoborus punctipennis					
Ostracoda					
Chironomidae	R				

Sites:	1	2	3	4		
Total Phytoplankton Genera	7	0	0	0	0	0
Total Zooplankton Genera	4	0	0	0	0	0

Scud also present in sample

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)

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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 7/25/22**

Site 1: High Crest Lake | **Site 2: Van Nostrand** | **Site 3: Forest Hill** | **Site 4: Johns Lake** | **Site 5: Mt. Spring Lake**

Phytoplankton

Bacillariophyta (Diatoms)	1	2	3	4	5
Asterionella					
Aulacoseira					
Cocconeis					
Cyclotella					A
Cymatopleura					
Cymbella					
Denticula					
Fragilaria					
Frustulia					
Gyrosigma					
Melosira					P
Nedium					
Stauroneis					
Stephanodiscus				P	
Sururekka					
Synedra		C			P
Tabellaria					
Pinnularia					
Navicula					
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon		R			R
Chromulina					
Mallomonas					
Ochromonas					
Synurophytes					
Chrysosphaerella		A		R	
Unknown filaments					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus					R
Chlamydomonas			R		
Botryococcus					
Chlorella					C
Coelastrum					
Eudorina					
Gloeocystis	R				
Dictyosphaerium					
Hydrodictyon					
Monoraphidium					
Mougeotia	C	P			
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya		R	A		
Treubaria			C		
Pediastrum	R		R	R	P
Volvox	R				
Zygnema					
Sphaerocystis					C
Ulothrix					
Desmids (Green Algae)					
Micrasterias					
Staurastrum	P	R	R		P
Spondylosium					
Cosmarium		R		R	
Closterium		P	R		
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)	A		P		P
Aphanizomenon					P
Aphanocapsa	A				P
Chroococcus					
Cylindrospermum					
Lyngbya				P	R
Microcystis		P	P		P
Nostoc					
Pseudoanabaena	P	P	R		
Oscillatoria					R
Coelosphaerium					P
Spirulina					
Aphanothece					
Cylindrospermopsis					
Euglenophyta (Euglenoids)					
Colacium					
Phacus			R		
Euglena sp				R	P
Trachelomonas		C	P		C
Pyrrhophyta (Dinoflagellates)					
Ceratium				B	C
Peridinium					
Gymnodinium					
Cryptomonads					
Chroomonas					

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.	P	R	C	R	
Daphnia sp.	C	R		P	
Eubosmina sp.					
Chydorus		R	R		
Diaphniosoma	R	R			
Ceriodaphnia	R	R		R	
Leptodora kindti					
Pleuroxus					

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.					
Dipatomus (H)					C
Nauplii	C	C	C	P	P
Skistodiaptomus sp.					
Microcyclops sp	P	A	A	R	
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid	P			C	
Mesocyclops					
Onychodiaptomus			R		
Tropocyclops					

Rotifera (Rotifers)	1	2	3	4	5
Keratella sp.	P	P		P	C
Kellicottia sp.			R		P
Asplanchna sp.	R				
Polyarthra		R		R	
Branchionus		R	R	R	R
Conochilus	C	A		C	P
Tricocerca	P	P			
Gastropus			A		
Pompholyx					P
Arthropoda (Arthropods)					
Chaoborus punctipennis	R	R			
Ostracoda			R		P
Chironomidae			R		

Sites:	1	2	3	4		
Total Phytoplankton Genera	8	11	11	7	19	0
Total Zooplankton Genera	12	13	8	10	7	0

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)

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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 7/26/22**

Site 1: Upper Greenwood Lake | **Site 2: Bubbling Springs** | **Site 3: Pinecliff Lake** | **Site 4: Wonder Lake**

Phytoplankton

Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**
Asterionella					
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Denticula					
Fragilaria	P		P	R	
Frustulia					
Gyrosigma					
Melosira			P	R	
Nedium					
Stauroneis					
Stephanodiscus		R			
Sururekka					
Synedra				R	
Tabellaria					
Pinnularia					
Navicula					
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon	R				
Chromulina					
Mallomonas					
Ochromonas					
Synurophytes					
Chrysosphaerella					
Unknown filaments					

Chlorophyta (Green Algae)	**1**	**2**	**3**	**4**	**5**
Actinastrum					
Ankistrodesmus					
Chlamydomonas					
Botryococcus					
Chlorella					
Coelastrum			R		
Eudorina					
Gloeocystis	P				
Dictyosphaerium					
Hydrodictyon					
Monoraphidium					
Mougeotia	P	R		P	
Koliella			R		
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus			P		
Spirogya	R				
Pandorina			P		
Treubaria					
Pediastrum	C	R	A		
Volvox					
Zygnema					
Sphaerocystis			P		
Ulothrix					
Desmids (Green Algae)					
Cosmarium			P		
Staurastrum			P		
Spondylosium					
Closterium					
Spinoclosterium					
Staurodesmus					

Cyanophyta (Blue-Green Algae)	**1**	**2**	**3**	**4**	**5**
Dolichospermum (formerly Anabaena)			P		
Aphanizomenon			P		
Aphanocapsa					
Chroococcus					
Cylindrospermum					
Lyngbya		P	R	C	
Microcystis	P		C		
Nostoc					
Pseudoanabaena	P				
Oscillatoria					
Coelosphaerium			P		
Spirulina			C		
Aphanothece					
Cylindrospermopsis	R				
Euglenophyta (Euglenoids)					
Colacium					
Phacus				R	
Euglena sp			P		
Trachelomonas	P	P	P	P	
Pyrrhophyta (Dinoflagellates)					
Ceratium	P	B	C	C	
Peridinium					
Gymnodinium					
Cryptomonads					
Chroomonas				A	

Zooplankton

Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**
Bosmina sp.	A	R	A/D	R	
Daphnia sp.		R			
Eubosmina sp.					
Chydorus				R	
Diaphniosoma	P		C		
Ceriodaphnia	P	P	A		
Leptodora kindti					
Pleuroxus					
Leydigia					
Diaphnosoma brachyurum					
Diaphanosoma birgei					

Copecoda (Copepods)	**1**	**2**	**3**	**4**	**5**
Cyclops sp.					
Dipatomus (H)			P		
Nauplii	P	P	P	A	
Skistodiaptomus sp.					
Microcyclops sp	C			C	
Ectocyclops			C		
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid	R				
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	**1**	**2**	**3**	**4**	**5**
Keratella sp.	P	A	C	P	
Kellicottia sp.					
Asplanchna sp.	C	P	P		
Polyarthra	R	R			
Branchionus	P		C		
Conochilus	A		P		
Tricocerca	R		P		
Gastropus			R		
Arthropoda (Arthropods)					
Chaoborus punctipennis					
Ostracoda			P	R	
Chironomidae					

Sites:	**1**	**2**	**3**	**4**		
Total Phytoplankton Genera	10	6	19	9	0	0
Total Zooplankton Genera	12	7	12	6	0	0

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)

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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes — **Sampling Date: 8/1/22**

Site 1: Shady Lake | **Site 2: Gordon Lake** | **Site 3: Kitchell** | **Site 4: Post Brook Frams** | **Site 5: Algonquin Waters**

Phytoplankton

Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**
Asterionella					
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Eunotia					
Fragilaria					
Frustulia					
Gyrosigma					
Melosira					P
Nitzschia	P				
Stauroneis					
Stephanodiscus					
Sururekka					
Synedra	P		A		C
Tabellaria					P
Pinnularia					
Navicula	C				P
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon			P		
Chromulina					
Mallomonas					
Ochromonas					
Synurophytes					
Chrysosphaerella					

Chlorophyta (Green Algae)	**1**	**2**	**3**	**4**	**5**
Actinastrum					
Ankistrodesmus	C				
Chlamydomonas	P				
Brachiomonas					
Chlorella					
Coelastrum					
Characium					
Gloeocystis				P	
Didymocystis					
Eudorina				C	
Monoraphidium					
Mougeotia					
Nannochloris					
Microspora					
Ochromonas					
Oedogonium					
Pleodorina				C	
Scenedesmus	P				
Spirogya	P		P		
Tetraspora	R			P	
Treubaria					
Pediastrum	R		P		C
Volvox					
Zygnema					
Sphaerocystis			P	P	R
Ulothrix					
Desmids (Green Algae)					
Cosmarium					
Staurastrum	P		B	P	P
Spondylosium		R			
Closterium	R				
Micrasterias	C				
Staurodesmus					

Cyanophyta (Blue-Green Algae)	**1**	**2**	**3**	**4**	**5**
Dolichospermum (formerly Anabaena)	R	A	P	P	R
Aphanizomenon				A/B	P
Aphanocapsa	P				C
Chroococcus					
Cylindrospermum					
Lyngbya	C	P		P	
Microcystis		A		C	
Nostoc					
Pseudoanabaena					
Oscillatoria					R
Coelosphaerium					
Spirulina					R
Merismopedia				P	
Euglenophyta (Euglenoids)					
Colacium					
Phacus	P				P
Euglena sp	C	P		P	
Trachelomonas	A	C	C	P	C
Lepocinclis	P				
Pyrrhophyta (Dinoflagellates)					
Ceratium	C	C	P	A	P
Peridinium	P				
Gymnodinium					P
Cryptomonads					
Chroomonas					R

Zooplankton

Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**
Bosmina sp.		P	C		P
Daphnia sp.		P		R	R
Eubosmina sp.					
Chydorus					
Diaphniosoma		R	P		
Ceriodaphnia		R	P	C	
Leptodora kindti					
Pleuroxus					

Copecoda (Copepods)	**1**	**2**	**3**	**4**	**5**
Cyclops sp.				P	
Dipatomus (H)				P	
Nauplii	P		C	C	P
Skistodiaptomus sp.					
Microcyclops sp		A	P		C
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid		P	R		

Rotifera (Rotifers)	**1**	**2**	**3**	**4**	**5**
Ascomorpha	R				
Branchionus			P		R
Asplanchna sp.				P	P
Polyarthra	P		P		P
Conochilus		A			C
Keratella	P		C		P
Tricocerca			R	C	P
Filinia			P	R	
Kellicottia		R		C	P
Pompholyx				A	P
Gastropus				C	
Monostyla	R				
Arthropoda (Arthropods)					
Chaoborus punctipennis	P				
Ostracoda		R	R		P
Chironomidae					

Sites:	**1**	**2**	**3**	**4**		
Total Phytoplankton Genera	20	7	9	13	17	0
Total Zooplankton Genera	5	8	11	7	11	0

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)

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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes — **Sampling Date: 8/2/22**

Site 1: Lindy's Lake | **Site 2: Farmcrest Acres** | **Site 3: Upper Mt. Glen** | **Site 4: Lower Mt. Glen**

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4	5
Asterionella					
Aulacoseira					
Cocconeis					
Cyclotella		P			
Cymatopleura					
Cymbella					
Eunotia	P				
Fragilaria	R				
Frustulia					
Gyrosigma					
Melosira	R	R			
Nitzschia		P			
Stauroneis					
Stephanodiscus				R	
Sururekka					
Synedra	P	P	C	R	
Tabellaria					
Pinnularia					
Navicula					
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon		P			
Chromulina					
Mallomonas					
Ochromonas					
Synurophytes					
Chrysosphaerella					
Unknown filaments					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus	P				
Chlamydomonas					
Brachiomonas	C				
Chlorella	P	P			
Coelastrum	P	R			
Characium		P			
Gloeocystis	C	P			
Didymocystis	P				
Koliella	P				
Monoraphidium					
Mougeotia					
Nannochloris	P				
Microspora					
Ochromonas					
Oedogonium					
Oocystis	R				
Scenedesmus	P	P			
Spirogya					
Tetraspora	R				
Treubaria					
Pediastrum	P	R	P		
Volvox					
Zygnema					
Sphaerocystis	P	P			
Ulothrix					
Desmids (Green Algae)					
Cosmarium		P			
Staurastrum	C	P	R	P	
Spondylosium					
Closterium					
Micrasterias					
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)	R	R	P		
Aphanizomenon	P	R			
Aphanocapsa					
Chroococcus					
Cylindrospermum					
Lyngbya			R	A	
Microcystis	R			C	
Nostoc					
Pseudoanabaena				A	
Oscillatoria					
Coelosphaerium	R				
Spirulina					
Aphanothece					
Euglenophyta (Euglenoids)					
Colacium					
Phacus		P			
Euglena sp		P	R		
Trachelomonas	C	A	A		
Lepocinclis		P			
Pyrrhophyta (Dinoflagellates)					
Ceratium	C	A	C	P	
Peridinium		A			
Gymnodinium					
Cryptomonads					
Chroomonas		R			

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.	A	P			
Daphnia sp.		P	R	P	
Eubosmina sp.					
Chydorus					
Diaphniosoma	R			P	
Ceriodaphnia	P	C		C	
Leptodora kindti					
Pleuroxus					

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.	C				
Dipatomus (H)		C			
Nauplii	C	C	C	R	
Skistodiaptomus sp.			A		
Microcyclops sp		P		P	
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Calanoid				P	

Rotifera (Rotifers)	1	2	3	4	5
Keratella sp.	P	P	A	P	
Gastropus	C				
Asplanchna sp.	P	C			
Polyarthra	P	R		R	
Hexarthra	P	R			
Brachionus	C	R	P	R	
Tricocerca	P			R	
Filinia	P		P		
Kellicottia		A		R	
Conochilus				C	
Monostyla		R			
Arthropoda (Arthropods)					
Chaoborus punctipennis				P	
Ostracoda					
Chironomidae					

Sites:	1	2	3	4		
Total Phytoplankton Genera	24	22	8	7	0	0
Total Zooplankton Genera	12	11	5	11	0	0

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)

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 8/3/22**

Site 1: Lookover Lake | **Site 2: Mt. Laurel Lake**

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4	5
Asterionella					
Aulacoseira					
Cocconeis					
Cyclotella	C				
Cymatopleura					
Cymbella					
Eunotia					
Fragilaria		P			
Frustulia					
Gyrosigma					
Melosira	P				
Nitzschia					
Stauroneis					
Stephanodiscus					
Sururekka					
Synedra	P				
Tabellaria					
Pinnularia					
Navicula					
Mastogloia					

Chrysophyta (Golden Algae)	1	2	3	4	5
Dinobryon	C	C			
Chromulina					
Mallomonas					
Ochromonas					

Synurophytes	1	2	3	4	5
Chrysosphaerella					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus	C				
Chlamydomonas					
Brachiomonas					
Chlorella	P				
Coelastrum	P				
Characium					
Gloeocystis	R				
Didymocystis					
Koliella					
Monoraphidium					
Mougeotia		P			
Nannochloris					
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus	P				
Spirogya		R			
Tetraspora					
Treubaria					
Pediastrum	C	P			
Volvox					
Zygnema					
Sphaerocystis					
Ulothrix					

Desmids (Green Algae)	1	2	3	4	5
Desmidium	R				
Staurastrum	P				
Spondylosium					
Closterium	R				
Micrasterias					
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)	R	R			
Aphanizomenon					
Aphanocapsa	C	C			
Chroococcus					
Cylindrospermum					
Lyngbya					
Microcystis	R	P			
Nostoc					
Pseudoanabaena		R			
Oscillatoria					
Coelosphaerium	P				
Spirulina					
Aphanothece					
Merismopedia		R			

Euglenophyta (Euglenoids)	1	2	3	4	5
Colacium					
Phacus	C				
Euglena sp	P	R			
Trachelomonas	C				
Lepocinclis					

Pyrrhophyta (Dinoflagellates)	1	2	3	4	5
Ceratium	C	C			
Peridinium					
Gymnodinium	P				

Cryptomonads	1	2	3	4	5
Chroomonas		P			

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.	P	R			
Daphnia sp.		R			
Eubosmina sp.					
Chydorus					
Diaphniosoma		C			
Ceriodaphnia	P	P			
Leptodora kindti					
Pleuroxus					

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.	P				
Dipatomus (H)	C				
Nauplii	C	P			
Skistodiaptomus sp.					
Microcyclops sp		R			
Limnocalanus macrurus					
Leptodiaptomus sp.		C			
Unknown Cyclopod					
Unknown Calanoid					
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	1	2	3	4	5
Ascomorpha	P				
Conochilus	C				
Asplanchna sp.	C	C			
Polyarthra	P	P			
Hexarthra					
Keratella	P	P			
Tricocerca					
Filinia					
Kellicottia	C	R			
Monostyla					

Arthropoda (Arthropods)	1	2	3	4	5
Chaoborus punctipennis					
Ostracoda		R			
Chironomidae					

Sites:	1	2	3	4		
Total Phytoplankton Genera	22	12	0	0	0	0
Total Zooplankton Genera	10	11	0	0	0	0

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)

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 10/3/22**

Site 1: Mt. Springs Lake | **Site 2: Johns Lake** | **Site 3: Van Nostrand Lake** | **Site 4: High Crest Lake** | **Site 5: Forest Hill Lake**

Phytoplankton

Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**
Asterionella					
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Eunotia					
Fragilaria	P			P	
Frustulia					
Gyrosigma					
Melosira		R			P
Nitzschia					
Stauroneis					
Stephanodiscus		R			
Sururekka					
Synedra					
Tabellaria					
Pinnularia					
Navicula			R		
Mastogloia					

Chrysophyta (Golden Algae)					
Dinobryon	P		C		
Chromulina					
Mallomonas					
Ochromonas					

Synurophytes					
Chrysosphaerella			P		

Chlorophyta (Green Algae)	**1**	**2**	**3**	**4**	**5**
Actinastrum					
Ankistrodesmus					
Chlamydomonas					
Brachiomonas					
Chlorella			R		
Coelastrum					
Characium					
Gloeocystis	R	R			R
Didymocystis					
Koliella					
Monoraphidium					
Mougeotia	C			A	B
Nannochloris					
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya		B	R		
Tetraspora					
Treubaria					
Pediastrum	C	C	P	R	R
Volvox					
Zygnema					
Sphaerocystis					
Ulothrix					

Desmids (Green Algae)					
Desmidium					
Staurastrum	P	R		P	
Spondylosium					
Closterium			P		
Micrasterias					
Staurodesmus					

Cyanophyta (Blue-Green Algae)	**1**	**2**	**3**	**4**	**5**
Dolichospermum (formerly Anabaena)	R			R	
Aphanizomenon					
Aphanocapsa			P		
Chroococcus					
Cylindrospermum					
Lyngbya					R
Microcystis	A	P		A	P
Nostoc					
Pseudoanabaena				P	
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Merismopedia					

Euglenophyta (Euglenoids)					
Colacium					
Phacus					
Euglena sp	R	R		R	
Trachelomonas	C			R	
Lepocinclis					

Pyrrhophyta (Dinoflagellates)					
Ceratium	P	P		P	P
Peridinium					
Gymnodinium					

Cryptomonads					
Chroomonas					

Zooplankton

Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**
Bosmina sp.	A	P	P	C	C
Daphnia sp.	P	P	R		
Eubosmina sp.					
Chydorus					
Diaphniosoma	P	P	R		
Ceriodaphnia	R	P		R	R
Leptodora kindti					
Pleuroxus					

Copecoda (Copepods)	**1**	**2**	**3**	**4**	**5**
Cyclops sp.					
Dipatomus (H)					
Nauplii	P	P	C	P	P
Skistodiaptomus sp.		C			
Microcyclops sp	P	P	P	P	R
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid	P				
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	**1**	**2**	**3**	**4**	**5**
Branchionus					P
Conochilus			P		P
Asplanchna sp.	P	R			
Polyarthra	P	P	P	P	P
Hexarthra					
Keratella	R		P	P	C
Tricocerca				R	
Lecane					R
Kellicottia			C		
Brachionus		R			

Arthropoda (Arthropods)					
Chaoborus punctipennis					
Ostracoda					
Chironomidae					

Sites:	**1**	**2**	**3**	**4**		
Total Phytoplankton Genera	11	9	8	10	7	0
Total Zooplankton Genera	10	9	8	7	8	0

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)

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes — **Sampling Date: 10/5/22**

Site 1: Lake Lookover | **Site 2: Pinecliff lake** | **Site 3: Upper Greenwood** | **Site 4: Wonder Lake**

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4	5
Asterionella			R		
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Eunotia					
Fragilaria	R		R	P	
Frustulia					
Gyrosigma					
Melosira	R	R	C		
Nitzschia					
Stauroneis					
Stephanodiscus			P		
Sururekka					
Synedra					
Tabellaria	R				
Pinnularia					
Navicula					
Mastogloia					

Chrysophyta (Golden Algae)	1	2	3	4	5
Dinobryon	R		P	R	
Chromulina					
Mallomonas					
Ochromonas					

Synurophytes	1	2	3	4	5
Chrysosphaerella					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus					
Chlamydomonas					
Brachiomonas					
Chlorella	A			C	
Coelastrum					
Characium					
Gloeocystis					
Gloeotila				P	
Koliella					
Monoraphidium					
Mougeotia	P	C			
Nannochloris					
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya		R		P	
Tetraspora					
Treubaria					
Pediastrum	P	C	P	P	
Volvox					
Zygnema					
Sphaerocystis					
Ulothrix					

Desmids (Green Algae)	1	2	3	4	5
Desmidium					
Staurastrum				R	
Spondylosium					
Closterium	R			P	
Micrasterias	R				
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)		R	R		
Aphanizomenon	R		P	P	
Aphanocapsa					
Chroococcus					
Cylindrospermum					
Lyngbya				P	
Microcystis	P	C	C		
Nostoc					
Pseudoanabaena	R	R	P		
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Merismopedia			R		

Euglenophyta (Euglenoids)	1	2	3	4	5
Colacium					
Phacus	R			R	
Euglena sp			R		
Trachelomonas	P		R	C	
Lepocinclis					

Pyrrhophyta (Dinoflagellates)	1	2	3	4	5
Ceratium			R		
Peridinium					
Gymnodinium					

Cryptomonads	1	2	3	4	5
Chroomonas					

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.	P	A	P	R	
Daphnia sp.		R			
Eubosmina sp.					
Chydorus		R	R	R	
Diaphniosoma	R	C	P	R	
Ceriodaphnia	R		P		
Leptodora kindti					
Pleuroxus					

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.					
Dipatomus (H)					
Nauplii	P	P	C	A	
Skistodiaptomus sp.					
Microcyclops sp	P	P	P	A	
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid	C	P	C		
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	1	2	3	4	5
Ascomorpha					
Conochilus	P	R	P		
Asplanchna sp.	R				
Polyarthra			C		
Hexarthra					
Keratella	P	P	P		
Tricocerca					
Filinia					
Kellicottia				R	
Monostyla					

Arthropoda (Arthropods)	1	2	3	4	5
Chaoborus punctipennis					
Ostracoda				R	
Chironomidae					

Sites:	1	2	3	4		
Total Phytoplankton Genera	14	7	13	12	0	0
Total Zooplankton Genera	9	9	10	6	0	0

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)

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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 10/6/22**

Site 1: Shady Lake | **Site 2: Kitchell Lake** | **Site 3: Gordon Lake** | **Site 4: Post Brook Farms** | **Site 5: Algonquin Waters**

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4	5
Asterionella		R		C	
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Eunotia					
Fragilaria	R	A			
Frustulia					
Gyrosigma					
Melosira					P
Nitzschia					
Stauroneis					
Stephanodiscus			R		
Sururekka					
Synedra					R
Tabellaria				P	A
Pinnularia					
Navicula	P				
Mastogloia					

Chrysophyta (Golden Algae)	1	2	3	4	5
Dinobryon	P			P	B
Chromulina					
Mallomonas					
Ochromonas					

Synurophytes	1	2	3	4	5
Chrysosphaerella					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus					
Chlamydomonas					
Brachiomonas					
Chlorella					
Coelastrum					
Characium					
Gloeocystis				R	
Didymocystis					
Koliella					
Monoraphidium					
Mougeotia	R	A	P	R	
Nannochloris					
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya		R			
Tetraspora					
Treubaria					
Pediastrum	R	P	R	R	R
Volvox					
Zygnema					
Sphaerocystis					
Ulothrix					

Desmids (Green Algae)	1	2	3	4	5
Desmidium					
Staurastrum		C			R
Spondylosium					
Closterium					R
Micrasterias					
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)		A		A	P
Aphanizomenon			B		A
Aphanocapsa					
Chroococcus					
Cylindrospermum					
Lyngbya	P	C			
Microcystis	P	P	P	C	P
Nostoc					
Pseudoanabaena	R				
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Merismopedia			R		

Euglenophyta (Euglenoids)	1	2	3	4	5
Colacium					
Phacus					
Euglena sp	P				
Trachelomonas	P	P			
Lepocinclis					

Pyrrhophyta (Dinoflagellates)	1	2	3	4	5
Ceratium	C		P		R
Peridinium					
Gymnodinium					

Cryptomonads	1	2	3	4	5
Chroomonas	R	P		A	

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.	C	A	C	P	
Daphnia sp.		R	C	A	P
Eubosmina sp.					
Chydorus	R				R
Diaphniosoma			P		P
Ceriodaphnia	P	R		R	P
Leptodora kindti					
Pleuroxus					
Holopedium					C

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.					
Dipatomus (H)					
Nauplii	P	P	P	P	P
Skistodiaptomus sp.					
Microcyclops sp	P	C	P	P	P
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid			P	P	P
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	1	2	3	4	5
Ascomorpha					
Conochilus			P		P
Asplanchna sp.					P
Polyarthra	P	P	P	P	C
Hexarthra					
Keratella			P		P
Tricocerca					R
Filinia					
Kellicottia			P	P	R
Platyias			R		

Arthropoda (Arthropods)	1	2	3	4	5
Chaoborus punctipennis					
Ostracoda					
Chironomidae					

Sites:	1	2	3	4		
Total Phytoplankton Genera	12	11	6	9	11	0
Total Zooplankton Genera	6	6	9	7	13	0

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)

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes — **Sampling Date: 10/10/22**

Site 1: Farm Crest Acres | **Site 2: Bubbling Springs** | **Site 3: Lindy's Lake** | **Site 4: Lower Mt. Glen Lake** | **Site 5: Upper Mt. Glen Lake**

Phytoplankton

Bacillariphyta (Diatoms)	**1**	**2**	**3**	**4**	**5**	
Asterionella	R	P	C	A	R	
Aulacoseira						
Cocconeis						
Cyclotella						
Cymatopleura						
Cymbella						
Eunotia						
Fragilaria	C	A	C		P	
Frustulia						
Gyrosigma						
Melosira	R				R	
Nitzschia						
Stauroneis						
Stephanodiscus	A					
Sururekka						
Synedra	R		P		R	
Tabellaria					R	
Pinnularia						
Navicula		R				
Mastogloia						
Chrysophyta (Golden Algae)						
Dinobryon			P	R		
Chromulina						
Mallomonas						
Ochromonas						
Synurophytes						
Chrysosphaerella						
Zooplankton						
Cladocera (Water Fleas)	**1**	**2**	**3**	**4**	**5**	
Bosmina sp.	C		A	R	P	
Daphnia sp.	P	P	R	A		
Eubosmina sp.						
Chydorus	R					
Diaphniosoma	P	P				
Ceriodaphnia	P		R		R	
Leptodora kindti						
Pleuroxus						
Sites:	**1**	**2**	**3**	**4**		
Total Phytoplankton Genera	11	12	11	10	11	0
Total Zooplankton Genera	10	6	9	9	5	0

Chlorophyta (Green Algae)	**1**	**2**	**3**	**4**	**5**
Actinastrum					
Ankistrodesmus					
Chlamydomonas		P			
Brachiomonas					
Chlorella					C
Coelastrum					
Characium					
Gloeocystis			R		
Didymocystis					
Koliella					
Monoraphidium					
Mougeotia	P		R	C	R
Nannochloris					
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya					
Tetraspora					
Treubaria					
Pediastrum		P	R		P
Volvox					
Zygnema					
Sphaerocystis					
Ulothrix					
Desmids (Green Algae)					
Desmidium					
Staurastrum	P	R			
Spondylosium	P	R			
Closterium					
Micrasterias					
Staurodesmus					
Copecoda (Copepods)	**1**	**2**	**3**	**4**	**5**
Cyclops sp.					
Dipatomus (H)					
Nauplii	P	P	P	C	A
Skistodiaptomus sp.	A				
Microcyclops sp	P		C	C	P
Limnocalanus macrurus					
Leptodiaptomus sp.		C		C	P
Unknown Cyclopod					
Unknown Calanoid			R		
Mesocyclops					
Diacyclops					
Tropocyclops					

Cyanophyta (Blue-Green Algae)	**1**	**2**	**3**	**4**	**5**
Dolichospermum (formerly Anabaena)				P	
Aphanizomenon			P	A	
Aphanocapsa					
Chroococcus					
Cylindrospermum					
Lyngbya		R			
Microcystis	R	P	P	P	
Nostoc					
Pseudoanabaena	R	R			R
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Merismopedia					
Euglenophyta (Euglenoids)					
Colacium					
Phacus					
Euglena sp				P	
Trachelomonas				R	
Lepocinclis					
Pyrrhophyta (Dinoflagellates)					
Ceratium	P	C	A	R	R
Peridinium					
Gymnodinium					
Cryptomonads					
Chroomonas		A	R	A	A
Rotifera (Rotifers)	**1**	**2**	**3**	**4**	**5**
Ascomorpha					
Conochilus				R	
Asplanchna sp.	P		R		
Polyarthra	P	P	P	P	
Hexarthra					
Keratella		P	C	P	
Tricocerca				R	
Filinia		R	C		
Kellicottia					
Pompholyx	P	P			
Arthropoda (Arthropods)					
Chaoborus punctipennis					
Ostracoda					
Chironomidae					

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)

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Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: West Milford Lakes | **Sampling Date: 10/13/22**

Site 1: Mt. Laurel Lake

Phytoplankton

Bacillariphyta (Diatoms)	1	2	3	4	5
Asterionella					
Aulacoseira					
Cocconeis					
Cyclotella					
Cymatopleura					
Cymbella					
Eunotia					
Fragilaria	C				
Frustulia					
Gyrosigma					
Melosira					
Nitzschia					
Stauroneis					
Stephanodiscus					
Sururekka					
Synedra					
Tabellaria					
Pinnularia					
Navicula					
Mastogloia					
Chrysophyta (Golden Algae)					
Dinobryon	A				
Chromulina					
Mallomonas					
Ochromonas	A				
Synurophytes					
Chrysosphaerella					

Chlorophyta (Green Algae)	1	2	3	4	5
Actinastrum					
Ankistrodesmus					
Chlamydomonas					
Brachiomonas					
Chlorella					
Coelastrum					
Characium					
Gloeocystis					
Didymocystis					
Koliella					
Monoraphidium					
Mougeotia					
Nannochloris					
Microspora					
Ochromonas					
Oedogonium					
Oocystis					
Scenedesmus					
Spirogya	R				
Tetraspora					
Treubaria					
Pediastrum	P				
Volvox					
Zygnema					
Sphaerocystis					
Ulothrix					
Desmids (Green Algae)					
Desmidium					
Staurastrum					
Spondylosium					
Closterium	R				
Micrasterias					
Staurodesmus					

Cyanophyta (Blue-Green Algae)	1	2	3	4	5
Dolichospermum (formerly Anabaena)					
Aphanizomenon					
Aphanocapsa					
Chroococcus					
Cylindrospermum					
Lyngbya					
Microcystis	A				
Nostoc					
Pseudoanabaena	R				
Oscillatoria					
Coelosphaerium					
Spirulina					
Aphanothece					
Merismopedia					
Euglenophyta (Euglenoids)					
Colacium					
Phacus					
Euglena sp					
Trachelomonas					
Lepocinclis					
Pyrrhophyta (Dinoflagellates)					
Ceratium					
Peridinium					
Gymnodinium					
Cryptomonads					
Chroomonas	P				

Zooplankton

Cladocera (Water Fleas)	1	2	3	4	5
Bosmina sp.					
Daphnia sp.					
Eubosmina sp.					
Chydorus	R				
Diaphniosoma	R				
Ceriodaphnia	P				
Leptodora kindti					
Pleuroxus					

Copecoda (Copepods)	1	2	3	4	5
Cyclops sp.					
Dipatomus (H)					
Nauplii	P				
Skistodiaptomus sp.					
Microcyclops sp	P				
Limnocalanus macrurus					
Leptodiaptomus sp.					
Unknown Cyclopod					
Unknown Calanoid					
Mesocyclops					
Diacyclops					
Tropocyclops					

Rotifera (Rotifers)	1	2	3	4	5
Ascomorpha					
Conochilus					
Asplanchna sp.					
Polyarthra	C				
Hexarthra					
Keratella	P				
Tricocerca					
Filinia					
Kellicottia					
Pompholyx					
Arthropoda (Arthropods)					
Chaoborus punctipennis					
Ostracoda	R				
Chironomidae					

Sites:	1	2	3	4		
Total Phytoplankton Genera	9	0	0	0	0	0
Total Zooplankton Genera	8	0	0	0	0	0

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)

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