UPPER MUSCONETCONG RIVER WATERSHED IMPLEMENTATION PLAN

MORRIS AND SUSSEX COUNTIES, NEW JERSEY

NOVEMBER 2020

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Cover photo: Prospect Point Preserve and Liffy Island (Jefferson Township) by Donna Macalle-Holly

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EXECUTIVE SUMMARY

Lake Hopatcong is the largest lake in New Jersey, with a surface area of 2,686 acres and approximately 39 miles of shoreline. The lake is on the border of Sussex and Morris Counties, surrounded by the Boroughs of Hopatcong and Mount Arlington and the Townships of Jefferson and Roxbury. Lake Hopatcong and its associated tributaries, Lake Shawnee and its sub-watersheds, form the headwaters of the Upper Musconetcong River Watershed. In turn, the outlet of Lake Hopatcong forms the Upper Musconetcong River and enters Lake Musconetcong approximately 1.28 miles from the Lake Hopatcong dam. Lake Musconetcong is a 329-acre waterbody also on the border of Sussex and Morris Counties, surrounded by the Boroughs of Netcong and Stanhope and the Townships of Roxbury and Byram. The lakes are highly valued resources for the state and have a substantial impact on the local economy. Although highly valued, the lakes have been documented to experience declined water quality conditions such as blue-green algae blooms and nuisance aquatic macrophyte growth. These poor water quality conditions have been attributed to elevated watershed-based pollutant loads from total phosphorus (TP).

In response to the documented water quality problems, a Total Maximum Daily Load (TMDL) analysis was developed in 2003 by the New Jersey Department of Environmental Protection (NJDEP) for the annual TP load in the Upper Musconetcong River Watershed. To address this issue, a Restoration Plan (the Restoration Plan) was developed for the Upper Musconetcong River Watershed for the Lake Hopatcong Commission (the Commission) and the Lake Musconetcong Regional Planning Board (LMRPB) in the mid-2000's which linked the existing TP TMDL to existing and targeted loads of phosphorus for all the municipalities surrounding both Lake Hopatcong and Lake Musconetcong. In turn, these existing and targeted loads were used to estimate existing and targeted (desirable) mean, growing season TP and chlorophyll-a concentrations for each lake.

The resulting Restoration Plan was an outline for a series of projects to be implemented within both the Lake Hopatcong and Lake Musconetcong watersheds to comply with their regulatory requirements as detailed in their respective TMDLs for TP. The Restoration Plan was approved by NJDEP in 2006 and was subsequently used to obtain funding for the implementation of a wide variety of stormwater control and watershed management projects over the past 14 years. Funding for these projects was obtained through two Clean Water Act Section 319 Non-Point Source pollution grants from NJDEP and a US Environmental Protection Agency (EPA) Targeted Watershed Grant (TWG). To date, these projects have addressed approximately 32% of the required reduction in Lake Hopatcong to be in compliance with the TMDL.

While the original Restoration Plan was extremely useful over the last decade as a guide in the implementation of projects to reduce TP loads, it has been updated in this document to better reflect current conditions and document other watershed-based improvements. Related to this is the fact that after the original plan was approved, NJDEP began to utilize the EPA Nine Elements approach to develop a Watershed Implementation Plan (WIP). As such, this document follows the requirements for the EPA WIP that addresses nine specific elements. This type of plan then covers a wide range of topics including identification of water quality problems, determining the cause of these problems, identifying measures to correct the problems, securing the technical and financial assistance to implement the plan, and developing criteria, schedules, and a monitoring program to track progress.

The early stages of this project focused on evaluating the progress towards TMDL compliance achieved thus far through the implementation of the watershed-based measures over the past 14 years. This evaluation was completed through a two-pronged approach both within the watershed and in the lakes. The first approach involved an inventory of recently completed BMPs and other watershed measures in order to update the municipal-based phosphorus loads for the four municipalities immediately surrounding Lake Hopatcong. This process helped to better understand where in the watershed restoration measures should be focused. In the original Restoration Plan, it was determined that in order for the WIP to be fair and objective, the targeted phosphorus load reductions would be divided on a proportional basis based on the areal extent of each municipality. Specifically, the amount of phosphorus each municipality currently contributes to the lake's existing phosphorus load was used to quantify its targeted reduction.

This revised WIP also included the collection of stormwater samples to aid in the identification of sites / sub-watersheds for both lakes that experience elevated pollutant loading. A drone was utilized to pick the stormwater sampling sites in areas within each lake's watershed that have been recognized as a prioritized area of concern relative to elevated stormwater pollutant loads. For Lake Hopatcong, three areas of concern were drone surveyed: the northeastern shoreline of the lake, north of Liffy Island (Township of Jefferson); the southern end of Crescent Cove (Borough of Hopatcong) and within the Hopatcong State Park. For Lake Musconetcong, two such areas of concern were drone surveyed: around the Musconetcong State Park (Borough of Netcong), and along the southern shore of the lake, north of Route 46 (Borough of Netcong).

The second approach included general water quality monitoring of Lake Hopatcong and Lake Musconetcong during the 2018 growing season (May through September) to provide an up-to-date water quality and ecological assessment of conditions within the lakes. In addition to the 2018 monitoring at Lake Hopatcong, this WIP included long-term analyses, with an emphasis on the 2006 – 2018 portion of the database, to quantify how the implementation of the Restoration Plan has impacted water quality data in Lake Hopatcong. The analyses were performed on water quality data collected at the mid-lake station as well as a number of other stations throughout the lake that have experienced nuisance blue-green algal blooms over the last few years.

After the completion of the various evaluation metrics, the focus was shifted towards determining the various management measures throughout the watershed that will aid in reducing TP loads to the lakes. This is essentially the most important component of the WIP and consists of a list of projects that could be designed and implemented to further reduce the TP, and other pollutants, loads entering Lake Hopatcong and Lake Musconetcong. A considerable amount of time was spent in the field identifying potential project sites, with a focus on sites that have the capacity to accommodate green infrastructure.

There were two main strategies associated with the field site assessments. The first strategy focused on enhancing, modifying, or upgrading the existing stormwater infrastructure throughout the watersheds of each lake. Thus, site assessments were conducted throughout the watershed and focused on locations that receive a large volume of stormwater runoff. The second strategy focused on conducting streambank site assessments along many of the small streams that feed Lake Hopatcong and Lake Musconetcong and shoreline site assessments in both lakes. Again, where feasible, green infrastructure was integrated into any recommended designs.

For each of the 52 identified locations, a proposed BMP/restoration measure is included along with an estimated cost for design and implementation as well as an estimated amount of TP that would be removed with the associated restoration measure. These measures include bioretention systems, basin retrofits, vegetated filters/swales, bioengineered streambank stabilization, MTDs, among others. In order to streamline the process of project implementation, a prioritized implementation schedule is provided as well as different avenues to secure technical and financial assistance, including state and federal grants. Finally, the necessary components required to track the progress of implemented projects is provided, including interim measurable milestones such as the number of project demonstrations or grant funding received, evaluation criteria such as the amount of TP removed, and both project site and surface water monitoring components.

INTRODUCTION

A Restoration Plan (the Restoration Plan) was developed for the Upper Musconetcong River Watershed for the Lake Hopatcong Commission (the Commission) and the Lake Musconetcong Regional Planning Board (LMRPB) in the mid-2000's (Princeton Hydro, 2006). Funding for the Plan was provided through the Rutgers's EcoComplex and Princeton Hydro was hired to develop it. The Upper Musconetcong River Watershed is essentially Lake Hopatcong, Lake Musconetcong and their respective watershed. The watershed-based plan linked the existing total phosphorus (TP) Total Maximum Daily Load (TMDL), developed by the New Jersey Department of Environmental Protection (NJDEP), to existing and targeted loads of phosphorus for all the municipalities surrounding both Lake Hopatcong and Lake Musconetcong. In turn, these existing and targeted loads were used to estimate existing and targeted (desirable) mean, growing season TP and chlorophyll-a concentrations for each lake.

Phosphorus is often the limiting nutrient in lake ecosystems, meaning the nutrient whose abundance is lowest relative to demand. This is particularly the case for freshwater systems and indeed holds for both lakes. As a result, phosphorus is often the primary nutrient responsible for excessive plant and algal growth. TP concentrations account for all species of phosphorus, including organic, inorganic, soluble and insoluble.

Once the targeted growing season TP and chlorophyll-a concentrations were established, the Restoration Plan identified prioritized locations where potential stormwater treatment measures, also known as Best Management Practices (BMPs), could be installed. The Plan also included some educational / public outreach material for distribution to residents, visitors and stakeholders in general.

The resulting Restoration Plan was an outline for a series of projects to be implemented within both the Lake Hopatcong and Lake Musconetcong watersheds to comply with their regulatory requirements as detailed in their respective TMDLs for TP. The Plan was approved by NJDEP in 2006 and was subsequently used to obtain funding for the implementation of a wide variety of stormwater control and watershed management projects. The grants used to complete the projects around Lake Hopatcong include two Clean Water Act Section 319 Non-Point Source pollution grants from NJDEP and a US Environmental Protection Agency (EPA) Targeted Watershed Grant (TWG). Additionally, the Township of Jefferson, which is the only municipality in the watershed where the residents were still entirely on septic systems, obtained a Clean Water Act Section 604(b) Water Quality Planning Grant from NJDEP to develop a Septic Management Plan for the entire portion of the township located in the Lake Hopatcong Watershed. This Plan included passing an ordinance for the mandatory pump-out of all septic system at least once every three years. Lake Musconetcong was also awarded a 319-grant from NJDEP for a detailed assessment in potentially dredging a large portion of the unconsolidated material from the lake.

While the Upper Musconetcong River Watershed Restoration Plan was extremely useful over the last decade as a guide in the implementation of projects to reduce TP loads, it needs to be updated to better reflect current land use conditions and document other watershed-based improvements. Related to this is the fact that after the Restoration Plan was approved, NJDEP began to utilize the US EPA Nine Elements approach to develop a Watershed Implementation Plan (WIP), a requirement for 319 funding. Thus, those watersheds that have an approved WIP, including the 9 elements, have a substantially higher chance of obtaining State and Federal funding. While large changes in land use for the Upper Musconetcong River watershed are not expected to have occurred over the last 10 to 12 years, there have been a considerable number of advances in NPS pollutant reduction technology over this period of time. Additionally, the lake-wide blooms of cyanobacteria in Lake Hopatcong over the summer of 2019, placed additional emphasis on the need to continue in the long-term efforts of reducing the TP loads in these lakes and comply with their respective TMDLs.

This document will be formatted to address the nine (9) elements of a Watershed Implementation Plan as defined by the EPA. These nine elements are meant to address all phases of a protection plan from characterization to conceptual mitigation and practical design, cost, implementation, and evaluation. The following list represents a summarized and abbreviated description of the nine elements as outlined in the Handbook for Developing Watershed Plans to Restore and Protect Our Waters (EPA, 2008).

1. Identification of causes and sources of pollution
2. An estimate of load reductions expected from management measures
3. A description of NPS management measures and implementation sites
4. Estimate the amount of technical and financial assistance to implement
5. Information and education component
6. Schedule for implementing the NPS management measures
7. A description of interim measurable milestones for implementation
8. Developing criteria to measure progress
9. Develop a monitoring component

BRIEF DESCRIPTION OF LAKE HOPATCONG

Lake Hopatcong is the largest lake in New Jersey, with a surface area of 2,686 acres and approximately 39 miles of shoreline. The lake is on the border of Sussex and Morris Counties, surrounded by the Boroughs of Hopatcong and Mount Arlington and the Townships of Jefferson and Roxbury. Lake Hopatcong and its associated tributaries, Lake Shawnee and its sub-watersheds, form the headwaters of the Upper Musconetcong River Watershed. In turn, the outlet of Lake Hopatcong forms the Upper Musconetcong River and enters Lake Musconetcong approximately 1.28 miles from the Lake Hopatcong dam (Appendix I).

Therefore, any restoration activities that occur within the sub-watersheds immediately draining into Lake Hopatcong will benefit Lake Musconetcong and other downstream waterways, in addition to Lake Hopatcong itself.

BRIEF DESCRIPTION OF LAKE MUSCONETCONG

Lake Musconetcong is a 329-acre waterbody located approximately 1.28 miles downstream of the dam of Lake Hopatcong (Appendix I). Similar to Lake Hopatcong, Lake Musconetcong is on the border of Sussex and Morris Counties, but is surrounded by the Boroughs of Netcong and Stanhope and the Townships of Roxbury and Byram. In sharp contrast to the complex morphometry of Lake Hopatcong, Lake Musconetcong is a shallow waterbody with a mean depth of 1.5 m (4.9 ft) and a maximum depth of 3.05 m (10.0 ft).

SUMMARY OF PAST STUDIES AND PROJECTS

A number of studies and projects have been conducted in the Upper Musconetcong River watershed over the last 17 years in an effort to improve water quality conditions and comply with the State's phosphorus TMDL. For convenience these studies and projects are summarized below:

SUMMARY OF THE REFINED PHOSPHORUS TMDL AND RESTORATION PLANS FOR LAKE HOPATCONG AND LAKE MUSCONETCONG

A Phase I Diagnostic / Feasibility study was conducted on the lake and watershed in 1981 (Princeton Aqua Science, 1983) and since then, a variety of lake and watershed projects have been implemented, many of them focusing on the control / management of nuisance submerged aquatic vegetation (SAV), particularly Eurasian watermilfoil (*Myriophyllum spicatum*) and tapegrass (*Vallisneria americana*). The primary mode of controlling nuisance SAV in Lake Hopatcong has been mechanical weed harvesting; however, some lakeshore residents / homeowner groups do hire certified applicators to treat select areas of the lake with State-approved aquatic herbicides.

From the early 1980's to early 2000 the Lake Hopatcong Regional Planning Board oversaw the implementation of various in-lake and watershed-based projects, primarily through State and Federal sources. In 2001 the State of New Jersey created the Lake Hopatcong Commission (the Commission) to serve as the stewards of Lake Hopatcong and its watershed. The Commission works cooperatively with governmental bodies and the public to monitor, protect, restore and manage the lake, its water quality and associated natural resources.

In 2003 the NJDEP conducted a Total Maximum Daily Load (TMDL) analysis for the Upper Musconetcong River watershed, which included Lake Hopatcong and Lake Musconetcong.

As previously stated, the pollutant of concern under the TMDL was total phosphorus (TP), since it is the primary nutrient driving and stimulating algal and aquatic plant growth. However, it should be noted that other pollutants are of concern at Lake Hopatcong, such as total suspended solids (TSS) and fecal coliform. The Lake Hopatcong TMDL for TP was completed and approved by NJDEP in September of 2003.

While the TMDL quantified how much the existing TP load needs to be reduced by in order to be in compliance with the TMDL targeted loads, the TMDL analysis did not describe how these reductions are to be achieved. Thus, Princeton Hydro was hired by the NJDEP and the New Jersey EcoComplex of Rutgers University to develop a Restoration Plan for both Lake Hopatcong and Lake Musconetcong, using the TMDL as a guide. Given the existing political boundaries within the Lake Hopatcong watershed, the targeted reductions in TP were quantified by municipality and not by land type or sub-watershed. Thus, each of the four municipalities has a specific reduction in TP they need to achieve in order to comply with the TMDL. In addition to this analysis, the Restoration Plan linked existing and targeted TP loads to existing and desirable water quality conditions, relative to the magnitude of algal blooms. Finally, the Restoration Plan also identified a series of high priority zones or sites that should be considered for the implementation of measures to reduce the existing, stormwater-based TP loads entering Lake Hopatcong. The Restoration Plan was completed and then approved by both NJDEP and US EPA for implementation activities. This made Lake Hopatcong eligible for State and Federal funds.

One of the first major steps in moving the Restoration Plan into the implementation phase was to request funds through the State's Nonpoint Source Pollution (NPS) 319(h) program. The 319(h) Program funds are provided by US EPA to designated state and tribal agencies to implement their approved nonpoint source management programs. The Commission has been awarded two 319-grants over the past 14 years for the implementation of watershed-based projects to reduce the TP loads entering Lake Hopatcong; one in 2005 and one in 2010, as detailed below (Princeton Hydro, 2012; 2017). Additionally, a US EPA-funded TWG grant, a competitive grant program that provides funding for community-driven watershed projects, was awarded to the Commission in 2006 for the design and installation of additional watershed projects (Princeton Hydro, 2013).

FIRST NON-POINT SOURCE (319) IMPLEMENTATION PROJECT; 2005

The Commission submitted an application for funding under the NPS 319-program to NJDEP under State Fiscal Year (SFY) 2005. Funding was awarded to implement a series of four (4) stormwater projects within the Lake Hopatcong watershed. These projects involved the installation of stormwater structures, including Manufactured Treatment Devices (MTDs), designed to aid in the reduction of TP and other pollutants of concern. MTDs are more structural means of reducing NPS pollution and frequently, but not always, includes technologies that may be exclusively manufactured by one or several companies. Under the Scope of Work, three projects were proposed for implementation in the Borough of Hopatcong, while one was proposed for the Township of Jefferson. These projects include:

- Installation of a combination Aqua-Swirl and Aqua-Filter within the Crescent Cove parking lot (Borough of Hopatcong, Sussex County, NJ). This MTD treats approximately 90 acres of land and the structures were installed in November / December of 2008.

- Installation of another Aqua-Swirl and Aqua-Filter combination within the Crescent Cove parking lot (Borough of Hopatcong, Sussex County, NJ). This MTD treats approximately 40 acres of land from a drainage area adjacent to the one for the first Aqua-Swirl / Aqua-Filter MTD. These structures were installed in May of 2011.

- Installation of an Aqua-Filter MTD just off Castle Rock Road (Township of Jefferson, Morris County, NJ). It should be noted that while the Aqua-Filter unit could be installed, existing site constraints prevented the installation of the Aqua-Swirl structure used in the two MTDs noted above, and which serves to pre-treat the stormwater for larger particulates before it enters the Aqua-Filter. Thus, since the space was not available for the installation of the Aqua-Swirl, a pre-treatment settling basin was designed and constructed for the pre-treatment of stormwater, prior to entering the Aqua-Filter. This project treats approximately 32 acres of land and was completed in August 2009.

- Installation to two (2) Filterra MTDs along Yacht Club Drive (Township of Jefferson, Morris County, NJ).

A summary of the TSS and TP reductions associated with this first Non-Point Source (319) Implementation Project are provided in a comprehensive table at the end of this section of the report (Table 1).

US EPA TARGETED WATERSHED GRANT; 2006

Similar to the objectives of the NPS grant projects, the principal objective of the Commission's Targeted Watershed Grant Project was to reduce the existing phosphorus load entering Lake Hopatcong. In addition to the main objective, there are several Subordinate Objectives that were addressed as part of the TWG project, including:

- Addressing other nonpoint source (NPS) pollutants, such as total suspended solids, which negatively impact the ecological and recreational value of Lake Hopatcong.

- Assessing the potential phosphorus removal capacity of several innovative stormwater and septic-based technologies.

- Further educating the Commissioners and staff of the Commission about concepts associated with watershed management and NPS pollution so they, in turn, can educate local stakeholders.

The tasks that were identified for the design and implementation projects under the Lake Hopatcong TWG originally included the following:

- Design and installation of several stormwater Best Management Practices (BMPs) or Manufactured Treatment Devices (MTDs) in the Township of Jefferson, the Borough of Mt. Arlington, and the Township of Roxbury.

- Pilot Study on the effectiveness of an on-site wastewater treatment system (septic system) peat biofilter treatment system in the Township of Jefferson.

- Implementation and documentation of an innovative retrofit to enhance the capacity of existing structural BMPs to remove phosphorus.

- The design and implementation of a holistic public outreach program for the Lake Hopatcong watershed.

- Additional training of Commission Operations Staff and additional quality monitoring of the Lake Hopatcong watershed.

- Project documentation and submission of the final report.

A number of MTDs and BMPs were installed throughout the Lake Hopatcong watershed to reduce the NPS pollutant load entering the lake from stormwater and surface runoff with the funds from the TWG:

- A three-chambered baffle box with polisher unit was installed along East Shore Road in the Township of Jefferson, Morris County, NJ. The drainage area for this baffle box with polisher unit is 125 acres.

- A three-chambered baffle box was installed along Yacht Club Drive in the Township of Jefferson, Morris County, NJ. The drainage area for this baffle box is 5.4 acres.

- A three-chambered baffle box was integrated into a larger stormwater infrastructure project being conducted by the Borough of Mt. Arlington, located just off of Windermere Avenue. The drainage area for the Mt. Arlington baffle box is 90 acres.

- Two stormwater treatment devices were designed and installed in a section of the Lake Hopatcong watershed, located in the Township of Roxbury, Morris County, NJ. Specifically, a three chambered baffle box MTD was installed along Singac Avenue, while an existing stormwater detention basin off King Road was retrofitted to function as a wetland stormwater basin, immediately down gradient of a baffle box MTD. This "treatment train" within the Township of Roxbury treats approximately 86 acres of surface runoff / stormwater.

A summary of the TSS and TP reductions associated with the USEPA Targeted Watershed Grant are provided in a comprehensive table at the end of this section of the report (Table 1).

SECOND NON-POINT SOURCE (319) IMPLEMENTATION PROJECT; 2010

The Commission was awarded a second NPS Implementation project in SFY2010 by the NJDEP. The NJDEP 319(h) funding under this grant was used to implement additional long-term measures to reduce nutrient and sediment loading to Lake Hopatcong, with a particular emphasis on total phosphorus (TP). These project activities included:

- The installation of a biofiltration basin and two Type A catch basins retrofit with SNOUT© Model 12F and debris stops at the Hopatcong State Park. This biofiltration basin has a drainage area of approximately 0.5 acres of impervious surfaces.

- The installation of a Manufactured Treatment Device (MTD) in Roxbury Township. This MTD has a drainage area of approximately 5.21 acres and is composed of high density residential and forested lands.

- The design, installation and oversight of four Filterra Units in Jefferson Township.

- The installation of two 240 sq. ft Floating Wetland Islands in Ashley Cove, Jefferson Township.

Along with nutrient reduction projects, the 319-grant was used to collect a variety of data to assess the ongoing health of the lake and watershed. These assessments included:

- In-Lake water quality monitoring programs for 2010, 2011, 2012, 2014, 2015 and 2016. The 2013 in-lake water quality program was funded by the Lake Hopatcong Foundation as a contributing in-kind match toward the grant.

- Selective stormwater monitoring was conducted before and after the installation of the biofiltration basin at Hopatcong State Park and the MTD along King Road. Various parameters, including total phosphorus (TP), soluble reactive phosphorus (SRP), total dissolved phosphorus (TDP) and total suspended solids (TSS), were sampled during the storm events to assess the nutrient reduction efficiency of the BMPs.

- The sampling of cyanotoxins, compounds produced by cyanobacteria that have the potential to negatively impact the health of humans and pets, during the 2015 growing season at select shoreline locations for the analysis of microcystins.

- A selective, near-shore bathymetric assessment was added to the expanded Scope of Work to quantify water depth and sediment thickness in near-shore and cove areas of Lake Hopatcong. Essentially, the goal of this activity was to identify and prioritize areas that have relatively high amounts of unconsolidated material as a result of high rates of sediment loading from the watershed.

In addition to the above mentioned grant projects, a number of other activities have taken place within the watershed with the goal of reducing the annual pollutant load. For example, Lake Hopatcong has conducted weed harvesting throughout the lake during the growing season months since 2002. Princeton Hydro conducted a study in 2016 that determined that an estimated 279 lbs. of phosphorus are removed annually through weed harvesting. Additionally, an estimated 40% of the lots within the septic zone of influence in the Borough of Hopatcong were sewered, resulting in an estimated annual reduction of 1,353 lbs of phosphorus.

A summary of the TSS and TP reductions associated with the second Non-Point Source (319) Implementation Project are provided in a comprehensive table at the end of this section of the report (Table 1).

Table 1: Summary of the Watershed-Based Activities that have been Implemented within the Lake Hopatcong Watershed to reduce its TSS and TP Pollutant Loads (2006 – 2016)

Year (s)	Management Activity	TSS Removed	TP Removed
2002 - 2016	**Mechanical weed harvesting** (mean annual amount Estimated from 2002 to 2016	Not applicable	279 lbs
	Partial sewering of Borough of Hopatcong (estimates 40% of the lots within the septic zone of influence were sewered)	Not applicable	1,353 lbs
2005	**NPS 319(h)-grant (SFY2005)** Two Aqua-Swirl / Aqua-Filter MTDs in Borough of Hopatcong plus Aqua-Filter MTD in Township of Jefferson Two Filterra MTDs in Township of Jefferson	6,966 lbs 999 lbs	15.3 lbs 0.6 lbs
2006	**US EPA Targeted Watershed Grant** 3-chambered baffle box in Township of Jefferson Second 3-chambered baffle box in Township of Jefferson 3-chambered baffle box in Borough of Mt. Arlington 3-chambered baffle box plus wetland stormwater basin in Township of Roxbury Retrofit septic system with peat biofilter in Township of Jefferson	87,609 lbs 3,785 lbs 63,079 lbs 68,886 lbs Not applicable	28.4 lbs 1.2 lbs 20.4 lbs 32.5 lbs 10.1 lbs
2010	**NPS 319(h)-grant (SFY2011)** Biofiltration basin in Hopatcong State Park Downstream Defender MTD in Township of Roxbury Four Filterra MTD Units in Township of Jefferson Two floating wetland islands in Township of Jefferson	801 lbs. 3,704 lbs. 3,147 lbs. Not applicable	0.5 lbs 1.5 lbs. 2 lbs. 20 lbs.
	Watershed-wide use of non-P fertilizers (Based on the 2008-09 study and only provides an estimate for residential lawns; conducted as part of the US EPA Targeted Watershed grant).	Not applicable	439 lbs
	Mandatory pump-outs of existing septic systems within zone of influence for the Township of Jefferson	Not applicable	114 lbs
	Total Amount of Pollutants Removed/Abated	**238,976 lbs (108,400 kg)**	**2,318 lbs (1,051 kg)**

IDENTIFICATION OF SOURCES OF POLLUTION

The following section corresponds with the first of the nine watershed plan elements and provides information related to the determination of the sources of pollution entering Lake Hopatcong and Lake Musconetcong. As previously stated, the TMDL developed in 2003 determined that TP was the pollutant of concern since it is recognized as the primary nutrient driving and stimulating algal and aquatic plant growth in Lake Hopatcong and Lake Musconetcong. The relationship between TP and algal growth was further supported in the original Restoration Plan by modeling that analyzed the effect that TP concentrations in Lake Hopatcong and Lake Musconetcong had on chlorophyll-a concentrations (Princeton Hydro, 2006). Chlorophyll-a is a pigment that all algae and plants possess and use in the process of photosynthesis. Therefore, measuring chlorophyll-a in lake water is an effective way of quantifying phytoplankton (free-floating) biomass. The TMDL for TP has since been linked to targeted (desirable) mean, growing season chlorophyll-a concentrations, as well as maximum concentrations, for each lake. These values can be used as an ecological measure of compliance with the TMDL (Table 2). These targeted chlorophyll-a concentrations were determined through modeling that was completed as part of the original Restoration Plan and are still used as ecological endpoints that correspond to compliance with the TMDL. While chlorophyll-a is being used as an "ecological endpoint" for the WIP of Lake Musconetcong and Lake Hopatcong, it is not the recommended final endpoint of the TMDL. The final targeted endpoint for the TMDL will remain TP for both lakes. However, utilizing an ecological endpoint such as chlorophyll-a puts the TMDL and associated WIP into a perspective that is tangible and easy to understand from a layperson's point of view. This is certainly the case since the nuisance harmful algal blooms (HABs) that have plagued Lake Hopatcong, and to a lesser degree Lake Musconetcong, particularly over the 2019 summer season.

It was determined in the Restoration Plan that over 80% of the annual phosphorus load entering Lake Hopatcong originates from surface runoff and septic systems. Therefore, the development of this document will focus on reducing surface runoff and septic system sources of phosphorus.

Table 2: Total phosphorus TMDL and associated targeted chlorophyll-a concentrations.

Lake	TP Total Maximum Daily Load (mg/L)	Targeted mean and maximum chlorophyll-a Concentration (µg/L)
Lake Hopatcong	0.03	8.1 / 13.6
Lake Musconetcong	0.03	8.9 / 14.4

TMDL PROGRESS

Based on all of the in-lake and watershed projects completed from the initial implementation of the Restoration Plan in 2006 to 2019, the amount of TP removed on an annual basis is estimated to be 1,073 kg (2,362 lbs). This accounts for approximately 32% of the amount of TP targeted for removal under the existing TMDL for Lake Hopatcong. In contrast, a similar analysis has not been completed for Lake Musconetcong, primarily due to fact that over the years that lake was infested with the aggressive, nuisance and invasive aquatic plant water chestnut (*Trapa natans*). Thus, most lake management efforts at Lake Musconetcong have focused almost exclusively on the eradication of this nuisance species through the use of aquatics herbicides, mechanical weed harvesting and the selective use of a hydro-raking. It should be noted that at one point the water chestnut covered approximately a third of Lake Musconetcong (about 100 acres); however, through the aggressive in-lake restoration efforts, coverage of this invasive species is down to less than 10 acres (as of 2019).

LAKE HOPATCONG

To compare the status of the water quality of Lake Hopatcong to the TP TMDL and targeted chlorophyll-a concentrations, it is best to look at growing season mean concentrations as growing season concentrations were used in the development of the TMDL and targeted ecological thresholds. Thus, for TP and chlorophyll-a, Figure 1 and 2, respectively, are presented that have yearly averages from 2006 to 2019 for all surface stations combined. Note on each figure Series 1 is the mean surface TP concentration, while Series 2 is the TMDL targeted goal of a mean TP concentration of 0.03 mg/L. Linear (Series 1) is the trend.

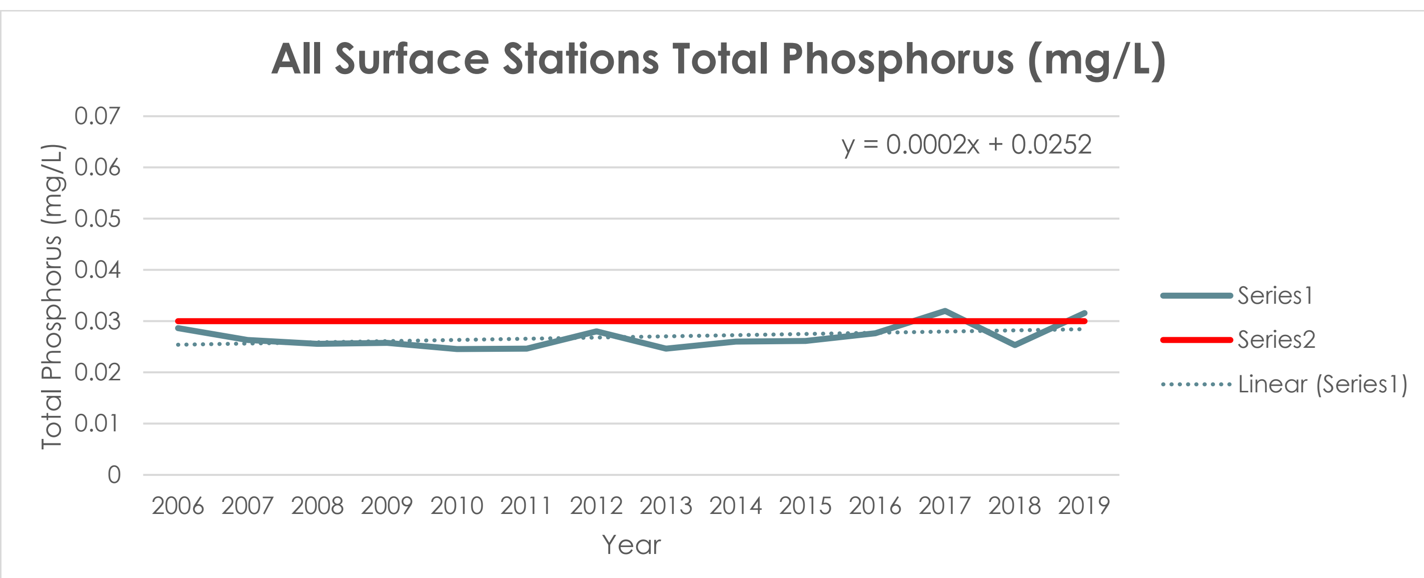


Figure 1: Average surface TP concentrations of all surface stations from 2006 – 2019 compared with the TMDL threshold.

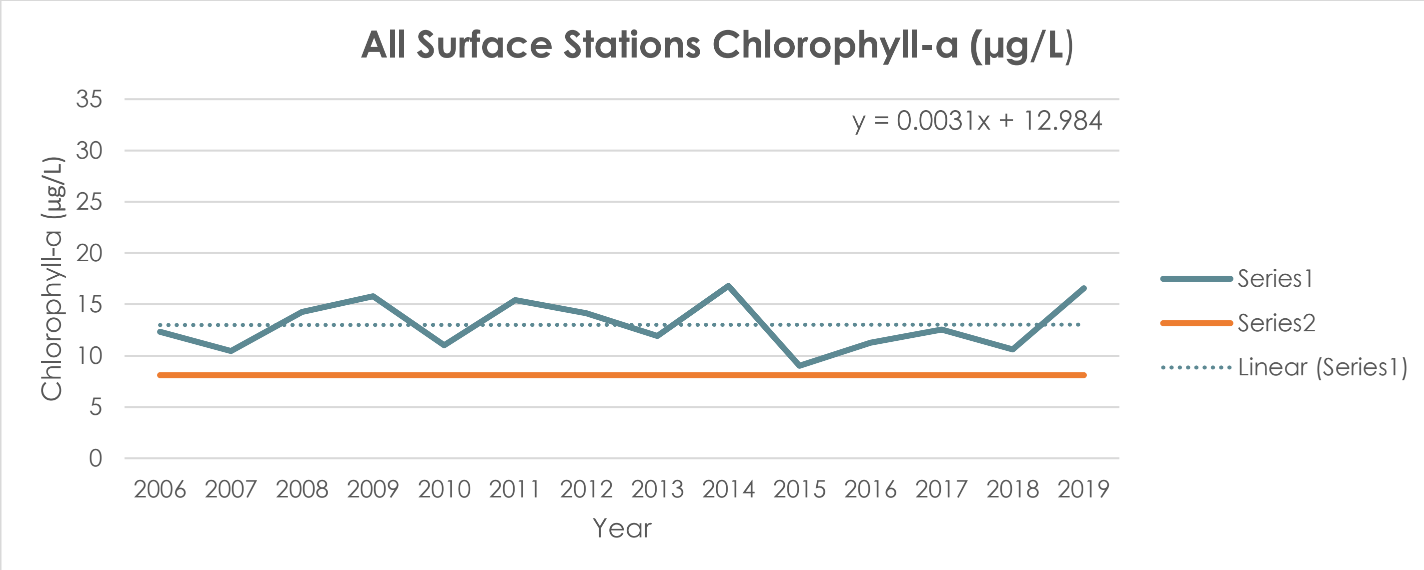


Figure 2: Average chlorophyll-a concentrations of all surface stations from 2006 – 2019 compared with the targeted concentrations.

LAKE MUSCONETCONG

Data for Lake Musconetcong is limited compared with the long-term database available for Lake Hopatcong since water quality data were only collected from 2018. Thus, to compare the status of the water quality of Lake Musconetcong to the TP TMDL and targeted chlorophyll-a concentration, Figures 3 and 4, respectively, are provided with the average concentration at each station, taken as surface grab samples over the course of three sampling events, as well as an average concentration from all stations over the course of the 2018 growing season. A full water quality report for the 2018 season can be found in Appendix II.

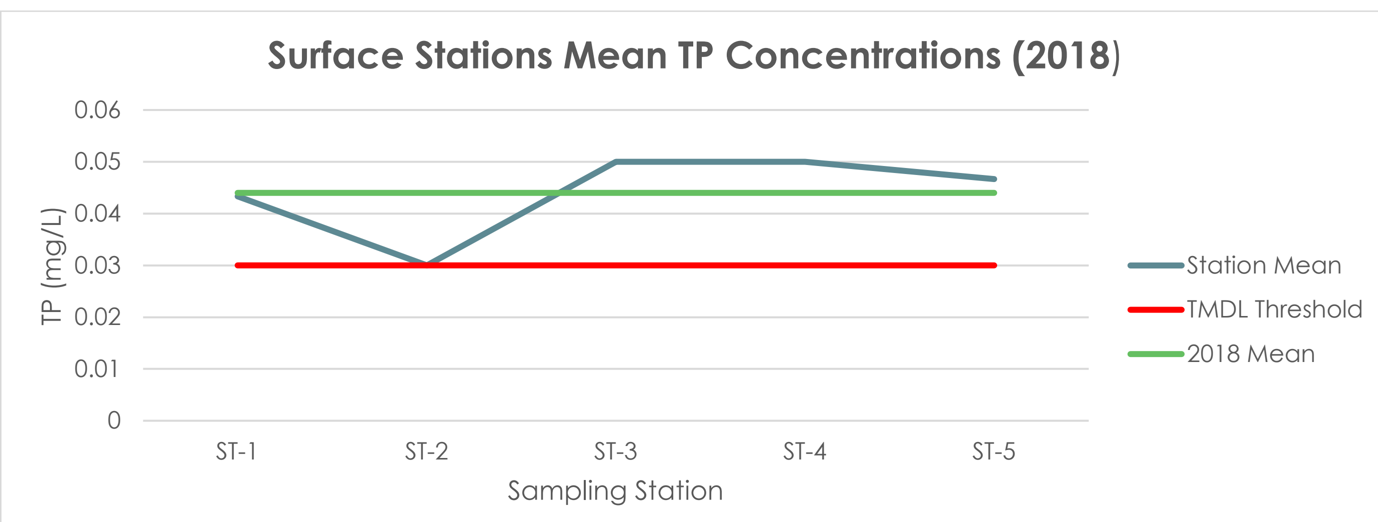


Figure 3: Average TP concentrations at each station as well as the overall 2018 mean concentration compared with the TMDL threshold.

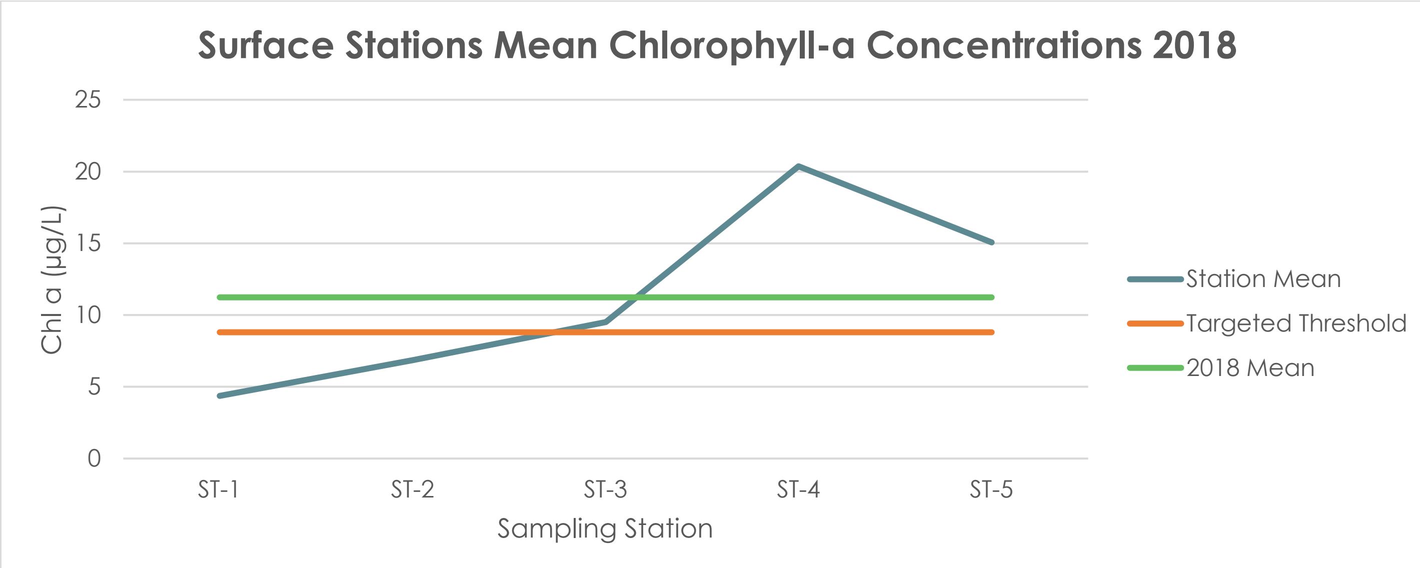


Figure 4: Average chlorophyll-a concentrations at each station as well as the overall 2018 mean concentration compared with the targeted threshold.

LAKE HOPATCONG WATER QUALITY DATA 2006 – 2019

The Lake Hopatcong water quality database is the longest, continuously monitored, lake-based database in New Jersey. The long-term analysis has been extremely valuable in identifying long-term trends and how efforts to meet the TP TMDL have contributed to water quality improvements. However, analyses have been limited to the lake's mid-lake sampling station (Station #2). While the mid-lake station is the location in the lake that best represents Lake Hopatcong as a whole, it would be extremely beneficial to run similar long-term trend analyses for other sections of the lake. A map with all sampling locations is provided in Appendix I.

While the mid-lake section of the lake is generally in compliance with both the State and TMDL-based water quality criteria, other sections of the lake experience poorer water quality conditions and high densities of nuisance aquatic vegetation. Thus, in addition to the mid-lake station (Station #2), data analysis was also performed on River Styx / Crescent Cove station (Station #3) as well as four of the northern stations (Woodport Bay, Station #1; Inlet from Lake Shawnee, Station #7; Northern Woodport Bay, Station #10; Jefferson Canals, Station #11) that have experienced nuisance blue-green algal blooms over the last few years. Any major trends that were observed during the data analysis of these specific stations will be discussed in this section. Although analyses have primarily been limited to the lake's mid-lake sampling station, 11 stations around the lake's various coves are continuously monitored for water quality conditions. Due to the size of Lake Hopatcong and the many coves that exist, it is important to monitor different areas of the lake to help determine the origin of the largest contributions of TP or other pollutants.

Figures from the long-term analysis of all sampling stations in Lake Hopatcong (besides stations 8 and 9) are available in Appendix III. Analyses were performed on the following parameters: temperature, Secchi depth (as a measure of water clarity), chlorophyll-a(as a surrogate for algal biomass), total phosphorus (TP), nitrate, ammonia, total suspended solids (TSS), specific conductance (dissolved substances). Descriptions on all of the major water quality parameters discussed in this section can be found as part of the report in Appendix II.

Mid-Lake Station (Station #2)

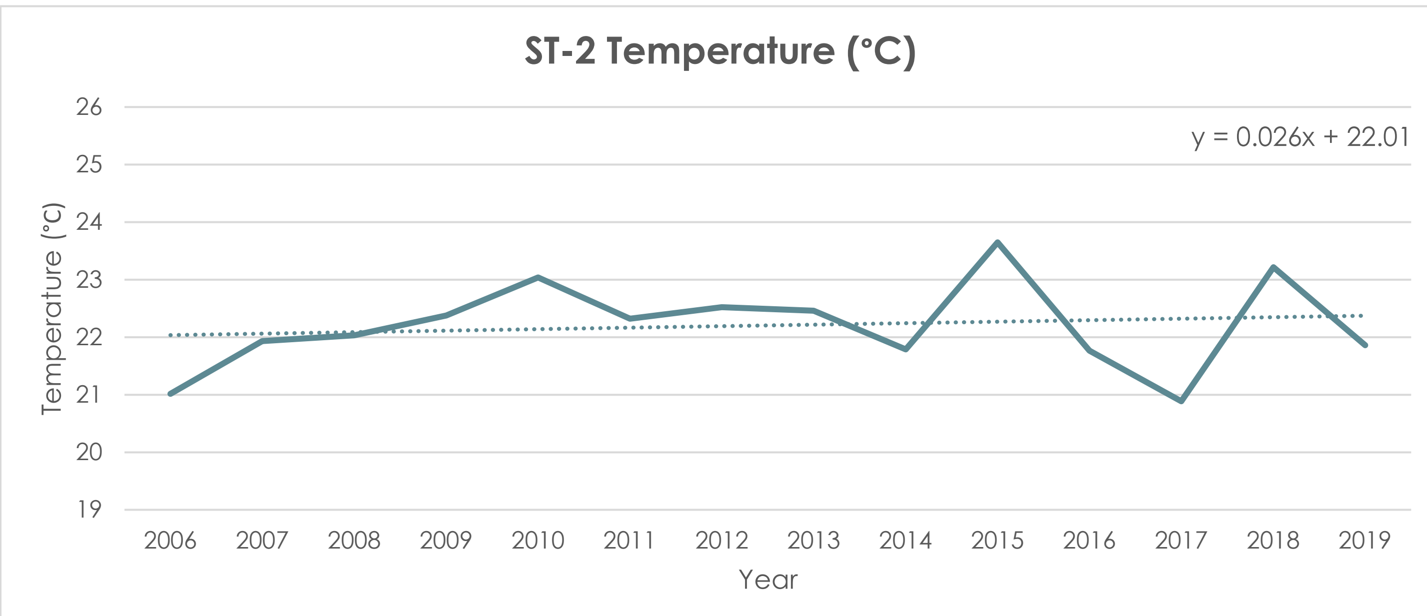


Figure 5: Average surface water temperatures at ST-2 from 2006 – 2019.

Yearly average surface water temperatures have been variable between 2006 and 2019 at the mid-lake station but the trend in water temperature has been increasing slightly over that time period, with the exception of 2017 in which the surface water was the coolest of the 12-year period (Figure 5). The slope of the trendline between 2006 and 2019 is 0.026.

Subsequent to the initiation of the development of this WIP, a lake-wide cyanobacteria bloom was experienced throughout Lake Hopatcong over the summer of 2019. This bloom was triggered by a combination of prevailing weather patterns and elevated TP concentrations throughout the lake in June 2019 and persisted through the summer season. Given the concerns associated with the impacts climate change will have on New Jersey in general, Princeton Hydro graphed the July surface water temperatures from Station 2 for the nearly continuous 30-year, water quality data base for Lake Hopatcong. The month of July was selected for this since it is historically the warmest month of the year in the northeastern portion of the United States. Station 2 was selected since it is the furthest away from land and thus is not impacted by shading. The results of this analysis are shown in Figure 5a.

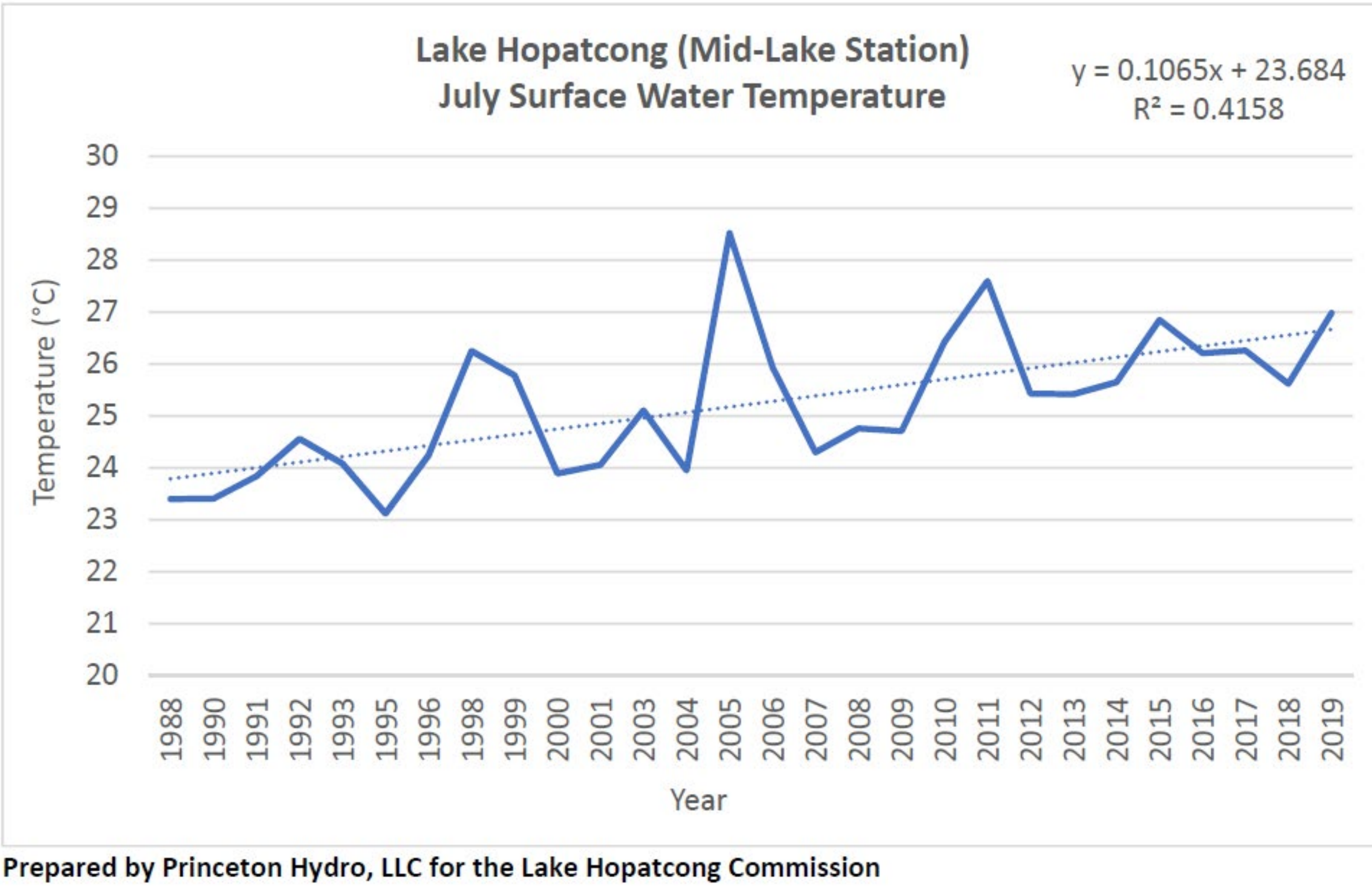


Figure 5a: July surface water temperatures at ST-2 from 1988 – 2019.

Note the slope of increase for the long-term July data is steeper than the growing season mean surface temperature from 2006 to 2019 (Figure 5). This indicates that the high summer season is heating up at a higher rate than the spring and/or late summer. It should also be noted that both graphs are statistically significant.

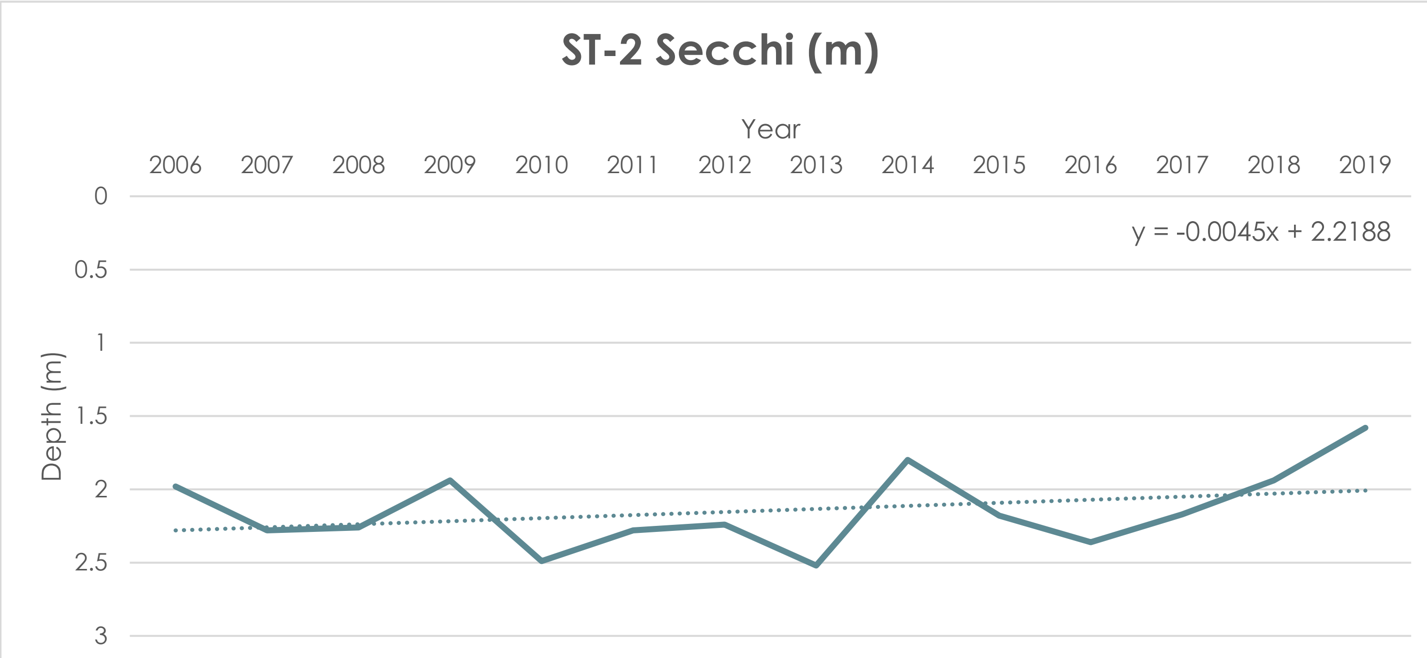


Figure 6: Average Secchi depth in meters at ST-2 from 2006 – 2019.

Growing season average Secchi depths have been variable between 2006 and 2019 at the mid-lake station (Figure 6). Overall, Secchi depth has remained relatively constant over the 12-year period with the exception of 2014 and 2019 (a relatively lower value, meaning lower clarity) which can be attributed to the elevated chlorophyll-a concentrations in those respective years in Figure 7.

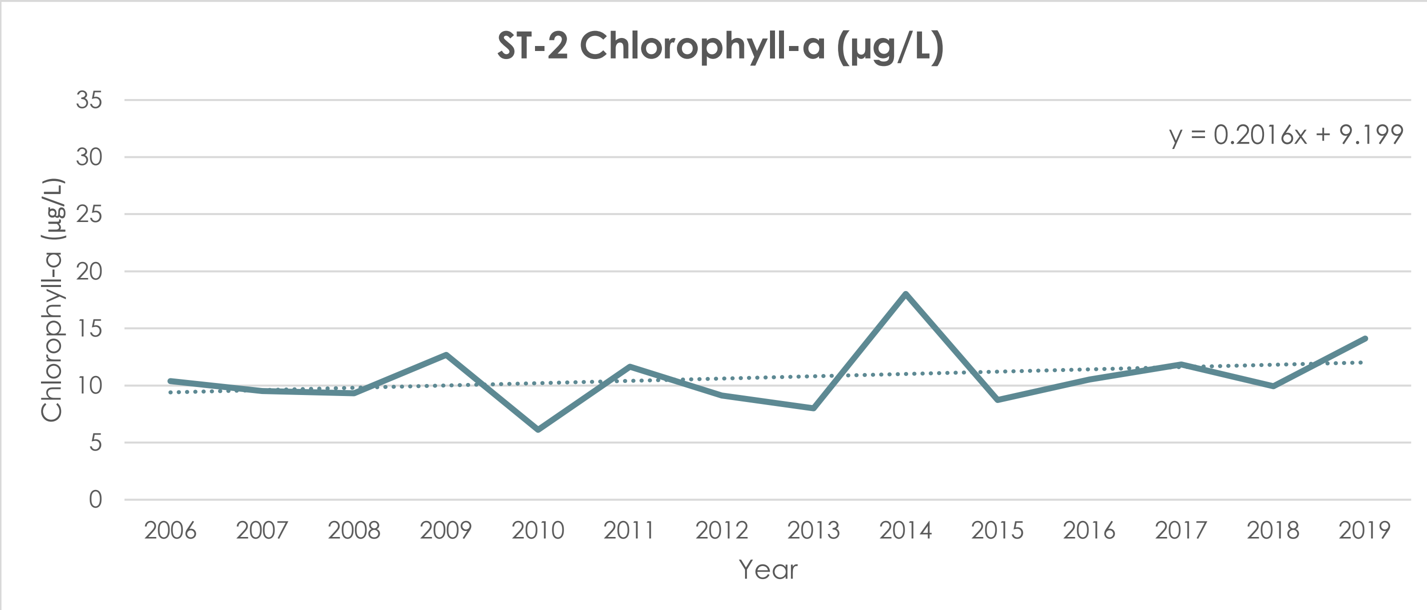


Figure 7: Average chlorophyll-a concentration, a surrogate for algal biomass, at ST-2 from 2006 to 2019.

Yearly average chlorophyll-a concentrations have been variable between 2006 and 2019 at the mid-lake station, with a slightly positive trendline (Figure 7); 2014 saw a sharp increase in algal biomass in the surface water.

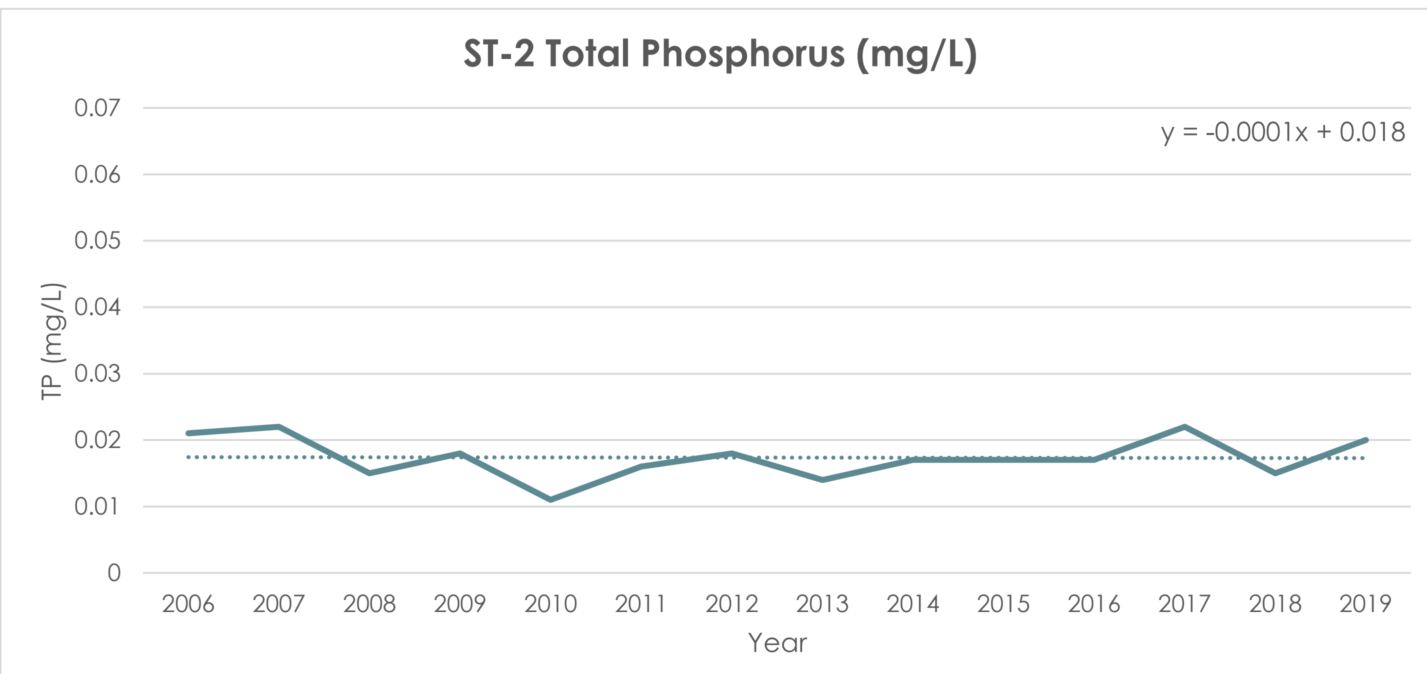


Figure 8: Average total phosphorus concentrations at ST-2 from 2006 to 2019.

Growing season average surface TP concentrations have been relatively constant between 2006 and 2019 at the mid-lake station (Figure 8). The slope of the trendline is -0.0001.

SUMMARY OF STATION 2

As a reminder, Station 2 is typically the focus of evaluation for the TMDL. Overall, the 13-year trend for the major water quality parameters at the mid-lake station for Secchi depth, chlorophyll-a, and TP have remained relatively constant. Although minimal, the negative trend in TP concentrations is a positive sign and exhibits the success that has been achieved through the implementation of the various watershed measures. This observation agrees with the fact that to date, only approximately on third of the TMDL is in compliance for TP.

The slight increase in chlorophyll-a concentrations and therefore algal biomass over this time period could be a result of the increasing surface water temperatures that have also occurred, and not necessarily explained solely by TP loads. Algal growth is at a maximum in warm waters with elevated nutrient concentrations, but TP concentrations at ST-2 have not increased over this time period. Water clarity as measured by Secchi depth is largely dependent on algal growth and the associated chlorophyll-a concentrations which is why Secchi depth decreased slightly over this time period. Additionally, the June 2019 mid-lake TP concentration (0.04 mg/L) was elevated, as were all of the surface water stations, which triggered the large cyanobacteria bloom in the summer of 2019.

WOODPORT BAY (STATION #1)

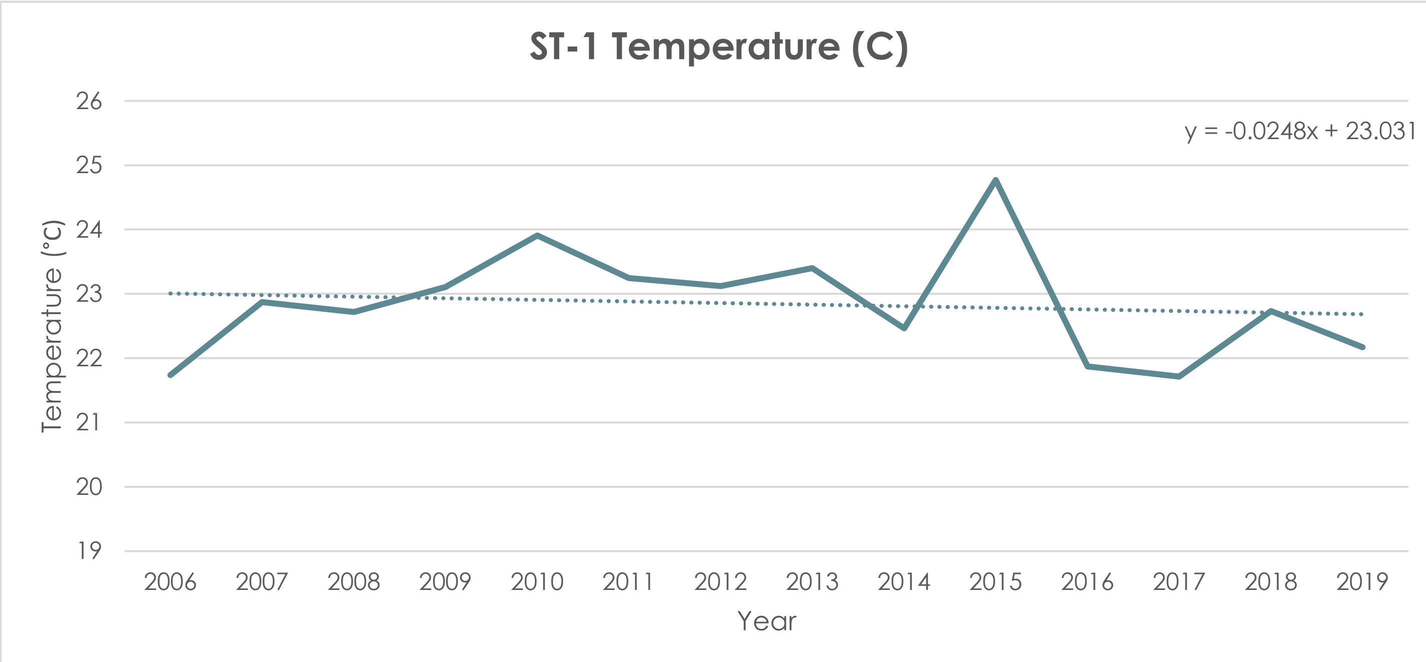


Figure 9: Average surface water temperatures at ST-1 from 2006 – 2019.

Yearly average surface water temperatures have been variable between 2006 and 2019 at ST-1. The slope of the trendline between 2006 and 2019 is -0.0248. Overall, temperature has remained relatively constant over the 12-year period with the exception of 2015, which was the warmest year of the 13-year period (Figure 9).

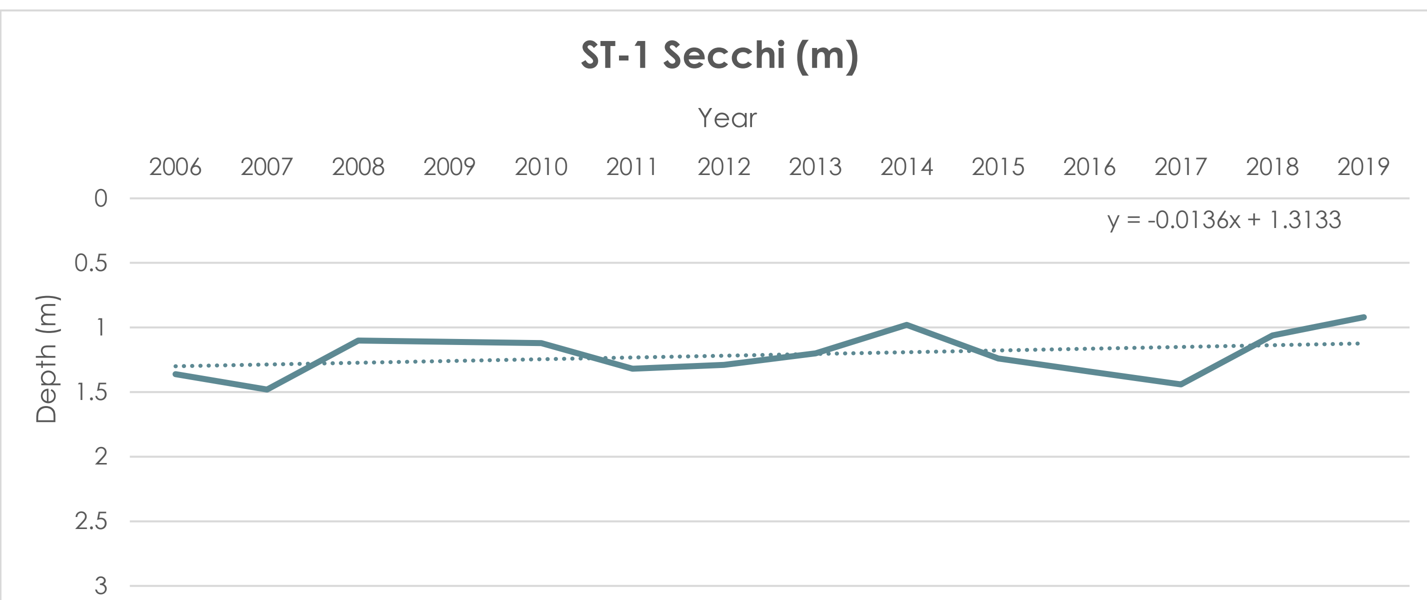


Figure 10: Average Secchi depth in meters at ST-1 from 2006 – 2019.

Yearly average Secchi depth has been variable between 2006 and 2019 at ST-1. The slope of the trendline between 2006 and 2019 is -0.0136. Overall, Secchi depth has remained relatively constant over the 13-year period (Figure 10).

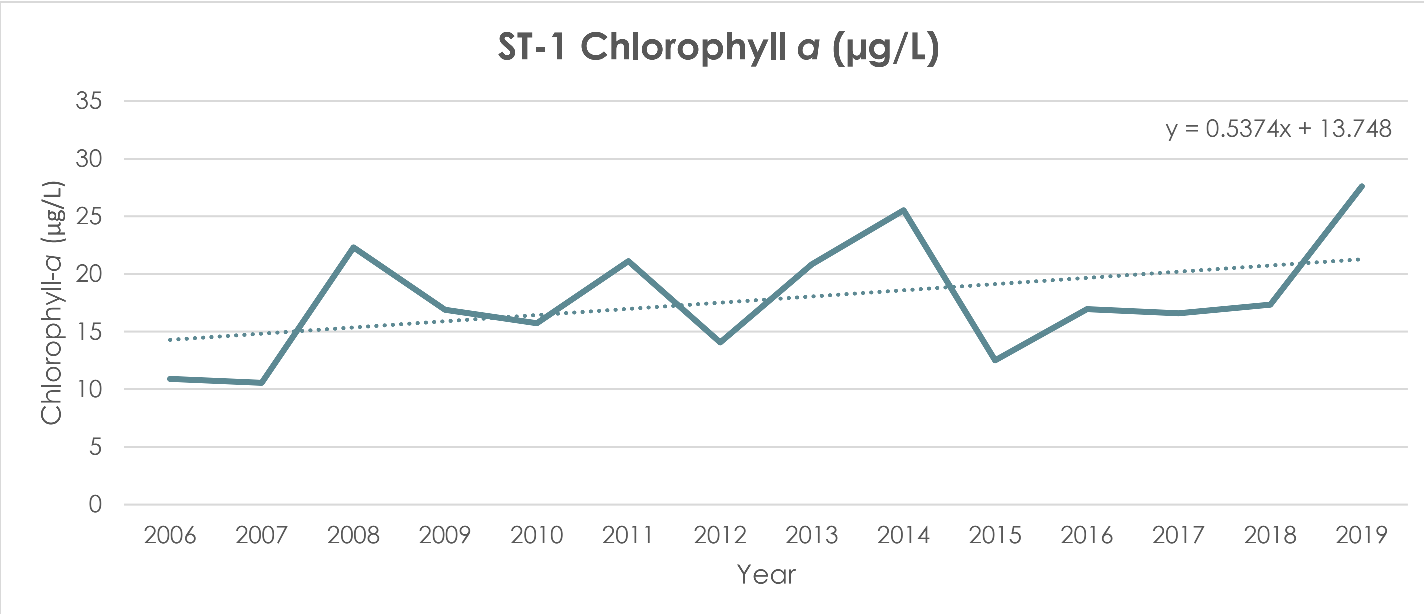


Figure 11: Average chlorophyll-a concentration at ST-1 from 2006 to 2019.

Yearly average chlorophyll-a concentrations have been variable between 2006 and 2019 at ST-1 <u>but a positive trendline is evident</u> (Figure 11). The slope of the trendline between 2006 and 2019 is 0.5374.

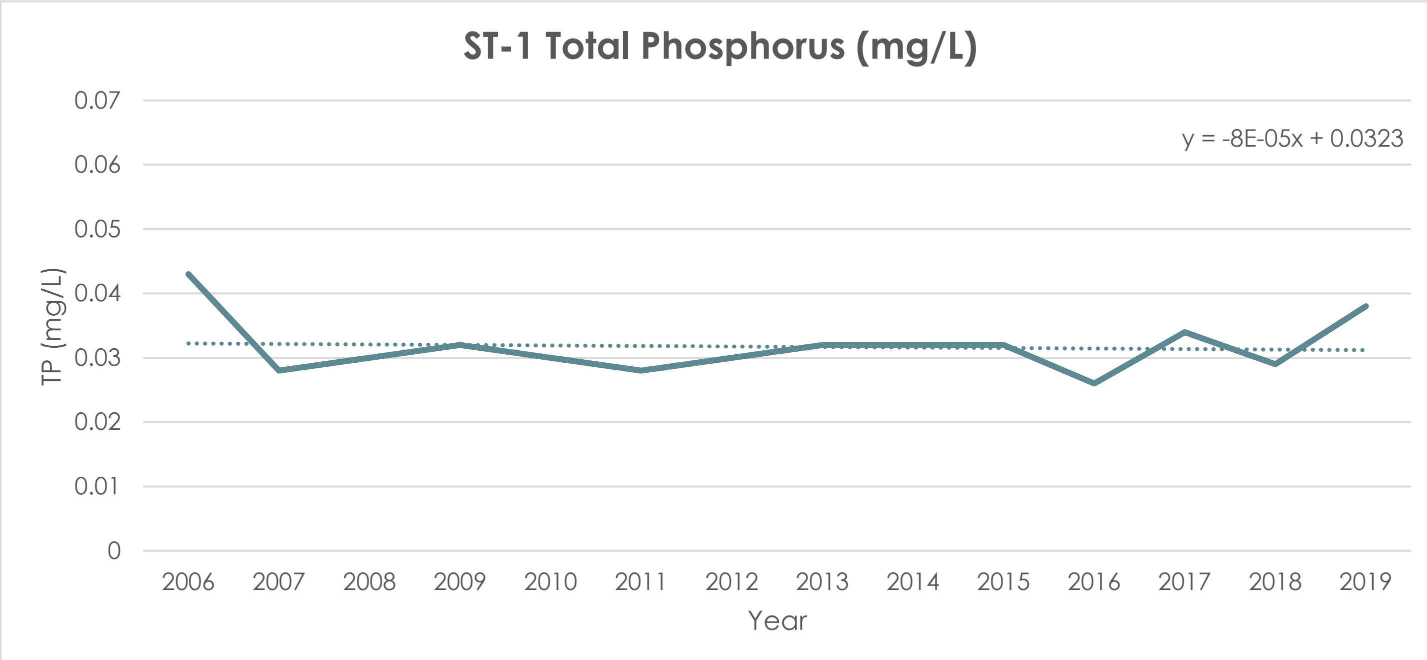


Figure 12: Average total phosphorus concentrations at ST-1 from 2006 to 2019.

Yearly average surface TP concentrations have been relatively constant between 2006 and 2019 at ST-1 (Figure 12). The slope of the trendline is -0.0003.

SUMMARY OF STATION 1

Similar to Station 2, the 13-year trends for the major water quality parameters of Secchi depth, chlorophyll-a, and TP have remained relatively constant at Station 1. Although minimal, the negative trend in TP concentration is a positive sign and could be attributable to various watershed management measures implemented within this time period.

The slight increase in chlorophyll-a concentration over this time period is possibly a result of climatic factors rather than increasing nutrient concentrations; TP concentrations have not increased at Station 1 over this time period. Water clarity as measured by Secchi depth is largely dependent on algal growth and associated chlorophyll-a concentrations which is why Secchi depth decreased slightly over this time period. Another factor that may explain the slight increase in chlorophyll-a in spite of the existing conditions, is more benthic algae (such as the filamentous cyanobacteria *Lyngbya*), being re-suspended in the water column. Indeed, such conditions have been observed in the northern end of the lake (Stations 1 and 10).

River Styx / Crescent Cove (Station #3)

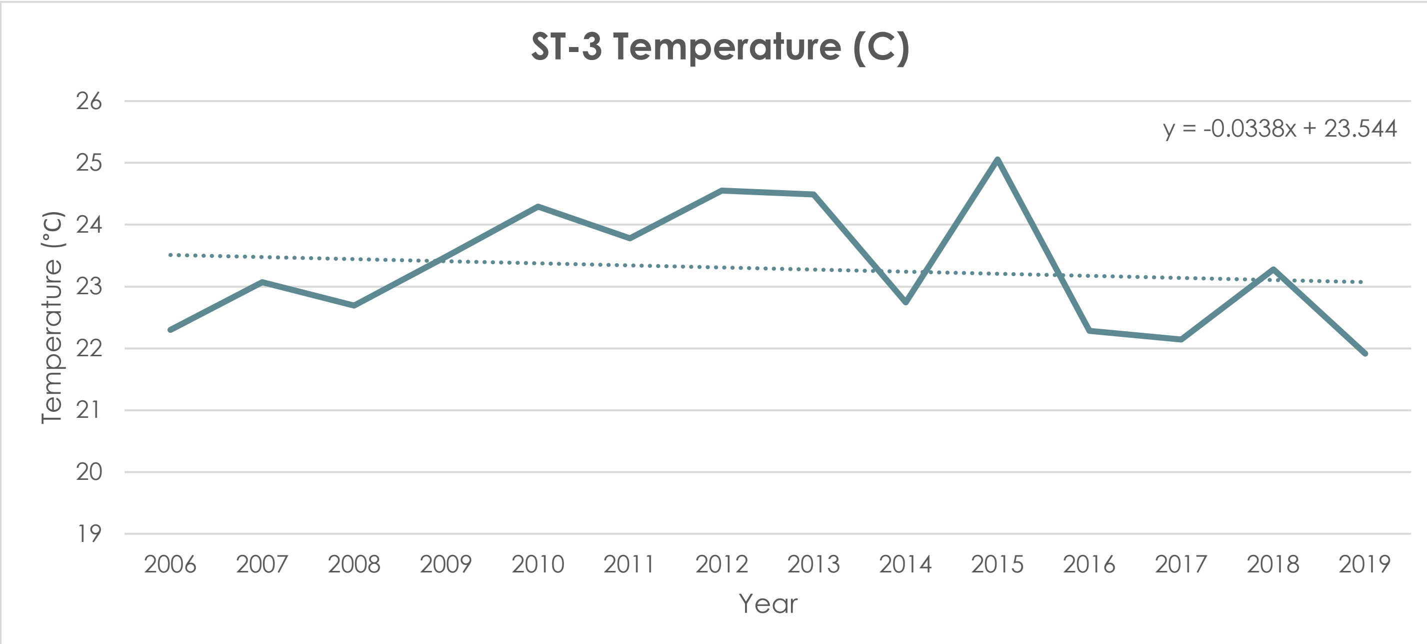


Figure 13: Average surface water temperatures at ST-3 from 2006 – 2019.

Yearly average surface water temperatures have been variable between 2006 and 2019 at ST-3 but the trend has been decreasing slightly over that time period (Figure 13). Surface water temperatures increased sharply in 2015, similar to the trend observed at all of the sampling stations.

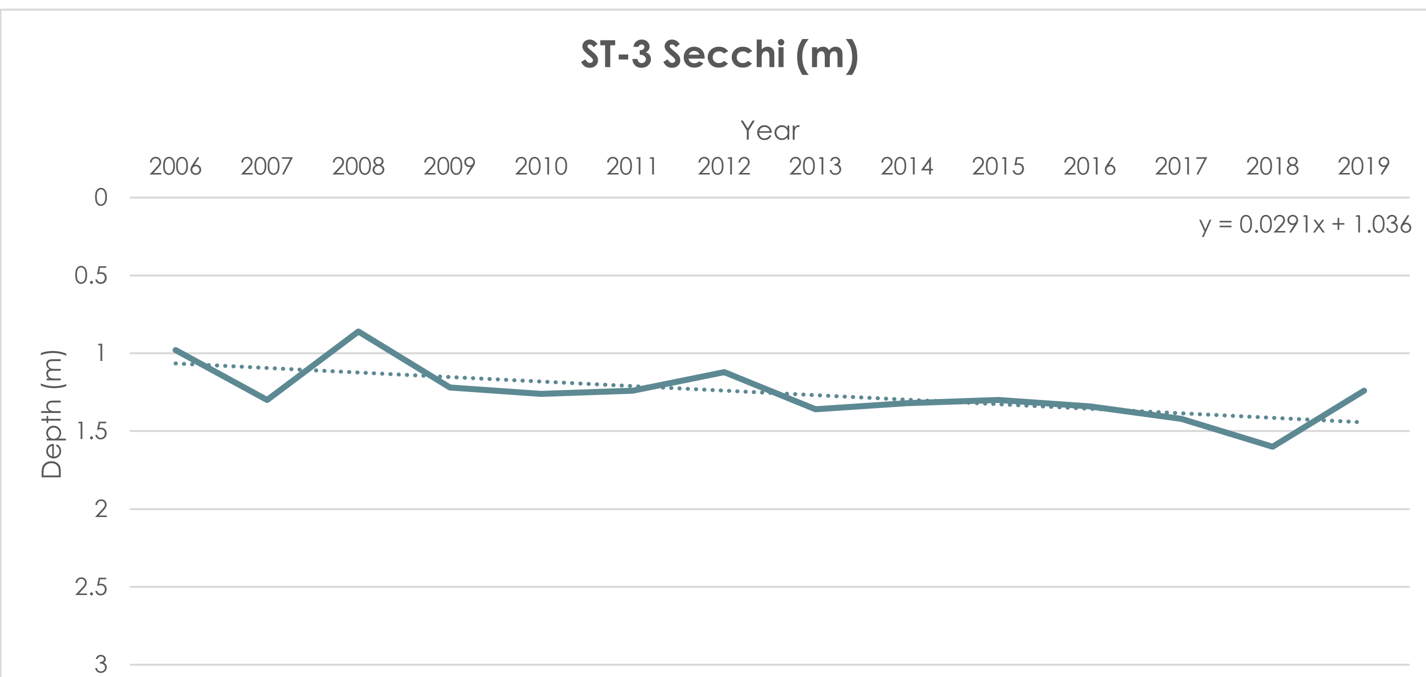


Figure 14: Average Secchi depth in meters at ST-3 from 2006 – 2019.

Yearly average Secchi depth has shown a moderate increase in depth from 2006 to 2019 at ST-3. (Figure 14) The slope of the trendline between 2006 and 2019 is 0.0291, indicating an estimated half meter of increased water clarity over this time period.

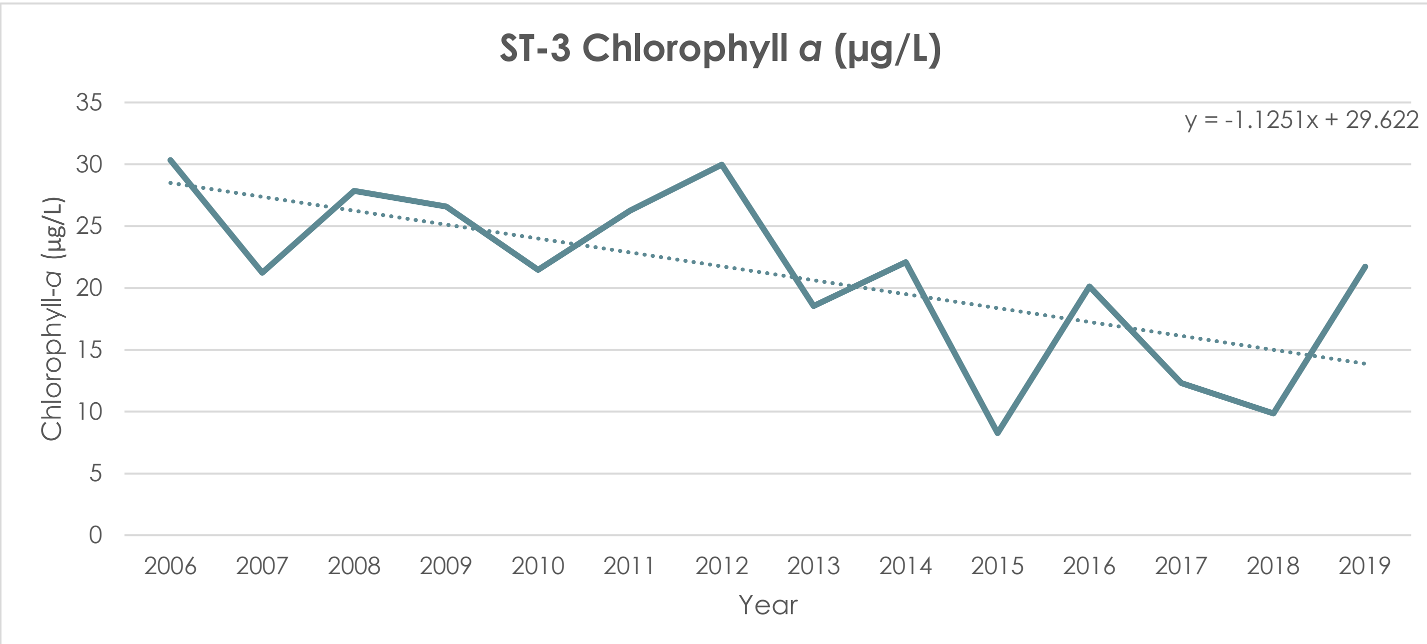


Figure 15: Average chlorophyll-a concentrations at ST-3 from 2006 to 2019.

Yearly average chlorophyll-a concentrations have decreased substantially between 2006 and 2019 at ST-3 and a strong negative trendline is evident (Figure 15). The slope of the trendline between 2006 and 2019 is -1.1251. Note this is one of the sharpest declines in chlorophyll-a concentrations of all of the sampling stations from 2006 to 2019.

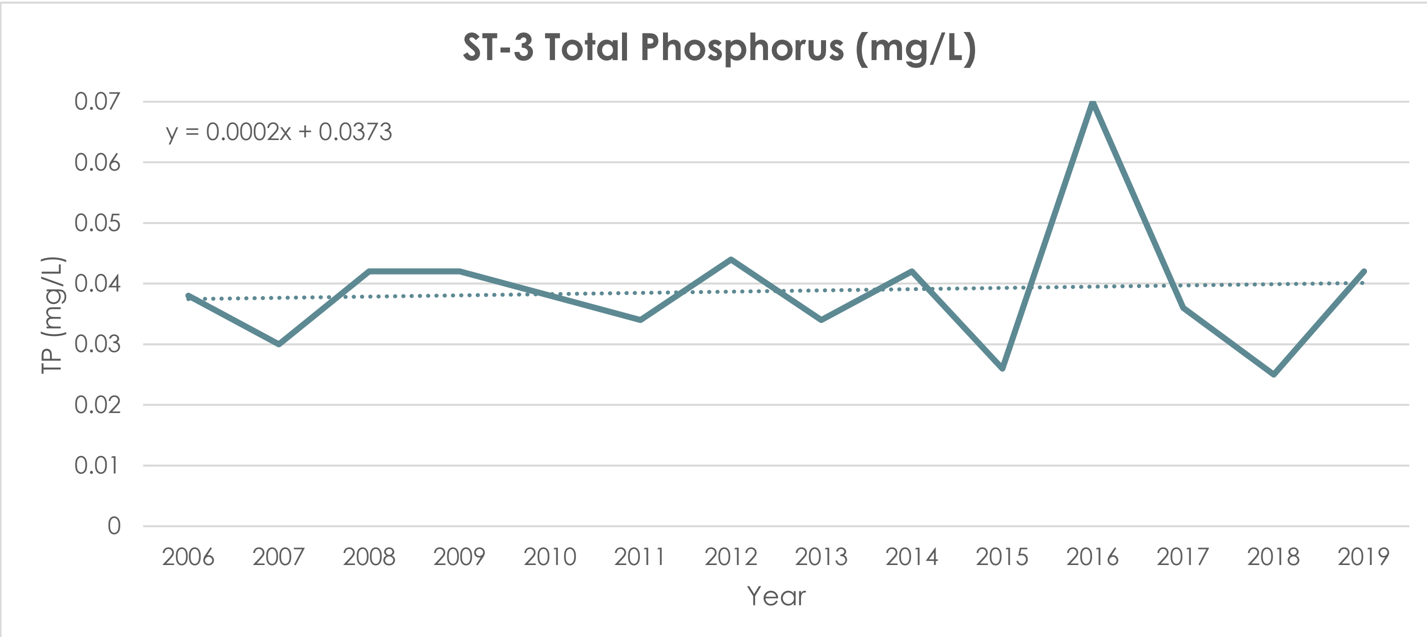


Figure 16: Average total phosphorus concentrations at ST-3 from 2006 to 2019.

Yearly average surface TP concentrations have been variable between 2006 and 2019 at ST-3, with the biggest spike in concentration observed in 2016 (Figure 16). Overall, TP concentrations have remained relatively constant.

SUMMARY OF STATION 3

Chlorophyll-*a* concentrations and the associated water clarity as measured by Secchi depth have both demonstrated improvements in water clarity in the isolate Crescent Cove. Chlorophyll-a concentrations have been variable from year to year, as was seen at other stations, but Station 3 exhibits a decreasing trend with slope of -1.1 µg/L, meaning that each successive year following this trend saw a decrease in chlorophyll-a of 1.1 µg/L. Water clarity has increased substantially over this same time period, with only 2019 falling below 1.3 meters after 2013.

Interestingly, the trend for TP concentration has increased over this time period (which would normally lead to increased chlorophyll-a), but to very minimal extents. TP concentrations spiked in 2016 due to one sampling event in early September that had a surface concentration of 0.2 mg/L. If not for this one sample date with an extreme spike in TP, the trend for TP would have been negative, following the trends of chlorophyll-a and Secchi depth as would be expected.

River Styx/ Crescent Cove has been an area of concern over the past 13 years and two large, manufactured stormwater treatment devices (MTDs) were installed in the parking lot of the beach club for just that reason. These MTDs capture and treat a substantial volume of stormwater from this area of the watershed before it enters the lake. Given the improvements in chlorophyll-a and water clarity in this cove, it appears as though the installed MTDs have made a substantial difference in reducing the pollutant load entering the lake. In addition to the MTDs, the partial sewering of the Borough of Hopatcong likely had a positive impact on the water quality of Crescent Cove. It is possible that the spike in TP in 2016 is the result of a lab or data entry error; all other TP and chlorophyll-a concentrations around the lake on the same day are closer to their average concentrations. Because all TP samples/dates show reduced concentrations except for that one date/sample we can speculate that the MTDs are operating in a limited capacity. While the settling chamber (Aqua-Swirl) portion of these MTDs have been maintained by the Borough of Hopatcong, the main chambers with the filter media have not. Thus, the Commission is working with the Borough to develop a plan to ensure that the Aqua-Filter portions of these MTDs are cleaned-out on a regular basis. Note, as part of an existing Harmful Algal Bloom grant (2020 / 2021), the filter media in these two MTDs will be replaced with Biochar, which is relatively low in cost and has a high affinity of removing nutrients, including phosphorus.

Finally, it should be noted that the increase in water clarity, as a result of reducing the amount of TSS entering the lake with the MTDs, allows more light to reach the sediments, stimulating rooted plant growth. While submerged vegetation can be a nuisance and needs some degree of maintenance, it is far easier to deal with the aquatics plants than algal blooms, which have the potential of becoming a Harmful Algal Bloom (HAB). In addition, the partial sewering of the Borough of Hopatcong since the completion of the original Restoration Plan, also contributed toward these improved water quality conditions at Station 3. As of the late of 2020, another 50 homes within this section of the watershed will be sewered by the Borough of Hopatcong.

INLET FROM LAKE SHAWNEE (STATION #7)

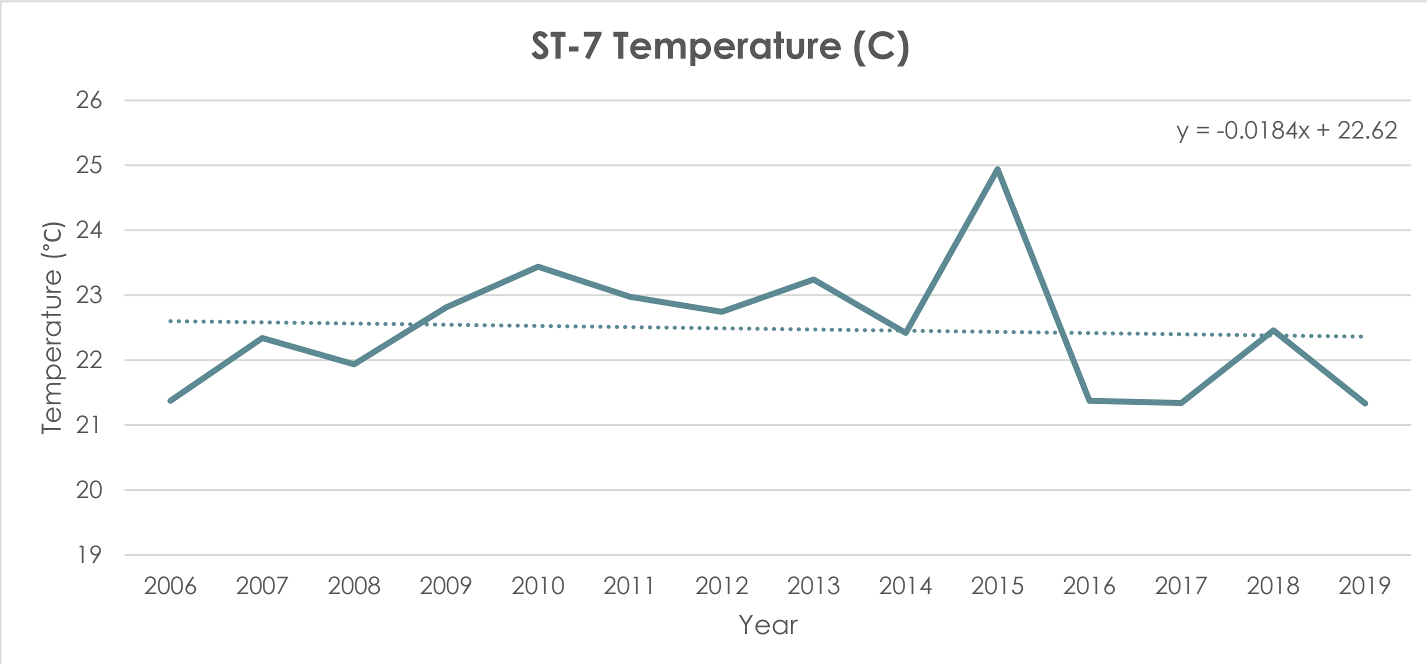


Figure 17: Average surface water temperatures Celsius at ST-7 from 2006 – 2018.

Yearly average surface water temperatures have been variable between 2006 and 2019 at ST-7 but the trend has been decreasing slightly over that time period with a spike in 2015 (Figure 17). The slope of the trendline between 2006 and 2019 is -0.0184.

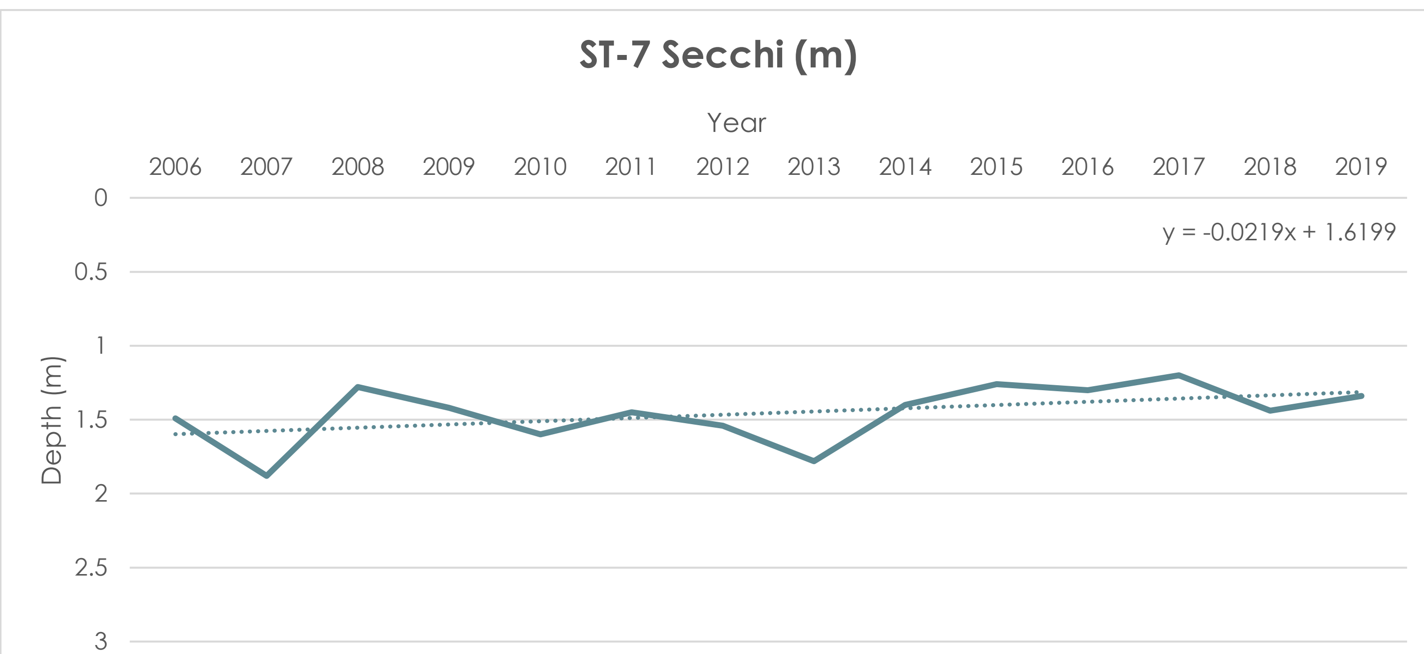


Figure 18: Average Secchi depth at ST-7 from 2006 – 2019.

Yearly average Secchi depth has been variable between 2006 and 2019 at ST-7; the trendline is slightly negative overall, indicating a slight decrease in Secchi depth over this time period (Figure 18). The slope of the trendline between 2006 and 2018 is -0.0219.

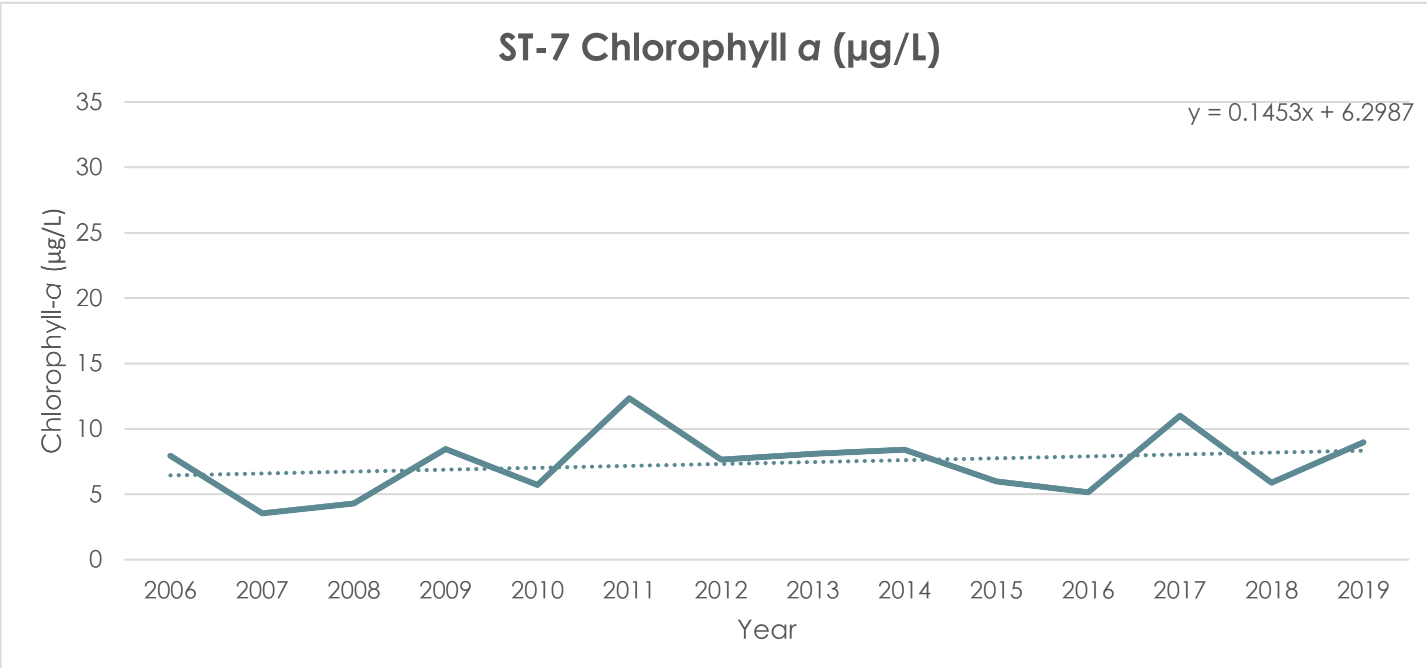


Figure 19: Average chlorophyll-a concentration at ST-7 from 2006 to 2019.

Yearly average chlorophyll-a concentrations have been variable between 2006 and 2019 at ST-7. The slope of the trendline slightly increases between 2006 and 2019 and is 0.1453 (Figure 19).

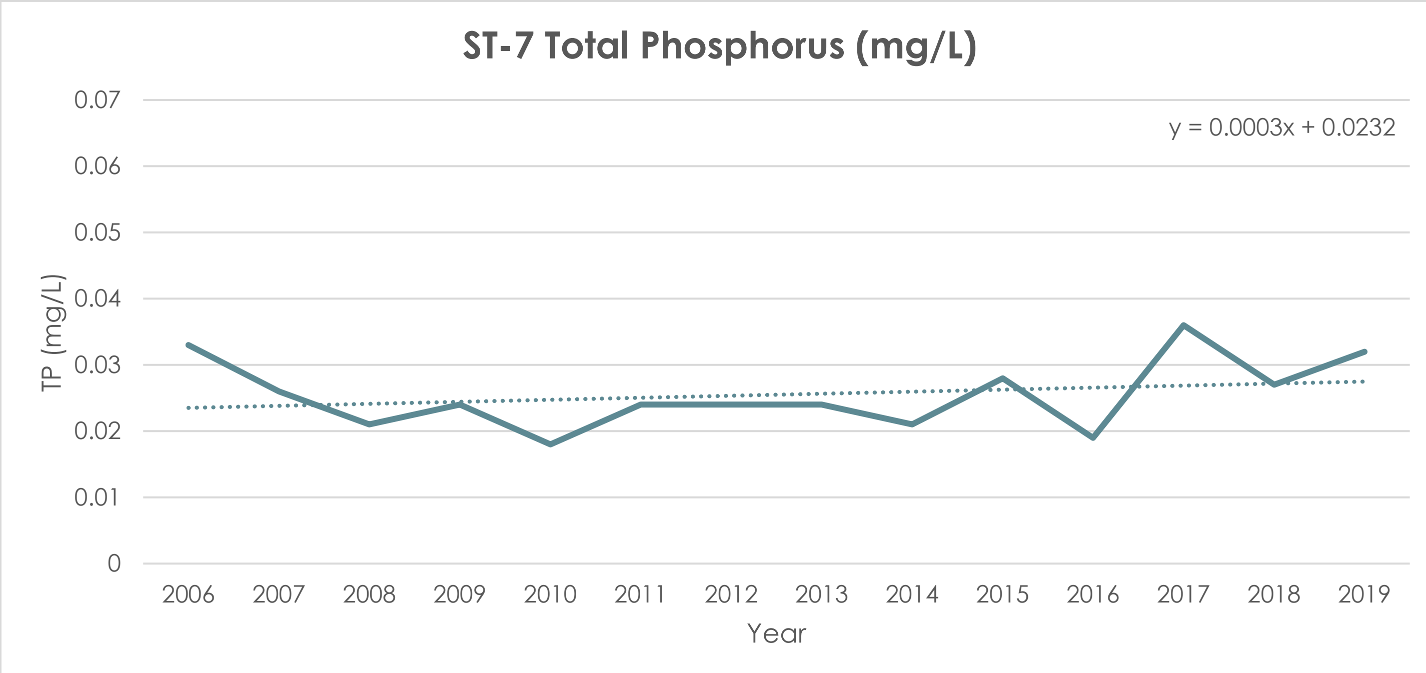


Figure 20: Average total phosphorus concentrations at ST-7 from 2006 to 2019.

Yearly average surface TP concentrations has remained relatively stable between 2006 and 2019 at ST-7 (Figure 20). The slope of the trendline between 2006 and 2019 is 0.0003.

SUMMARY OF STATION 7

Overall, the 13-year trends for the major water quality parameters of Secchi depth, chlorophyll-a, and TP have remained relatively constant for Station 7.

The slight increase in chlorophyll-a concentration over this time period is possibly a result of climatic factors rather than increasing nutrient concentrations. Algal growth is at a maximum in warm waters with high nutrient concentrations; TP has remained relatively constant during this time period, but surface water temperatures have increased, one would therefore have anticipated less clarity but that's not the case here. However, since most in-lake sampling occurs over non-storm event conditions, it is possible that any watershed-based phosphorus entering the lake is quickly assimilated by algae and/or settles to the bottom adsorbed onto sediment particles.

NORTHERN WOODPORT BAY (STATION #10)

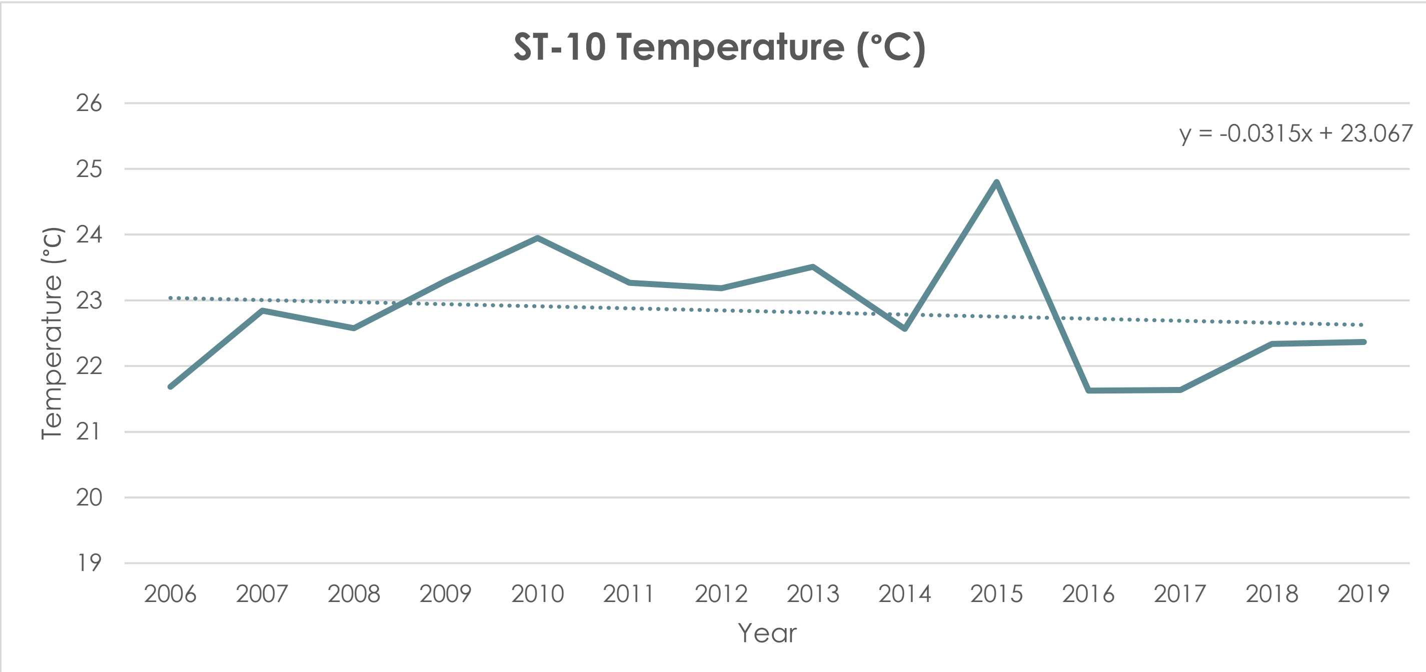


Figure 21: Average surface water temperatures at ST-10 from 2006 – 2019.

Yearly average surface water temperatures have remained relatively constant between 2006 and 2019 at ST-10 (Figure 21). The slope of the trendline between 2006 and 2019 is -0.0315.

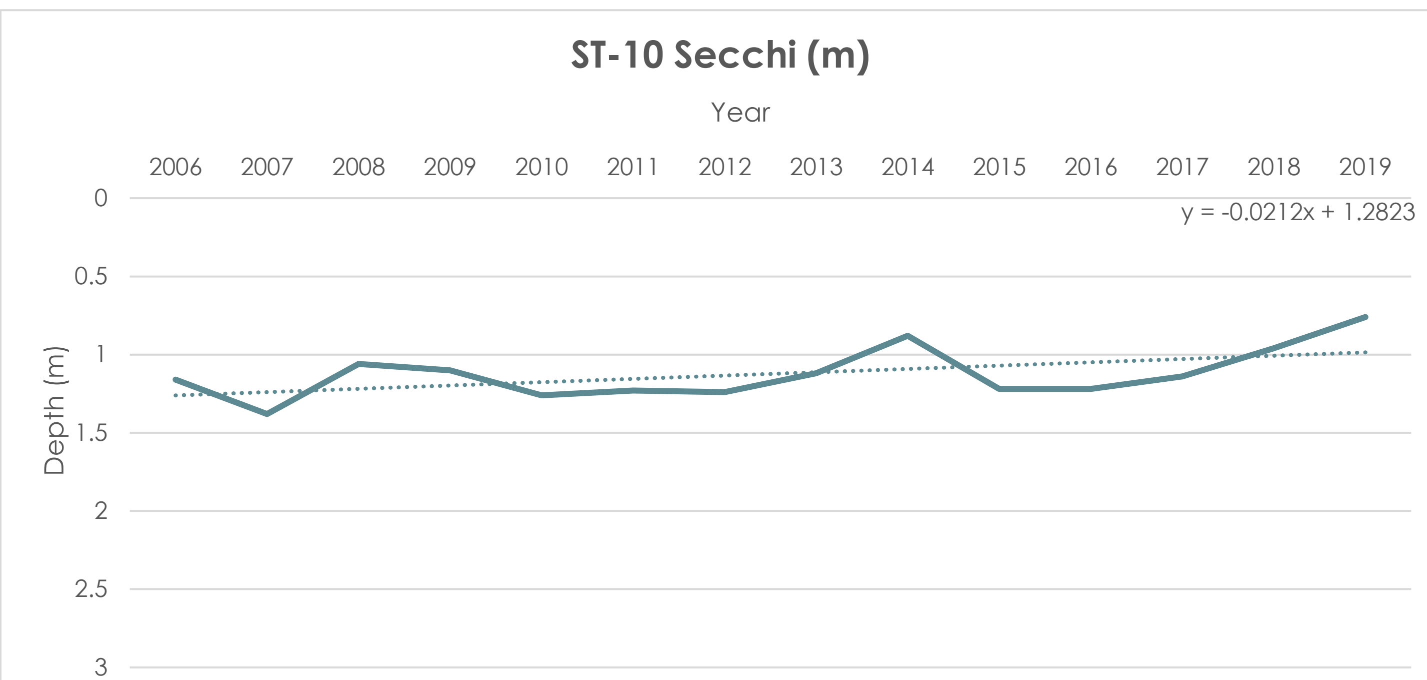


Figure 22: Average Secchi depth in meters at ST-10 from 2006 – 2019.

Yearly average Secchi depth has remained relatively constant between 2006 and 2019 at ST-10 (Figure 22). The slope of the trendline between 2006 and 2019 is -0.0212.

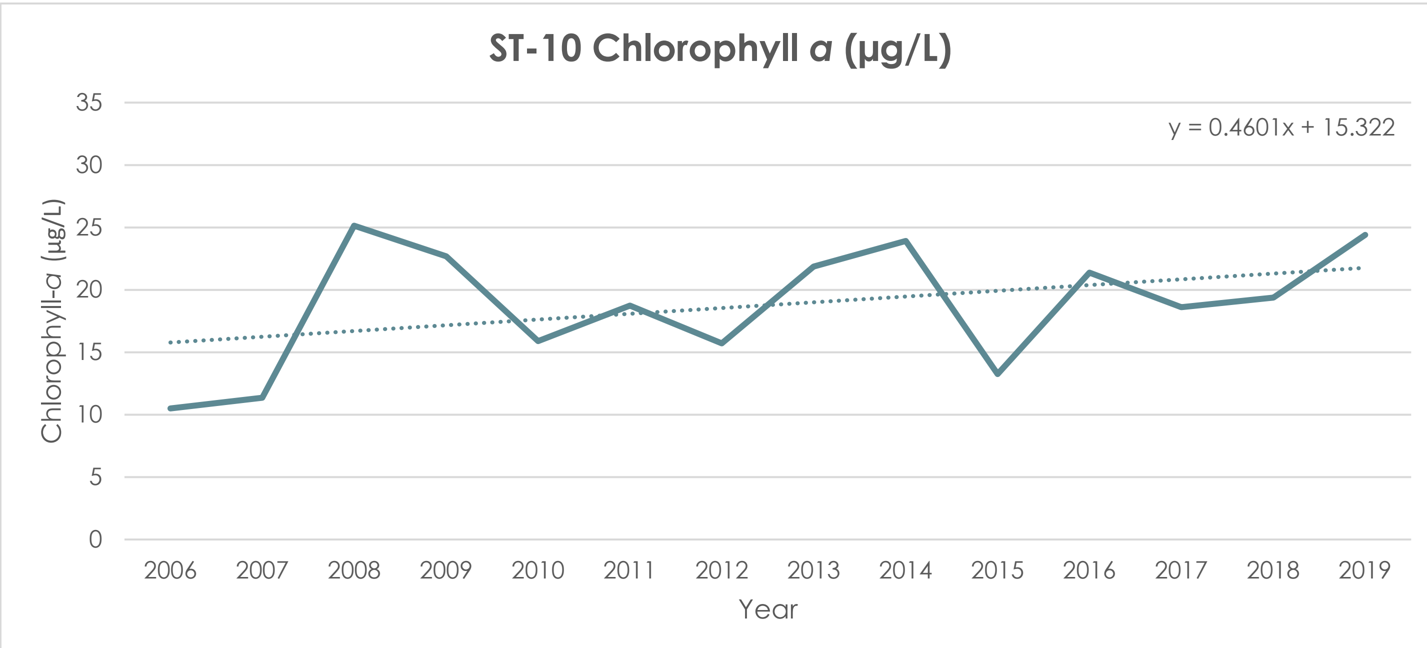


Figure 23: Average chlorophyll-a concentration at ST-10 from 2006 to 2019.

Yearly average chlorophyll-a concentrations have been quite variable between 2006 and 2019 at ST-10 but a positive trendline is evident (Figure 23). The slope of the trendline between 2006 and 2019 is 0.4601.

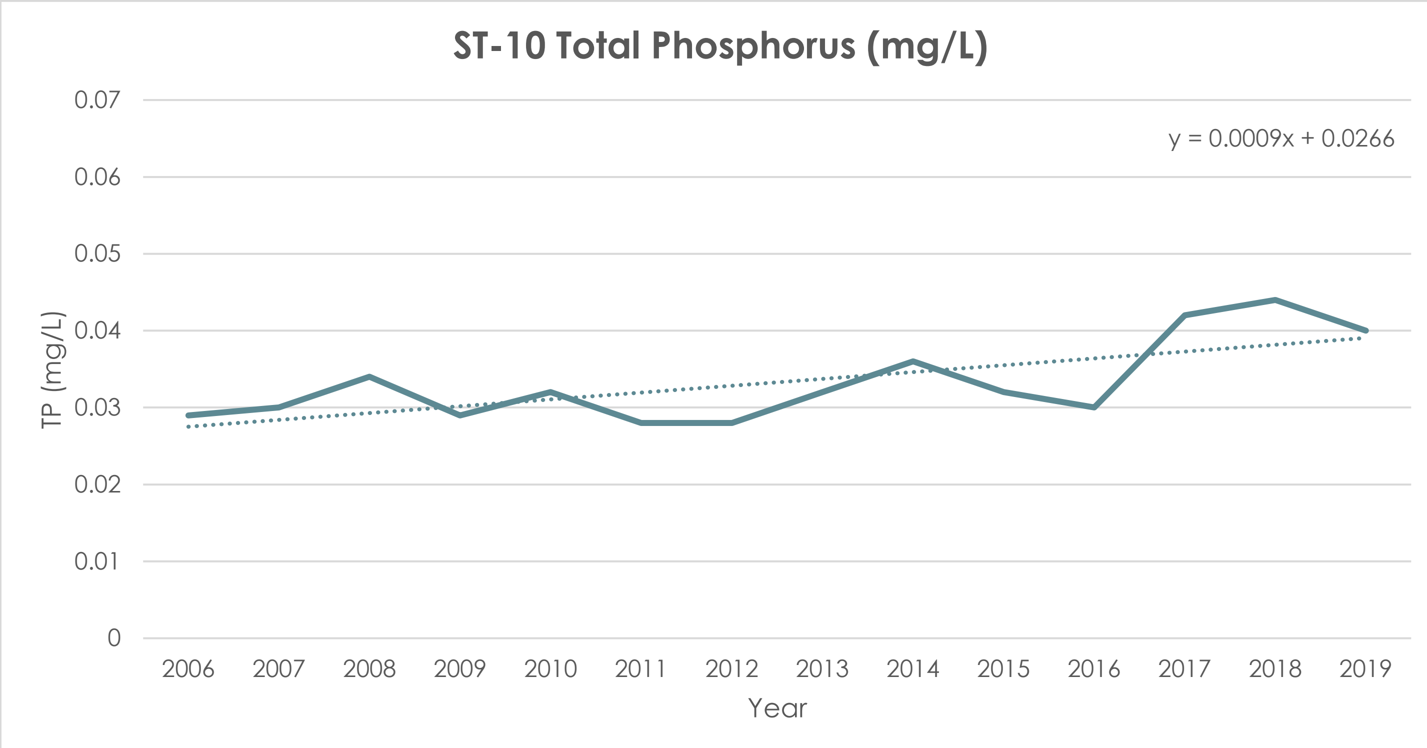


Figure 24: Average total phosphorus concentrations at ST-10 from 2006 to 2019.

Yearly average surface TP concentrations were relatively stable between 2006 and 2016 before a sharp increase over the next few years (Figure 24). The slope of the trendline between 2006 and 2019 is 0.0009.

SUMMARY OF STATION 10

Overall, the 13-year trends for the major water quality parameters of Secchi depth, chlorophyll-a, and TP have not shown improvements relative to water quality at Station 10, with significant inter-year variability over this time period, making the predictability of these trends difficult. Surface water temperatures have decreased slightly here, but it appears as though the increase observed in TP concentrations resulted in an increase in chlorophyll-a and a decrease in water clarity. Average TP concentrations have increased substantially in 2017 and 2018, both with values above 0.04 mg/L. Additionally, the June 2019 TP concentration at Station 10 was the highest out of all the in-lake sampling stations, being 0.07 mg/L.

Northern Woodport Bay has been a recent area of concern due to activity in the mining quarry located immediately upgradient in the watershed. Thus, this bay should be a priority when deciding on what watershed measures will be implemented to help reduce pollutant loads.

JEFFERSON CANALS (STATION #11)

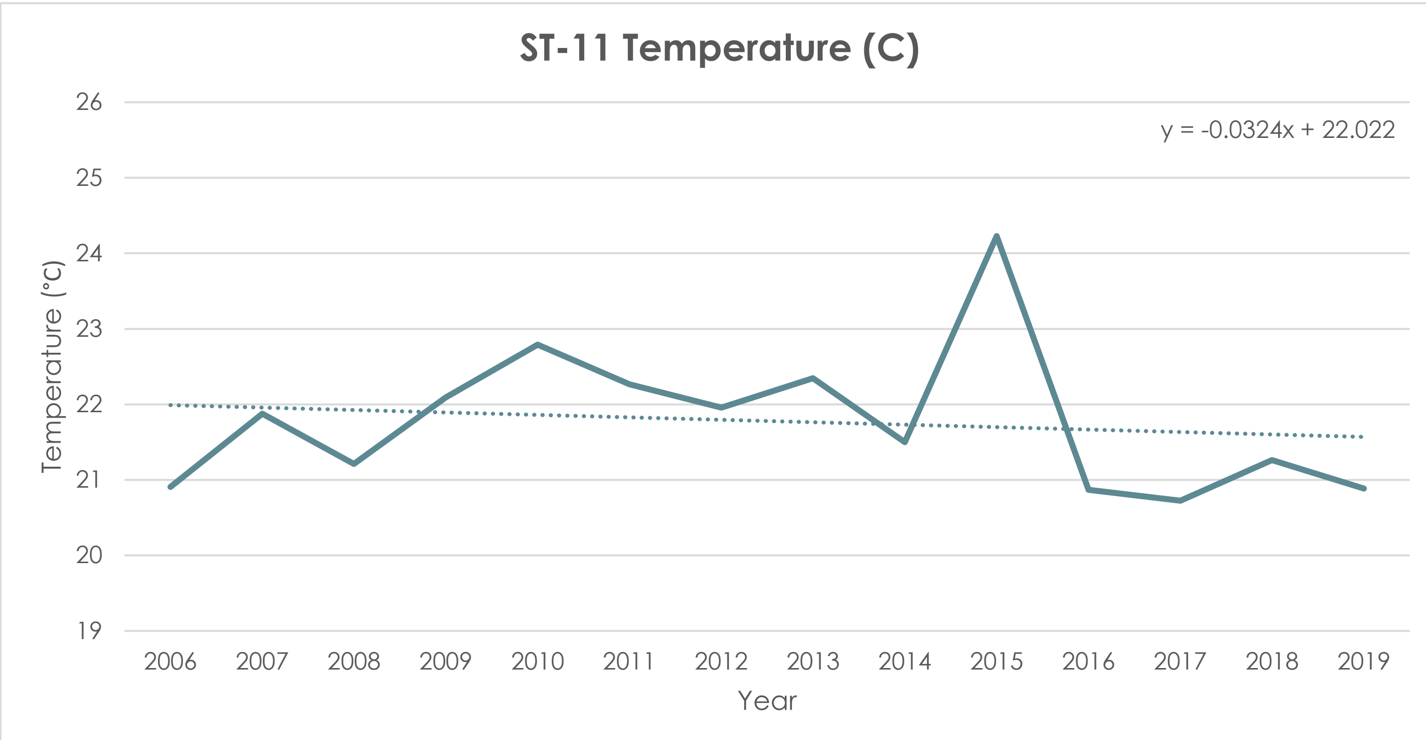


Figure 25: Average surface water temperature at ST-11 from 2006 – 2019.

Yearly average surface water temperatures have remained relatively constant between 2006 and 2019 at ST-11 (Figure 25). The slope of the trendline between 2006 and 2019 is -0.0324.

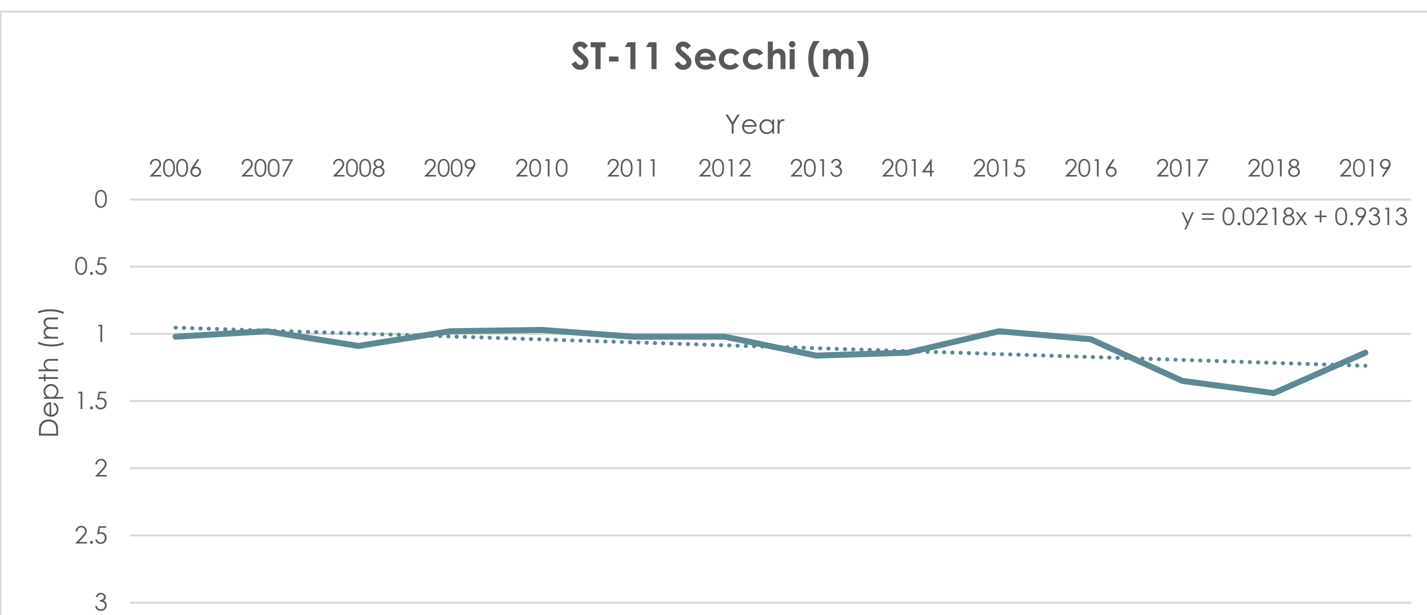


Figure 26: Average Secchi depth at ST-11 from 2006 – 2019.

Yearly average Secchi depth has shown a slight increase in depth (increase clarity) from 2006 to 2019 at ST-11 (Figure 26). The slope of the trendline between 2006 and 2019 is 0.0218.

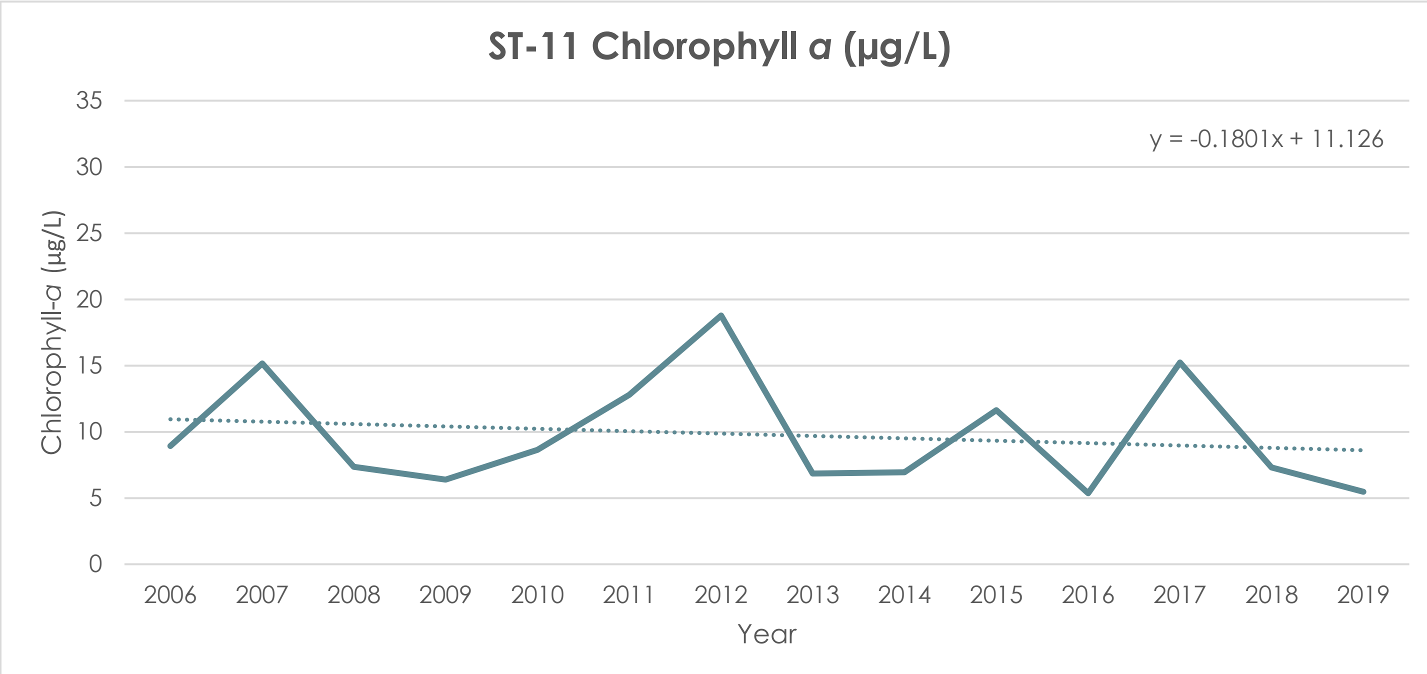


Figure 27: Average chlorophyll-a concentration at ST-11 from 2006 to 2019.

Yearly average chlorophyll-a concentrations have been variable between 2006 and 2019 at ST-11, and no distinct trend can be observed (Figure 27). The slope of the trendline between 2006 and 2008 is -0.1801.

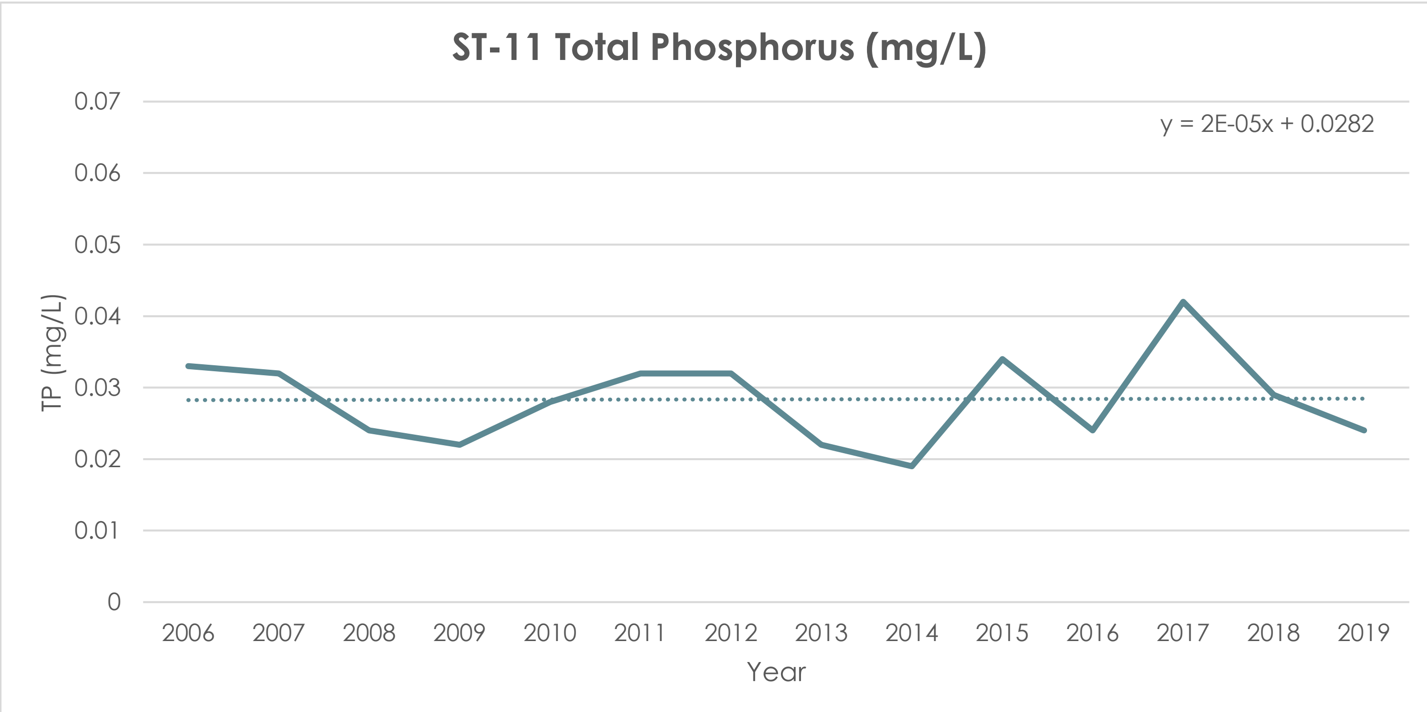


Figure 28: Average total phosphorus concentrations at ST-11 from 2006 to 2019.

Yearly average surface TP concentrations have been variable between 2006 and 2019 at ST-11, and no distinct trend can be observed (Figure 28).

SUMMARY OF STATION 11

Overall, the 13-year trends for the major water quality parameters of Secchi depth, chlorophyll-a, and TP have remained relatively constant. Although the overall trends have been relatively constant, the two years with the highest average TP concentrations occurred over the past four years. Thus, this area of the lake should be another priority when deciding on what watershed measures will be implemented to help reduce pollutant loads.

ESTIMATE OF LOAD REDUCTIONS

This section corresponds to the second US EPA element, an estimate of load reductions expected from management measures. As recommended by the US EPA, this section will focus on presenting the required load reductions per municipality for Lake Hopatcong that have been outlined in the TMDL and the original restoration plan.

GENERAL APPROACH FOR ADDRESSING STORMWATER TOTAL PHOSPHORUS LOADS ENTERING LAKE HOPATCONG AND LAKE MUSCONETCONG

LAKE HOPATCONG

Based on a combination of water quality monitoring/testing and simplified modeling, it was determined that all of implemented in-lake and watershed-based management measures have resulted in a reduction of the targeted TP load by 32% or approximately 1,051 kg per year (2,318 lbs / year) (Table 3). While these reductions in phosphorus have resulted in improvements in some sections of Lake Hopatcong, other sections are not attaining desirable water quality conditions; this was evident in some of the various station's long-term water quality figures presented in the previous section. This was also particularly obvious during the 2019 growing season when elevated TP concentrations in June 2019 resulted in cyanobacterial blooms that persisted through the summer season. Thus, efforts need to continue to reduce the lake's annual TP load in order to comply with its TMDL and attain desired water quality conditions.

Table 3: Existing and Targeted Phosphorus TMDL for Lake Hopatcong as of 2018.

Described Scenarios	TP in kgs (lbs) per year
Annual TP load targeted for removal	3,297 kgs (7,253 lbs)
Amount of TP removed between 2006 and 2018	1,051 kgs (2,318 lbs)
Required percent reduction to attain targeted TP load	32 %
Amount of TP remaining to be removed	2,246 kgs (4,935 lbs)

LAKE MUSCONETCONG

While Lake Musconetcong was also awarded a Non-Point Source (NPS) 319-grant after the original 2006 Restoration Plan was approved, the main focus of the grant was to quantify the lake's internal phosphorus load and estimate the amount of unconsolidated material in the sediments. Additionally, no inventory of recently completed stormwater / watershed projects has been conducted at Lake Musconetcong since the completion and approval of the Restoration Plan. While progress toward compliance for its TMDL has been documented for Lake Hopatcong, no similar analysis has been conducted for Lake Musconetcong. However, based on the original Restoration Plan, approximately 67% of the TP load entering Lake Musconetcong originates from the outlet of Lake Hopatcong. The required reduction in the existing TP load to comply with the TMDL of Lake Musconetcong is identified as 1,286 kg (Princeton Hydro, 2006). Thus, it is recommended that this targeted reduction be proportionally divided between what is entering Lake Musconetcong via Lake Hopatcong's outlet and what is entering Lake Musconetcong has stormwater / surface runoff from its immediate drainage basin.

MUNICIPAL-BASED PHOSPHORUS LOADS FOR LAKE HOPATCONG

It was determined in the Restoration Plan that over 80% of the annual phosphorus load entering Lake Hopatcong originates from surface runoff and septic systems, therefore, focusing the development of the WIP on reducing surface runoff and septic system sources of phosphorus will attain the targeted phosphorus load for Lake Hopatcong. Collectively, the surface runoff and septic system sources of phosphorus is defined as the "municipal-based" phosphorus load because it is the municipal-based phosphorus loads originating from the four municipalities immediately surrounding Lake Hopatcong that will be reduced to attain the targeted TMDL phosphorus load.

In the original Restoration Plan, it was determined that in order for the WIP to be fair and objective, the targeted phosphorus load reductions will be divided on a proportional basis. Specifically, the amount of phosphorus each municipality currently contributes to the lake's existing phosphorus load was used to quantify its targeted reduction.

The Township of Jefferson alone accounts for over half of the total municipal-based load. The Borough of Hopatcong was the second largest source of municipal-based phosphorus, accounting for 29% of the total. In contrast, the Borough of Mount Arlington and the Township of Roxbury combined account for less than 10% of the total load. These results are partly due to the fact that both Mount Arlington and Roxbury are sewered, while Hopatcong is not fully sewered and Jefferson is not sewered at all within the Lake Hopatcong watershed. It should be noted that approximately 40% of the lots within the septic zone of influence in the Borough of Hopatcong have been sewered since the original Restoration Plan was developed. Again, no homes within the Township of Jefferson located in the Lake Hopatcong Watershed have been sewered.

MUNICIPAL-BASED PHOSPHORUS LOADS FOR LAKE MUSCONETCONG

The current municipal-based phosphorus loads entering Lake Musconetcong have not been updated with the TP reductions from BMPs or other watershed management measures that have been implemented since the original restoration plan was created. Even so, it was documented in the original Restoration Plan that the outflow of Lake Hopatcong accounts for

67% of the total TP load to Lake Musconetcong (Princeton Hydro, 2006). Therefore, efforts to reduce the phosphorus load entering Lake Hopatcong will translate to an improvement in the water quality conditions of Lake Musconetcong.

As previously identified, it is estimated that with all of the watershed-based efforts implemented to date, the Lake Hopatcong TP load has been reduced by approximately 1,051 kg per year (2,318 lbs / year), which accounts for approximately 32% of the amount of TP targeted for reduction under its TMDL. With a phosphorus retention coefficient of 72% for Lake Hopatcong, this means that the TP load leaving Lake Hopatcong through its outflow is reduced by 746 kg (1,641 lbs) per year. Additionally, based on data provided by the Lake Musconetcong Regional Planning Board (LMRPB), the average, amount of TP removed through mechanical weed harvesting is 177 kg (389 lbs) per year. Thus, between the reduction efforts at Lake Hopatcong and the mechanical weed harvesting, the reduction of TP at Lake Musconetcong is estimated to be 923 kg per year.

It was previously identified that the amount of TP targeted for removal under the Lake Musconetcong TMDL is 1,286 kg per year. Deducing the amount of TP removed through watershed efforts at Lake Hopatcong and the mechanical weed harvesting from the 1,286 kg, results in 363 kg of TP to be removed for Lake Musconetcong's compliance with its TMDL.

SELECTIVE STORMWATER MONITORING

A major component of this revised WIP included the collection of stormwater samples to aid in the identification of sites / sub-watersheds for both lakes that experience elevated pollutant loading. TSS and TP are the pollutants of concern. In the past, stormwater sampling sites were identified based on the results of watershed models. However, a more empirical approach was taken in this WIP as recommended by the Commission. Aerial drones were deployed immediately after a storm of sizeable magnitude (e.g. at least 0.50" storm event) in select sections of each watershed in order to identify potential sites, gullies, swales or other stormwater infrastructure that appear to generate large, and possibly highly turbid, stormwater runoff.

A drone was utilized in areas within each lake's watershed that has been recognized as a prioritized area of concern relative to elevated stormwater pollutant loads. For Lake Hopatcong, three areas of concern were drone surveyed: the northeastern shoreline of the lake, north of Liffy Island (Township of Jefferson); the southern end of Crescent Cove (Borough of Hopatcong) and within the Hopatcong State Park. For Lake Musconetcong, two such areas of concern were drone surveyed: around the Lake Musconetcong Boat Launch (Borough of Netcong), and along the southern shore of the lake, north of Route 46 (Borough of Netcong).

Princeton Hydro deployed the drones immediately after (within 6 hours) each storm event to collect video information on areas prone to stormwater issues, including flooding or high stormwater discharge. After each drone monitoring event, the video was reviewed and potential locations for stormwater sampling were identified. The drone surveys occurred on two separate dates: 14 March 2019 and 16 April 2019.

The drone survey on 14 March 2019 focused on two sites around Lake Hopatcong, including the northeastern shoreline of the lake in the Township of Jefferson and around the southern end of Crescent Cove in the Borough of Hopatcong. The survey in the northeastern portion of the lake was focused around the un-named tributary that drains an existing quarry; issues have been raised over elevated amounts of turbidity that may have been experienced in this stream, potentially as a result of the land-based activities and associated stormwater infrastructure (e.g. a local quarry). Thus, this un-named tributary was selected as a stormwater sampling site (D-1) which can be found on the Stormwater Sampling Locations Map in Appendix I. The sampling point was located just north of Prospect Point Road, before the tributary passes through a culvert and into Lake Hopatcong.

The drone survey around the southern end of Crescent Cove was focused around the two un-named tributaries that drain the surrounding neighborhood before each pass through an MTD (each is an AquaSwirl device with an AquaFilter) in the Crescent Cove Beach Club parking lot. Crescent Cove is a relatively shallow cove that receives little mixing with the main body of the lake and has been an area of concern due to nuisance algae and/or high aquatic vegetation growth over the years. The un-named tributary that passes by Dupont Avenue before discharging into a culvert under the Crescent Cove Beach Club Parking lot was chosen as the stormwater sampling site (D-2) at this location due to the large volume of stormwater that passes through. The sampling site was located just west of the beach club parking lot, just before the stream enters the culvert and passes through the MTD. This site can be found on the Stormwater Sampling Locations Map in Appendix I.

The third proposed site around Lake Hopatcong for the drone survey and stormwater sampling was located in Hopatcong State Park. A permit was required to fly a drone in the State Park, and the initial permit application was submitted to NJDEP in early March. Princeton Hydro contacted NJDEP again in late May for an update on the status of the permit and were told that the permit was just sent out for review and signature. Since then, no updates or permits have been received from NJDEP. Thus, for the sake of time, the Hopatcong State Park was surveyed on foot and a sampling location at one of the pipes that drains the parking lot was chosen (D-3). This site can be found on the Stormwater Sampling Locations Map in Appendix I.

The second drone survey on 16 April 2019 focused on Lake Musconetcong and included the area around the Lake Musconetcong Boat Launch (Borough of Netcong), and along the southern shore of the lake, north of Route 46 (Borough of Netcong). The survey around the boat launch did not reveal any locations where large volumes of stormwater were flowing along the surface. Thus, it was assumed that the majority of the stormwater in this area is located below the surface and the sampling point was chosen based off of this. The location just next to the parking lot of the boat launch contains a sub-surface MTD and was chosen as the location of the sampling point (D-5). The sampling point was located just downstream of the MTD and should provide a valuable indication of how the MTD is functioning. This site can be found on the Stormwater Sampling Locations Map in Appendix I.

The drone survey along the southern end of the lake, north of Route 46, was focused on a couple of very small, un-named tributaries located south of Center Street. The drone survey revealed that these small tributaries traveled sub-surface under the parking lot of the auto-shops located just south of Center Street before collecting in a small basin just south of the road. After collecting in the small basin, the water entered a culvert that traveled under the road before discharging into the southern end of Lake Musconetcong. The sampling point (D-4) was located in the small basin that received the water from the small tributaries before entering the culvert. This site can be found on the Stormwater Sampling Locations Map in Appendix I.

After the stormwater sampling sites were located with the use of the drone surveys, each one was sampled during at least three different storm events, using standard storm sampling procedures referenced in the Quality Assurance Protection Plan (QAPP) and submitted to NJDEP. All stormwater sampling sites were located with GPS and placed onto a map which can be found in Appendix I. Grab samples were collected during or immediately after each storm event for analysis of TP and TSS (Figures 29 & 30). A QAPP was submitted to NJDEP for review of the stormwater sampling to ensure that all sampling protocol and laboratory methodology is accepted and approved by NJDEP (Appendix IV). Three stormwater events were completed after the sampling sites were chosen: 29 May 2019, 31 May 2019, and 8 July 2019. Results from all three stormwater events can be found in Figure 29 and Figure 30. Results from the stormwater sampling events were used to aid in the prioritization of sites for the design and installation of stormwater BMP and/or other watershed-based measures.

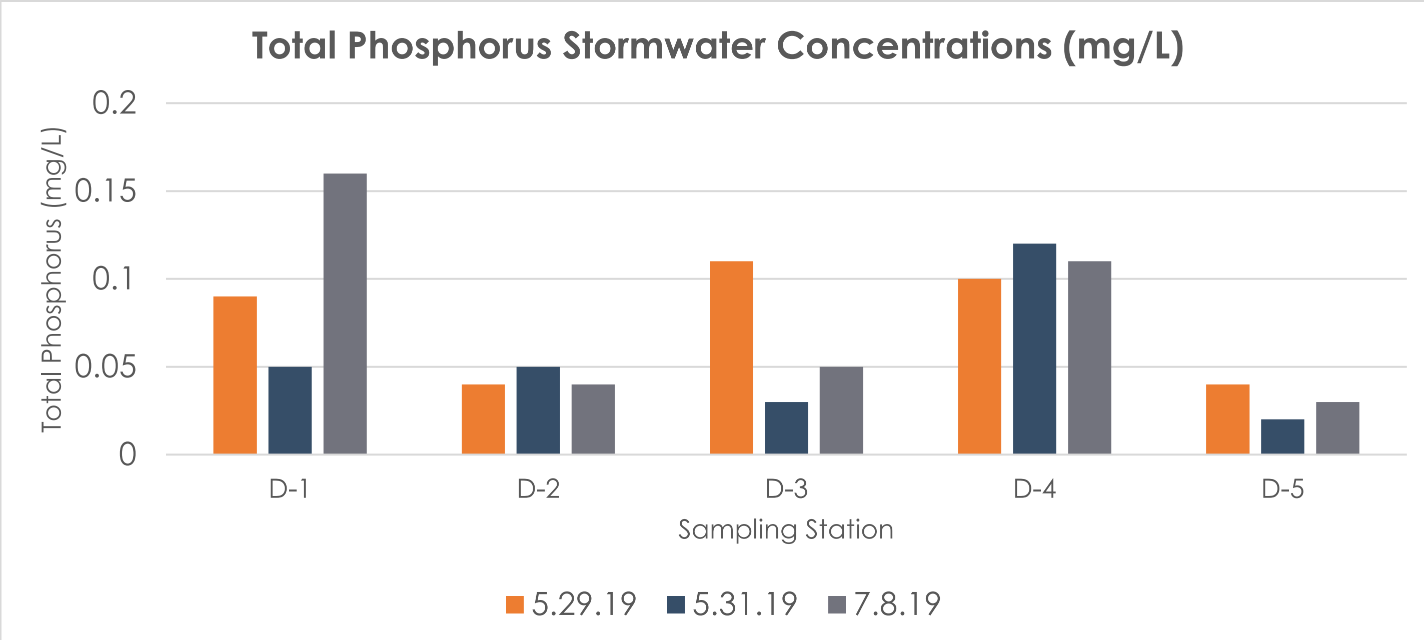


Figure 29: TP concentrations at all stormwater sampling sites on 29 May 2019, 31 May 2019, and 8 July 2019. Station locations as mentioned above; D-1: un-named quarry tributary, D-2: Crescent Cove Beach Club parking lot, D-3: Hopatcong State Park, D-4: South end of Lake Musconetcong along Center Street, D-5: Lake Musconetcong Boat Launch.

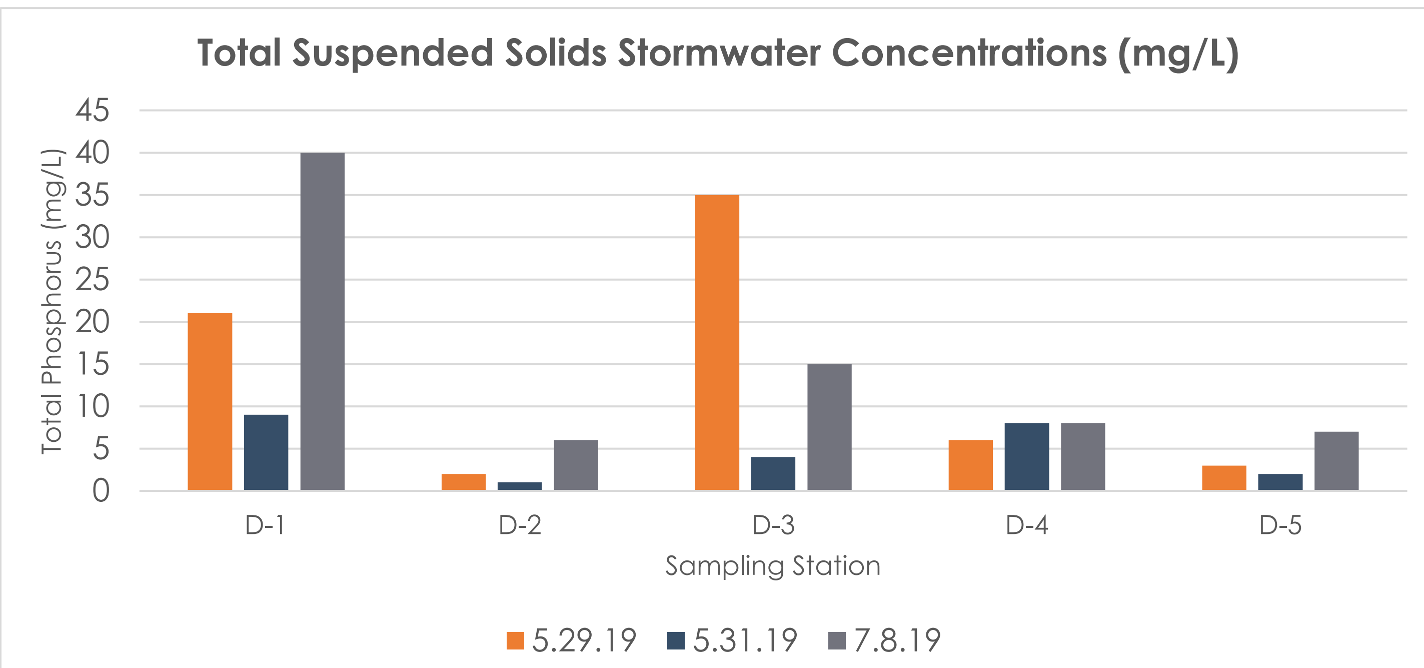


Figure 30: TSS concentrations at all stormwater sampling sites on 29 May 2019, 31 May 2019, and 8 July 2019. Station locations as mentioned above; D-1: un-named quarry tributary, D-2: Crescent Cove Beach Club parking lot, D-3: Hopatcong State Park, D-4: South end of Lake Musconetcong along Center Street, D-5: Lake Musconetcong Boat Launch.

MANAGEMENT MEASURES

This section corresponds to the third of the EPA elements and consists of a description of the management measures necessary to achieve the required 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 further reduce the TP, and other pollutants, loads entering both lakes. Thus, a considerable amount of time was spent in the field identifying potential project sites, with a focus on sites that have the capacity to accommodate green infrastructure. Green infrastructure 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.

There were two main strategies associated with the field site assessments. The first strategy focused on enhancing, modifying, or upgrading the existing stormwater infrastructure throughout the watersheds of each lake. Thus, site assessments were conducted throughout the watershed and focused on locations that receive a large volume of stormwater runoff. Wherever possible, green infrastructure was integrated into any proposed project. The second strategy focused on conducting streambank site assessments along many of the small streams that feed Lake Hopatcong and Lake Musconetcong and shoreline site assessments in both lakes. Again, where feasible, green infrastructure was integrated into any recommended designs.

As stated in the previous section, the use of aerial drones was also useful in locating streams throughout the watershed that are subject to severe erosion. The original Restoration Plan did not address TP / TSS pollutant loads entering the lakes through streambank and/or shoreline erosion. Thus, this WIP initiates this work through the identification of 25 streambank / shoreline locations (20 around Lake Hopatcong and 5 around Lake Musconetcong) that were formally assessed relative to their existing conditions. Princeton Hydro utilized the New Jersey Department of Environmental Protection's Habitat Assessment Scorecards developed as part of the NJDEP Volunteer Monitoring Program. It should be noted that this Habitat Assessment protocol is very similar to the one previously developed by Princeton Hydro for the Highlands.

The proceeding section is organized into two main sections; the first section will outline candidate sites for stormwater basin retrofits or BMPs and will include recommended restoration measures and estimated costs. The second section will outline candidate sites for streambank and shoreline restoration and will include recommended restoration measures and very general price estimates.

CANDIDATES FOR RETROFITS OR BMPS

This sub-section outlines a number of potential sites for the implementation of various watershed measures aimed at reducing the annual TP load of both Lake Hopatcong and Lake Musconetcong. A table is presented at the end of this sub-section that lists the proposed watershed measure, the amount of TP and TSS removed, and an estimated price (Table 5).

A few of the sites outlined below are locations that have already been selected by the Rutgers Cooperative Extension Water Resources Program (RCEWRP) as potential candidates for green infrastructure and/or other best management practices. RCEWRP has entered into a partnership with the William Penn Foundation; this partnership is focused on assisting communities within the New Jersey Highlands in their effort to address stormwater runoff and water quality. Three of the boroughs that were outlined with potential watershed restoration measures include Mount Arlington, Hopatcong, and Netcong. A full list of the sites that were selected by the RCEWRP can be found through the following link: http://water.rutgers.edu/Projects/William_Penn/WilliamPenn.html. It should be noted that based on our engineering-based review of the cost estimates provided by RCEWRP, these costs are low for the recommended implementation activities and do not include any design / permitting.

The location of all sites can be found on the Candidate Sites for Retrofits or BMPs Map in Appendix I. In addition to the site map, technical sheets with relevant information on the various proposed BMP or MTDs can be found in Appendix V. Aerial views of all project sites can be found in Appendix VI.

A few additional points should be noted. First, the cost estimates provided below are only for implementation / installation. They do not include engineering, design, possible permitting and monitoring. These components of any stormwater / watershed project cannot be understood and accurately budgeted until more site-specific information is collected. Thus, Princeton Hydro strongly recommends that a higher level, engineering-based assessment of the proposed project sites listed below be conducted. This higher-level assessment would include, but not be limited to, evaluating on-site issues such as:

- **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 be initiated. Without such information results could be extremely cost prohibitive and even disastrous.
- **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.

- **Permit Requirements** – Depending on some of the factors listed above, as well as the location of the site relative to the lake and associated waterways, permitting can vary from none to minimal to substantial. Thus, the potential required permitting must be determined in order to quantify the total costs associated with the design phase.
- **Access and Ownership** – Issues such as right-of-ways and easements need to be seriously considered in the selection of specific BMPs, MTDS and/or green infrastructure projects. Additionally, the source of the funding for implementation may limit where a project can be implemented. For example, typically if a project is being covered through an NPS 319-grant, the project site 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 and a Memorandum of Understanding (MOU) be executed between all pertinent parties prior to the initiation of a project.

Again, given the additional information that needs to be collected and reviewed to better understand the costs in the design and implementation of projects, as well as the long-term maintenance, associated with any watershed / stormwater project, Princeton Hydro strongly recommends an additional, engineering-grade assessment of the project sites. Such assessments will not only provide a better estimate of costs and necessary activities (e.g. permitting) but they will also save time and money in the long-run, making the projects more "shovel ready" for the implementation phase.

In addition, at the request of the Lake Hopatcong Commission, the NJ Highlands Council and NJDEP, a list of the BMP / MTD projects that were completed from when the original Restoration Plan was completed in 2006 to 2018 is provided as well.

Finally, a simplified modeling scenario was conducted where the entire watershed was sewered. That is, under this scenario, reductions in TP loading were estimated if the remaining 60% of the homes with on-site wastewater treatment systems (septic systems) in the Borough of Hopatcong were sewered and all of the homes in the Township of Jefferson were sewered as well. It should be noted that this modeling exercise is very preliminary and more site-specific data would be required to conduct a more accurate and refined analysis on how sewering the entire Lake Hopatcong watershed would translate into improvements in water quality and, specifically, reductions in algal biomass.

BOROUGH OF HOPATCONG

SITE 1: ST. JUDE PARISH (40.9509, -74.6467)

This site was selected by the RCEWRP as a candidate for green infrastructure and was included in this report because of the potential for TP and TSS reduction that exists. The building is situated in the middle of a paved parking lot, with grass surrounding the southern half of the building and pavement surrounding the northern side. There is also a small circular grassy area at the entrance of the parking lot, downhill from the building.

RECOMMENDED RESTORATION MEASURE: Rutgers recommends the installation of bioretention systems in the two grassy areas currently present on site; the small, circular patch of grass at the entrance and the patch of grass located adjacent to the building. These two bioretention systems will capture, treat, and infiltrate rooftop and parking lot runoff. Princeton Hydro also recommends the consideration of porous pavement and/or grassed pavers to increase infiltration. In addition to the bioretention systems, downspout planter boxes can be installed on the opposite side of the building to capture and treat additional runoff from the roof.

ESTIMATED COSTS: The estimated costs provided by the RCEWRP for the installation of approximately 1,305 square feet of bioretention systems and five planter boxes is $11,525. This includes $6,525 for the bioretention systems and $5,000 for the planter boxes. Note these cost estimates were derived from the RCEWRP and are considered low by Princeton Hydro.

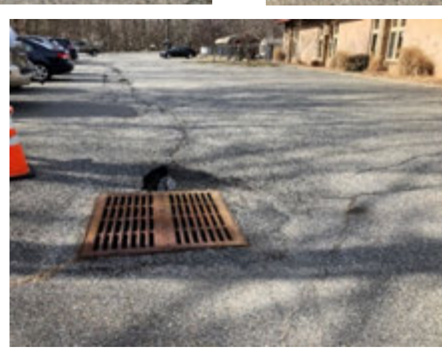
SITE 2: WEST SIDE METHODIST CHURCH (40.9510, -74.6468)

Another site that was selected by the RCEWRP as a candidate for potential BMPs is the West Side Methodist Church. In addition to the BMPs that were suggested by Rutgers, Princeton Hydro recommends a few additional measures that will work to capture and treat the maximum amount of stormwater from this site. Similar to the previous site, the building is situated in the middle of a paved parking lot. A few patches of grass are present along the west side of the building, while the surface along the east side of the building is almost entirely pavement. A grassy area with a storm drain in the center exists at the entrance of the parking lot, downhill from the building and much of the parking lot. A small stream exists on the opposite side of the parking lot on the west side of the site.

RECOMMENDED MEASURES: The two BMPs recommended by Rutgers include a small bioretention system on one of the patches of grass adjacent to the west side of the building, and a 750-gallon cistern on the east side of the building. Together, these two BMPs will capture a small portion of stormwater runoff from the roof of the building. In addition to these two BMPs, depending on site-specific conditions, the grassy area at the entrance of the parking lot could be converted to a bioretention system. This would allow for additional runoff from the parking lot to be captured and infiltrated.

Another potential measure includes the implementation of a manufactured treatment device (MTD) in the large catch basin located near the entrance of the parking lot. The pavement around the catch basin is damaged and in need of repair and could be retrofitted with an Aqua-Guardian or similar device to increase the removal of phosphorus. Routine maintenance / clean-outs of the MTD will be required at least 1-2 times per year.

ESTIMATED COSTS: The estimated cost provided by the RCEWRP for the installation of approximately 240 square feet of bioretention system and a 750-gallon cistern is $2,700. The cost of the additional bioretention system at the entrance of the parking lot would be approximately $45,000. The installation of a small MTD at the catch basin near the entrance of the parking lot is estimated to cost approximately $5,000. In total, if all of the recommended measures are to be implemented, the estimated range would be approximately $50,000 - $60,000. Again, based on Princeton Hydro's experience, this cost estimate provided by the RCEWRP is too low for implementation.



SITE 3: DEFIANCE ENGINE #3 (40.9347, -74.6606)

Firehouse #3 is another site that was selected by the RCEWRP as a good candidate for potential BMPs. The firehouse is located at the southern portion of the site, surrounded by a paved parking lot. The firehouse and parking lot at the southern end of the site are uphill, and stormwater runoff travels across the parking lot towards a grassy area in the back. There are three catch basins already in place in the back of the parking lot.

RECOMMENDED MEASURES: Following a site visit, we recommend a different set of BMPs than did Rutgers, but those recommendations can still be viewed at the link provided at the beginning of this section. The three catch basins at the back of the parking lot could be retrofit with Aqua-Guardians or similar MTDs to increase the removal of phosphorus from the surface runoff. To further enhance the phosphorus removal, the MTDs would include filter media such as Biochar. Alternative measures could include vegetated buffers / swales along with porous pavement

ESTIMATED COSTS: The installation of the MTDs, including the units and a supply of the nutrient filtering media is estimated to cost around $15,000. The alternative measures of vegetated buffers / swales and/or porous pavement is estimated to cost between $15,000 and $30,000.

SITE 4: BELL AVENUE (40.9403, -74.6598)

Bell avenue is a steep street that runs perpendicular to Crescent Cove, with no swales or other vegetative structures in place to capture or treat stormwater. The outflow pipe into Crescent Cove also receives runoff from other surrounding streets in the neighborhood, including Crescent Road, which also lacks swales or other vegetative structures to help capture stormwater. Also, based on Princeton Hydro's previous experience, this site has some constraining / limitation issues such as a fiber optic line as well as shallow depth to bedrock.

RECOMMENDED MEASURES: Some type of MTD may be installed in one of the catch basins at the end of the Bell Avenue / Crescent Road intersection to capture and treat surface flows from these two streets. If possible, it would be beneficial to modify the current subsurface drainage system in that immediate area in order to divert all stormwater through the MTD before it is discharged into Crescent Cove. The implementation of roadside swales on Bell Avenue and Crescent Road would also be beneficial, but this would require additional investigations into existing easements and right-of-ways. Additionally, these swales may be stabilized and vegetated to enhance pollutant uptake. The swales may also be augmented with Biochar to increase nutrient uptake. Also, it may be possible to daylight the pipe shown below, design it as a vegetated swale.

ESTIMATED COSTS: Additional survey work is required to obtain a reasonable estimate of the costs associated with the design and installation of a MTD and additional vegetated / stabilization efforts that would capture and treat all of the stormwater from this area before it is discharged back into Crescent Cove. Additional work would also be required to give a reasonable estimate for the cost of roadside swales. However, a very preliminary estimate for the installation of the set of recommended measures at the intersection of Bell Avenue and Crescent cove is estimated to cost approximately $400,000.




SITE 5: QUICKCHEK DETENTION BASIN (40 LAKESIDE BLVD) (40.9214, -74.6661)

The QuickChek on Lakeside Blvd. has a detention basin located at the south end of the site, between the parking lot and Lakeside Blvd. The basin has a concrete channel, lacks vegetation, and was filled with leaves and other organic matter at the time of the site visit that seems to be causing a partial blockage of the drain. The basin appears to be the primary stormwater treatment for the parking lot and the building. The basin has one inlet that is directly across the concrete channel from the outlet structure. A small amount of water was ponded in the bottom of the basin above the concrete channel and surrounding grass during the site visit. The basin may need a new trash rack and a possible modification of its outlet structure.

RECOMMENDED MEASURES: This detention basin could be retrofitted to enhance the basin's retention time and filtration efficiency. Such a retrofit would focus on the removal of the concrete channel, potential minor re-grading to lengthen the flow path, and a native, naturalized landscaping renovation of the current mowed grass vegetation. These modifications would reduce the sediment and nutrient loading and improve the runoff volume and rate reductions currently provided by the basin.

ESTIMATED COSTS: Retrofitting the existing basin is estimated to cost between $50,000 and $100,000.

SITE 6: VALE WAY AND COVE ROAD INTERSECTION (40.9251, -74.6608)

Vale Way is a relatively steep street that runs perpendicular to Cove Road, with no swales or other vegetative structures in place to capture or treat stormwater. The outflow pipe into Ingram Cove also receives runoff from other surrounding streets in the neighborhood, including Cove Road, which also lacks swales or other vegetative structures to help capture stormwater. There is a private beach/park area between the intersection of the two streets and Lake Hopatcong. There are multiple catch basins and other underground stormwater infrastructure in the immediate area which can potentially be retrofitted with MTDs or other green infrastructure that would capture and treat stormwater. An investigation into the hydrology of this area revealed that this location is a point where stormwater from a large portion of the surrounding neighborhood enters the lake, largely through subsurface stormwater infrastructure. Thus, the implementation of MTDs in this drainage system would be recommended.

RECOMMENDED MEASURES: There are multiple stormwater structures already in place on Cove Road and Vale Way that could potentially be retrofitted with nutrient reducing structures. The area would be an ideal candidate for the implementation of a three chambered nutrient separating baffle box or similar MTD. This MTD would likely capture and treat a large majority of the stormwater from the surrounding neighborhood before it is discharged back into Lake Hopatcong just on the other side of the park.

ESTIMATED COSTS: Depending on the amount of construction that would be required to install the three chambered baffle box or other similar structure, a ballpark estimate for the implementation of the MTD would be between $150,000 - $200,000. With some additional vegetated planting and stabilization work, the estimated cost would likely be somewhere between $200,000 - $300,000.

ROXBURY TOWNSHIP

SITE 7: HOPATCONG STATE PARK (40.9160, -74.6633)

A biofiltration basin was installed in Hopatcong State Park as part of the second NPS Implementation project. Unfortunately, the basin was completely mowed over and is now limited in its ability to filter and treat stormwater. The biofiltration basin has a drainage area of approximately 0.5 acres of impervious surfaces.

RECOMMENDED MEASURES: The biofiltration basin needs to be revegetated in order to treat the stormwater at its highest level of pollutant removal efficiency. In addition, other measures should be considered at the State Park to reduce the incoming stormwater / surface runoff pollutant loads that flow into the beach area. Such measures may include the use of porous pavement, vegetative filter strips and sewering the bathroom facility. These additional measures should be considered in more detail in the proposed Beach Restoration Plan for the Hopatcong State Park Beach.

ESTIMATED COSTS: The cost for revegetating the biofiltration basin is estimated to be approximately $5,000.

SITE 8: VERIZON BUILDING (LAKE MUSCONETCONG WATERSHED) (40.9070, -74.6644)

There is a large grassy area located on the side of the Verizon building, between Kingsdale Road and the building. There is currently a storm drain catch basin in the middle of the grass area, and the area is already graded like a small basin to allow the water to flow to the center.

RECOMMENDED MEASURES: This grass area would be an ideal candidate for a bioretention system. The installation of any type of BMP in this location would require additional investigation into existing easements and right-of-ways due to the close proximity to the Verizon building. If the installation of a bioretention system is possible, this BMP would be utilized to its maximum potential if runoff from the Verizon building, the parking lot, and the street were all directed to the bioretention system. Additional engineering recommendations include curb cuts for positive drainage to the grate, as well as minimizing the loss of the existing trees.

ESTIMATED COSTS: The estimated cost range for the design and installation of a bioretention system next to the Verizon building would likely be in the range of $100,000 - $200,000. This estimate is a ballpark range and would be dependent on the amount of additional work that would be required to direct the maximum amount of stormwater to the basin.

SITE 9: AURIEMMA COURT (40.9186, -74.6526)

There is a detention basin in the middle of Auriemma Court that has three inlets and one small outlet structure. It appears as though the detention basin receives stormwater from the surrounding community. The basin was dry on the day of the site visit and exhibits signs of major sedimentation issues. The inlet structures seem fairly dated, and it appeared that it has not been maintained besides mowing for quite some time. The outlet structure was covered in sediment, grit, and other organic matter during the site visit. The basin lacks vegetation throughout besides the current turf grass that is in place. The grass in the middle of the basin looks eroded, which is contributing to the aforementioned sedimentation issues.

RECOMMENDED MEASURES: This site is an ideal candidate for a basin retrofit that would address the major sedimentation issues and associated limited capability of nutrient filtration. The first major component of the basin retrofit would consist of a stabilization of the sediment and revegetation throughout the basin. Note this more than likely will include the removal of accumulated material to restore the capacity of the basin. The revegetation would decrease the rate of sedimentation by stabilizing the soil and would work to increase the assimilation of nutrients. Additional investigations into the structure and function of the inlet and outlet structures are also recommended to determine how efficiently the system is functioning.

ESTIMATED COSTS: An estimated range of cost for the basin stabilization and revegetation is between $200,000 - $250,000. Additional investigations into the functionality of the inlet and outlet structures could raise this price substantially depending on any additional work, but a cost for this is not available at this time.




SITE 10: DETENTION BASIN / WET POND (MT. ARLINGTON BLVD.) (40.9188, -74.6457)

There is a stormwater basin located just north of Mt. Arlington Blvd. The basin appears to have one major inlet on the south side, which drains a small creek that runs on the opposite side of Mt. Arlington Blvd, and one outlet structure on the north end of the basin. There was a small amount of water present in the basin during the site visit which comes from the small creek. The basin is likely at least partially wet at all times, but the amount of standing water was minimal. Except for the trees present in the basin, there did not seem to be much additional vegetation, and the drainage in the surrounding area looked poor.

RECOMMENDED MEASURES: The location of this basin at the receiving end of a stream that drains a substantial portion of the surrounding neighborhood makes it an ideal candidate for a basin retrofit. Based on field observations, this basin could potentially be converted into more of a functional wetland basin, which would provide enhanced nutrient removal. However, some additional field investigations would be required. The idea here would be to add emergent vegetation that would sequester nutrients from the standing water before it either infiltrates the soil or is discharged through the outlet structure.

ESTIMATED COSTS: Retrofitting the existing basin into a more functional wetland BMP is estimated to cost somewhere in the range of $200,000 to $300,000.

SITE 11: RETENTION BASIN (MT. ARLINGTON BLVD.) (40.9186, -74.6464)

There is a retention basin located just west of the detention basin mentioned in site 11. Both basins are located in the same wooded area, but each have separate inlet and outlet structures. This basin is located just behind a pump station and was emitting a foul odor during the site visit. There was also some type of algae bloom in the center of the pond during our site visit, as well as a white film on the surface of the water throughout. Thus, Princeton Hydro recommends that the Borough work with the Sewage Authority and conduct a site inspection to determine if there is an issue with the pump station. The drainage around this area was poor during the site visit, especially between the outlet structure and Lake Hopatcong, as standing water was observed between the street and wooded area.

RECOMMENDED MEASURES: Due to the limited spacing in this wooded area, the costs of retrofitting this retention basin may be higher relative to the other basins discussed. The smell, suspicious algae bloom, and white surface film in the water should be investigated further. It is likely that these issues are a result of being located next to the pumping station, but if there is a leak or other failure in the station, it should be addressed prior to upgrading the basin. This site and the previously mentioned detention basin should both be investigated further to determine the best course of action to address both basins. If these basins could be connected and revegetated in some fashion, the assimilation and nutrient sequestration of the stormwater would increase greatly.

ESTIMATED COSTS: Due to the uncertainty of what the major issue behind the water quality in the retention pond, an estimated cost cannot be provided until further investigation. However, excluding any costs associated with repairs necessary for the pump station, retrofitting the basin is estimated to cost between $200,000 and $500,000.

BOROUGH OF MOUNT ARLINGTON

SITE 12: RIDGEVIEW LANE (40.9249, -74.6383)

This site is an apartment complex with approximately six small, paved parking lots, a road that runs down the middle, and two large detention basins that receive all of the stormwater runoff from the complex. Each small parking lot has at least one curb-side storm drain, and the road that runs down the center of the complex also has storm drains. The detention basin on the south side of Ridgeview Lane has two inlets on each side of the basin, and one grated outlet structure in the middle. The detention basin was dry during the time of the site visit, and it appeared to be mowed, with minimal vegetation other than the grass. The detention basin on the north side of Ridgeview Lane had some water pooled in the middle during the site visit and appeared to also contain two inlets and one outlet structure. It was difficult to tell if the basin was wet by design, or because of poor infiltration and drainage.

RECOMMENDED MEASURES: The numerous curbside storm drains in the parking lots of this complex make them ideal candidates for tree box biofiltration systems. Depending on which drains receive the greatest volume of stormwater, each small parking lot could be retrofit with at least one curbside storm drain with tree box units. The tree boxes would allow for a large portion of the stormwater in the apartment complex to be treated by the nutrient reducing media before the water is discharged into the detention basins. In addition to the aforementioned units, each of the detention basins could be retrofitted to enhance filtration and retention, further reducing the nutrient loads of the discharged water. The modifications and upgrades to the basins would likely be relatively minor considering neither of the basins contains a concrete channel but would be focused on revegetation, modification to the outlet structures, and the potential modification of the soil to allow for better filtration and nutrient removal.

ESTIMATED COSTS: The estimated cost for the installation of approximately six tree box units throughout the complex would likely be between $200,000 - $300,000. Depending on the amount of work that would be required to enhance the two detention basins to maximum efficiency, a ballpark estimate of the cost would be between $50,000 - $100,000. In total, if six tree box units are installed and both basins are retrofit, an estimated range of cost would be between $350,000 - $400,000.

SITE 13: ARTHUR R. ONDISH MEMORIAL BEACH (40.9288, -74.6380)

There is a stream just uphill from the beach that runs through a culvert before it travels under the parking lot, eventually discharging into the lake. The streambanks in this area are lined with rip rap for erosion control but lack vegetation and are covered with sand at points. There is a curbside storm drain on the opposite side of the parking lot from where the stream enters the culvert. An investigation into the hydrology of the stream and associated discharge into Lake Hopatcong revealed that this stream drains a substantial portion of the upstream neighborhood. Thus, this location is a strong candidate for upgrades to the stormwater infrastructure.

RECOMMENDED MEASURES: There are multiple stormwater structures already in place in the parking lot that could potentially be retrofitted with nutrient reducing structures. The parking lot, between the culvert and the curbside storm drain, would be an ideal candidate for the implementation of a three chambered nutrient separating baffle box. This MTD would likely capture and treat a large majority of the stormwater from the surrounding neighborhood before it is discharged back into Lake Hopatcong just on the other side of the park. In addition to the MTD, the curbside drain could be retrofitted with a tree box bioretention system. The tree box would be located between the MTD and the lake, effectively capturing and treating excess surface flow that bypasses the MTD. Additionally, the streambanks should be cleared of sand and vegetated, creating shoreline buffers to capture and treat additional stormwater runoff. Also, if riprap is still used, it should be replaced with large, natural rock. Finally, the creation of a floodplain adjacent to the stream may be a potential option depending on land ownership. There is an existing baffle box near this project site in which additional filter media (e.g. Biochar) can be added to the system to increase phosphorus removal.

ESTIMATED COSTS: Depending on the amount of construction that would be required to install the three chambered baffle box in the parking lot, a ballpark estimate for the implementation of the MTD would be between $150,000 - $200,000. The estimated cost to install one tree box bioretention system would be approximately $50,000. In total, if a three chambered baffle box and one tree box unit are installed in the parking lot, the estimated cost would likely be somewhere between $200,000 - $250,000.

SITE 14: ALTENBRAND AVENUE AND WINDEMERE AVENUE (40.9282, -74.6368)

These two streets are uphill from the beach mentioned in site 13. Altenbrand Avenue is a steep road that runs perpendicular to Lake Hopatcong, with no roadside conveyance including swales or other vegetation or stormwater infrastructure to capture or treat stormwater. Windemere Avenue is slightly uphill from Altenbrand Avenue, and it appears as though some runoff from Windemere Avenue drains out of a pipe onto Altenbrand Avenue.

RECOMMENDED MEASURES: There is a catch basin on Windermere Avenue that may be a good candidate for a MTD device with filter media. There is also a curbside storm drain on the south side of Windermere Avenue that would be a good candidate for the installation some type of green infrastructure such as a rain garden. Both of these stormwater structures run through the same stormwater system that was discussed as part of site 13. The installation of these nutrient reducing structures would work to decrease the sediment and nutrient load before the stormwater passed through the potential MTD discusses as part of site 13.

ESTIMATED COSTS: The estimated cost for the installation of a small MTD on Windemere Avenue with some type of biofiltration system is estimated to cost between $50,000 and $75,000.

SITE 15: EDITH M DECKER SCHOOL (40.9343, -74.6291)

This site consists of an elementary school and large paved parking lot in front of the school that has a grassy area located in the center. There is a small stream that runs along the front of the site, between the parking lot and Howard Blvd. The stream travels through a culvert and under Howard Blvd. before discharging into Lake Hopatcong down the street. There are two large catch basins located between the parking lot and the stream in front of the school. There is also a curbside storm drain and multiple smaller catch basins on the side of the parking lot that drain to the same location as the stream.

RECOMMENDED MEASURES: Due to the relatively large size of the parking lot and multiple stormwater structures, this site is an ideal candidate for multiple BMPs and/or MTDs, coupled with some vegetated buffers and breaking up the impervious surfaces. The grassy area in the middle of the parking lot could potentially be constructed into a bioretention / rain garden. This would require further investigation into the drainage pattern of stormwater through the parking lot. Additionally, an MTD with filter media could be installed in one of the large catch basins located between the parking lot and stream to capture and treat stormwater from the parking lot before it is discharged into the stream. There is also a smaller catch basin on the south side of the parking lot that was covered in sediment during the site visit. This storm drain could also be retrofit with a small MTD with filter media to capture and treat additional stormwater before it is discharged back into the creek.

ESTIMATED COSTS: The estimated cost range for the design and installation of a rain garden in the center of the parking lot would likely be in the range of $15,000 - $25,000. A cost estimate for the installation of two Aqua-Guardians and associated vegetated buffers would be between $30,000 - $45,000. Thus, the total cost for implementation is estimated to cost between $45,000 and $70,000.

SITE 16: HOWARD BLVD (IN FRONT OF EDITH M DECKER SCHOOL) (40.9340, -74.6298)

The culvert that drains the stream that runs across the front of the school travels under Howard Blvd before emptying into Lake Hopatcong; this culvert also receives runoff from a small stream southeast of the culvert. Thus, the culvert receives runoff from the entire Edith M Decker school property and parts of the surrounding neighborhood. There are also two catch basins on Howard Blvd near the school that drain runoff from the street before it is discharged into the lake.

RECOMMENDED MEASURES: Somewhere between the culvert and Lake Hopatcong would be an ideal location for a three chambered nutrient separating baffle box with up flow filter. This MTD would capture and treat a large portion of surface runoff from the surrounding neighborhood before it enters Lake Hopatcong. Both of the catch basins located on Howard Blvd could also be retrofitted with small MTDs and filter media (such as Biochar), which would allow for the surface runoff from Howard Blvd to be captured and treated before it is discharged back into the lake.

ESTIMATED COSTS: A ballpark estimate for the installation of a three – chambered baffle box and associated small MTDs with filter media would be in the range of $300,000 - $400,000.

JEFFERSON TOWNSHIP

SITE 17: KENTUCKY AVENUE STREAM CROSSING (40.9741, -74.6303)

A stream passes under Kentucky Avenue through a culvert before it empties into Lake Hopatcong. The stream receives stormwater from a substantial portion of the surrounding neighborhood, approximately 0.5 square miles. There are multiple catch basins on Kentucky Avenue that drain to the stream; one is located directly next to the stream crossing and was flowing during the site visit.

RECOMMENDED MEASURES: The catch basins at this site may be good candidates to be retrofitted with small MTDs and filter media to aid in the removal of phosphorus and suspended sediment. The catch basin located just next to the stream crossing would be the priority catch basin due to the amount of water flow during the site visit. There is a second catch basin located at the corner of Kentucky Avenue and Louisiana Avenue that would also be a good candidate based on the size of the catch basin.

ESTIMATED COSTS: The sizing, design, and installation of two small MTDs, including the units and a supply of the nutrient filtering media is estimated to cost $30,000.

SITE 18: ALABAMA AVENUE AND NEW JERSEY AVENUE (40.9721, -74.6301)

New Jersey Ave is a steep street that runs straight down to Lake Hopatcong with no swales or vegetative surfaces to capture stormwater before it enters the lake. There are a number of catch basins and curbside storm drains on the street that capture the stormwater. One of the relatively large catch basins is located at the end of the street, just before the lake. This drain receives a large portion of the stormwater from the surrounding neighborhood and was flowing during the site visit.

RECOMMENDED MEASURES: The large catch basin located just before the lake is an ideal candidate for the implementation of a three chambered nutrient separating baffle box. It seems as though there is already existing stormwater infrastructure in place under the road that would make the installation of a large MTD relatively straight forward. This catch basin would be the best location for the MTD because it Is the closest to the lake and would capture and treat the largest volume of stormwater.

ESTIMATED COSTS: Depending on the amount of construction that would be required to install the three chambered baffle box at the end of New Jersey Avenue, a ballpark estimate for the implementation of the MTD would be between $150,000 - $200,000.

SITE 19: NEW JERSEY AVENUE (40.9656, -74.6288)

There is what appears to be a small intermittent stream that passes through a property on New Jersey Avenue before emptying into a catch basin on the street. The water was flowing through the catch basin during the site visit, which occurred the morning after a rain event. The drainage on the property that the intermittent stream passes through looked to be poor, as ponding was evident on the grass. Stormwater from this catch basin empties out into Lake Hopatcong on the other side of New Jersey Ave and drains a substantial portion of the surrounding neighborhood.

RECOMMENDED MEASURES: The catch basin on Ohio Street would be a good candidate to be retrofit with a small MTD and filter media to aid in the removal of phosphorus and suspended sediment from the stormwater. However, some additional, on-site engineering assessments should be conducted to determine the feasibility of some stabilization of the existing stormwater conveyance system.

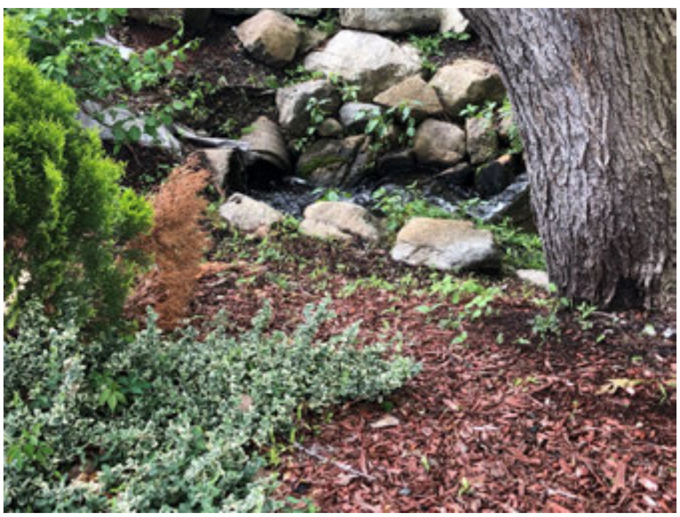
ESTIMATED COSTS: The installation of a small MTD with filter media is estimated to cost $15,000.

SITE 20: BRADY ROAD AND NORTH LAKESIDE AVENUE (40.9632, -74.6222)

There is a small stream on the west side of Brady Road that travels underground and into a catch basin in the parking lot on the west side of the Brady Road and North Lakeside Avenue intersection. The lake is located just on the other side of Brady Road and it receives stormwater from the catch basin. The catch basin also seems as though it receives a substantial volume of surface runoff from the street and parking lot; there was water still draining off the road during the morning of the site visit after rain the previous evening. There was a foul smell coming from the area of the catch basin, which may possibly be related to a nearby septic system.

RECOMMENDED MEASURES: An MTD, possibly a three-chambered baffle box, could be installed between two inlets or along the pipe system, not in an existing inlet, located in the parking lot just to the west of Brady Road. This catch basin is relatively large and receives runoff from the small stream and the surrounding streets. This MTD would likely capture and treat a large volume of the stormwater from the surrounding area before it is discharged back into Lake Hopatcong just on the other side of the road.

ESTIMATED COSTS: Depending on the amount of construction that would be required to install the three chambered baffle box on Brady Road, a ballpark estimate for the implementation of the MTD would be between $150,000 - $200,000.



SITE 21: OAKWOOD ROAD AND SHORE ROAD (40.9839, -74.6169)

Oakwood Road is a steep street that runs straight down to Lake Hopatcong with no swales or vegetative surfaces to capture stormwater before it enters the lake. There are a number of catch basins on the street that capture the stormwater. One of the relatively large catch basins is located at the end of the street, before the water is eventually discharged into the lake.

RECOMMENDED MEASURES: The large catch basin located at the end of the road is an ideal candidate for the installation of a small MTD with filter media, like Biochar. It seems as though there is already a large storm sewer system in place under the road that would make the installation of an MTD relatively straight forward. This catch basin would be the best location for the MTD since it is the closest to the lake and would capture and treat the largest volume of stormwater.

ESTIMATED COSTS: The installation of a small MTD with filter media is estimated to cost $15,000.

SITE 22: QUARRY STREAM / PROSPECT POINT ROAD (40.9867, -74.6163)

This is the stream that drains the granite quarry, passes under Prospect Point Road and enters Lake Hopatcong. There was a sediment boom in place during the site visit on 29 May 2019 which was likely placed there by NJDEP. This site is now a point of focus by the NJDEP and any potential BMP plans should be discussed further with them. In addition to the stream, there are multiple curbside storm drains on the side of Prospect Point Road.

RECOMMENDED MEASURES: In addition to what is decided between NJDEP, the quarry, and The Commission, there are currently two curbside storm drains located in close proximity, although it has been noted that these drains have been assessed in the past and were not fit for filter media. Also, a stormwater pond on the quarry property may require some maintenance and possible upgrades to maximize its pollutant removal capacity.

ESTIMATED COSTS: Currently (October 2020) under discussion among the quarry, NJDEP and the Commission.

SITE 23: LORETTACONG DRIVE AND RT 181 INTERSECTION / STREAM CROSSING (40.9879, -74.6117)

There is a small stream that passes under Lorettacong Drive just before it empties into Lake Hopatcong. There is a curbside storm drain on top of the culvert that the stream passes through under Lorettacong Drive. There are also multiple curbside storm drains on Route 181 located adjacent to Lorettacong Drive.

RECOMMENDED MEASURES: The curbside storm drains here are all good candidates to be retrofit with tree box tree boxes and/or small MTDs. The tree boxes would allow for a large portion of the stormwater from the road to be treated by the nutrient reducing media before the water is discharged into either the creek or the lake.

ESTIMATED COSTS: The estimated cost to install two tree box bioretention systems would be approximately $75,000.

SITE 24: LORETTACONG DRIVE / LAKE WINONA STREAM CROSSING (40.9888, -74.6063)

The stream that drains Lake Winona passes under Lorettacong Drive at this site before it empties into Lake Hopatcong. There is a catch basin located just southeast of the stream crossing on Lorettacong Drive that was flowing during the site visit.

RECOMMENDED MEASURES: The catch basin located next to the stream is a good candidate to be retrofit with a small MTD with filter media. This catch basin appears to be the terminal catch basin that receives stormwater from the entire street, including other basins up the road.

ESTIMATED COSTS: The installation of a small MTD with filter media is estimated to cost $15,000.

SITE 25: ALPS LANE (40.9805, -74.6091)

Alps Lane is a relatively steep street that runs straight down to Lake Hopatcong with no swales or vegetative surfaces to capture stormwater before it enters the lake. There are a number of catch basins and curbside storm drains on the street that capture the stormwater. One of the relatively large catch basins is located at the end of the street, just before the lake.

RECOMMENDED MEASURES: The large catch basin located just before the lake is an ideal candidate for the implementation of a three chambered nutrient separating baffle box. It seems as though there is already a large storm sewer system in place under the road that would make the installation of a large MTD relatively straight forward. This catch basin would be the best location for the MTD because it Is the closest to the lake and would capture and treat the largest volume of stormwater. In addition, an engineering assessment should be conducted to determine the feasibility of roadside vegetated swales.

ESTIMATED COSTS: Depending on the amount of construction that would be required to install the three chambered baffle box at the end of Alps Lane, a ballpark estimate for the implementation of the MTD would be between $150,000 - $200,000. Note this does not include any roadside vegetated swales or other potential green infrastructure.

SITE 26: LAKESIDE FIELDS PARKING LOT (40.9616, -74.6018)

The parking lot at Lakeside Fields has multiple catch basins and curbside storm drains that capture the runoff from the parking lot. These catch basins bring all of the parking lot runoff to a central location that travels under Swan Lane and empties out into a little creek, which then flows into Lake Hopatcong.

RECOMMENDED MEASURES: The catch basin located just before the outflow pipe into the stream would be an ideal candidate for the installation of a nutrient separating three chambered baffle box. This catch basin appears to be the terminal basin that receives runoff from at least the parking lot of the park and Swan Lane. This MTD would be in a position to capture and treat the maximum volume of stormwater before It empties back out into the lake. Additionally, the mulched / curbed area shown below may be a good candidate for a vegetated retention swale.

ESTIMATED COSTS: Depending on the amount of construction that would be required to install the three chambered baffle box on Swan Lane and converting the mulched curbed area into a vegetated swale, a ballpark estimate for the implementation of this project would be between $250,000 - $400,000.

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SITE 27: EAST SHORE ROAD / EAST SHORE PARK (40.9580, -74.6194)

A small stream passes under East Shore Road through a culvert at this site. There are currently three storm drains above the culvert on East Shore Road. In addition, there is a catch basin located just west of the outflow pipe, on Benedict Drive. Also, it should be noted that a three-chambered baffle box system was installed along the road here as part of a previous grant to the Lake Hopatcong Commission.

RECOMMENDED MEASURES: East Shore Road above the culvert is an ideal candidate for the installation of a three chambered nutrient separating baffle box. Thus, one was already installed as part of the previous grant. However, the existing phosphorus removal capacity of the existing baffle box may be substantially increased if some additional filter media (e.g. Biochar) is added to the system. Additionally, the channel may benefit from some stabilization efforts and the possible expansion of the pooled area that is backwater from the cove.

ESTIMATED COSTS: The cost of installing new filter media into the existing baffle box would be minimal. However, additional engineering site-assessments would be necessary to provide an estimate for the costs to conduct additional stabilization efforts and expand the pooled area. A VERY preliminary estimate to stabilize the existing channel is $100,000 and $150,000 and does not include any work on the pooled area.

Table 5: Proposed Stormwater Projects Summary.

Site and Recommendations	Total P Removed (lbs/yr)	Total Suspended Solids Removed (lbs/yr)	Estimated Costs	Ownership
St. Jude Parish Bioretention system Planter boxes	.5	330	$12,000	Private
West Side Methodist Church Bioretention system (2) Cistern Aqua-Guardian	.75	604	$50,000 - $60,000	Private
Defiance Engine #3 Aqua-Guardians (3)	.5	320	$15,000	Public
Bell Avenue Three chambered baffle box Vegetates swales	35	93,075	$400,000	Public
Hopatcong State Park Revegetation of biofiltration basin	-	-	$5,000	State
QuickChek (40 Lakeside Blvd) Retrofit detention basin	1	660	$50,000 - $100,000	Private
Vale Way and Cove Road Three chambered baffle box tree box (2)	10	22,910	$200,000 - $300,000	Public
Verizon Building Bioretention system	.75	575	$100,000 - $200,000	Private
Ridgeview Lane tree box (6) Retrofit detention basin (2)	3	6,030	$350,000 - $400,000	Private
Auriemma Court Retrofit detention basin	2	3,450	$200,000 - $250,000	Public
Mt. Arlington Blvd (both sites) Basin retrofit	27	53,750	$400,000 - $800,000	Public
Arthur R Ondish Memorial Beach Three chambered baffle box tree box Vegetated shoreline buffer	50	130,630	$200,000 - $250,000	Municipal
Altenbrand Avenue and Windermere Avenue Aqua-Guardian tree box	.25	240	$50,000 – 75,000	Public
Edith M Decker School Bioretention system Aqua-Guardian (2)	1.5	2,755	$45,000 - $70,000	Public
Howard Blvd Three chambered baffle box Aqua-Guardian (2)	27	72,950	$300,000 - $400,000	Public
Kentucky Ave Aqua-Guardian (2)	5.5	15,670	$30,000	Public
Alabama Ave and New Jersey Ave Three chambered baffle box	5.5	15,670	$150,000 - $200,000	Public
New Jersey Avenue Aqua-Guardian	7	19,300	$15,000	Public

Site and Recommendations	Total P Removed (lbs/yr)	Total Suspended Solids Removed (lbs/yr)	Estimated Costs	
Brady Road Three chambered baffle box	9	24,100	$150,000 - $200,000	Public
Oakwood Road and Shore Road Aqua-Guardian	1	2,400	$15,000	Public
Quarry Stream Under Review	-	-	-	Private
Lorettacong Dr and Route 181 tree box (2)	.5	1,200	$75,000	Public
Lorettacong Drive and Lake Winona Stream Crossing Aqua-Guardian	1	3,000	$15,000	Public
Alps Lane Three chambered baffle box	4.75	12,660	$150,000 - $200,000	Public
Lakeside Fields Three chambered baffle box	1	2,400	$250,000 - $400,000	Municipal
East Shore Park Three chambered baffle box	17.5	48,000	$100,000 - $150,000	Municipal
Totals	**187.5**	**472,109**	**$3,327,000 – $4,637,000**	

CANDIDATES FOR STREAM RESTORATION

This sub-section outlines a number of potential sites for streambank and shoreline restoration. To aid in the survey of the stream sites, Princeton Hydro utilized the New Jersey Department of Environmental Protection's Habitat Assessment Scorecards developed as part of the NJDEP Volunteer Monitoring Program. An example of the scorecards that were used can be found in Appendix VII. Assessment factors include the following habitat parameters:

- Epifaunal substrate / available cover
- Pool substrate characterization
- Pool variability
- Sediment deposition
- Channel flow status
- Channel alteration
- Channel sinuosity
- Bank stability
- Bank vegetative protection
- Riparian Vegetative zone width

For the sake of time management and practicality while in the field, the scorecards were only filled out at 11 of the 16 proposed stream sites; the remaining 9 in-lake shoreline sites were only assessed for erosion / vegetative cover. If a stream reach was extremely small, shallow, ephemeral, drainage path, etc. the scorecard was not filled out. The purpose of these streambank and shoreline assessments were to assess potential sites for streambank/shoreline restoration that would reduce the TP and TSS loads entering both lakes. While all of the information on the scorecards is valuable to assess the overall ecological health of stream segments, the field assessments were focused on reducing TP and TSS sources in order to comply with the associated TMDLs. The stream assessment scorecards and protocol will be discussed further in the Education and Outreach section of this document; the NJDEP Habitat Assessment Scorecards developed as part of the NJDEP Volunteer Monitoring Program will be used in full when Princeton Hydro trains local volunteers on how to conduct the Stream Assessments.

The stream assessments were completed on two dates: 15 August 2019 and 22 August 2019. A review of CLIMOD indicated that the region received minimal rainfall for at least 24 hours leading up to the assessments. The region received 0.08 inches of precipitation within the 24 hours leading up to the 15 August 2019 assessment and 0.00 inches of precipitation before the 22 August 2019 assessment; CLIMOD states that the region received 0.29 inches of rainfall on 22 August 2019, but this occurred after the assessments. Thus, all of the streams can be considered at or near baseflow during the time of assessment.

Estimating prices and load reductions for streambank and shoreline restoration includes many variables and is difficult to estimate without detailed site-assessments. Thus, it must be emphasized that any estimates, in particular the cost estimates, need to take in to account many of the site-specific factors previously described for the candidate sites for retrofits or BMPs. Thus, the actual price of any implementation streambank / shoreline project may be lower (e.g. the volunteer planting of native vegetation) or higher (e.g. requires a substantial amount of earth-moving / re-grading) than the estimated price range. In addition, these cost estimates are for implementation, which includes labor and materials; however, this does not include design, engineering and/or permitting requirements. For the sake of this WIP, a preliminary pollutant load reductions and cost estimates for the implementation of these tasks are provided in Tables 6 and 7 at the end of this section.

The location of all sites can be found on the Candidate Sites for Retrofits or BMPs Map in Appendix I.

BOROUGH OF MOUNT ARLINGTON

SITE 28: MEMORIAL PARK BRIDGE CROSSING (40.9279, -74.6375)

There is a small un-named tributary that flows through Memorial Park before traveling under a bridge located on Altenbrand Avenue and eventually through Arthur R. Ondish Memorial Beach and into Lake Hopatcong. There is a small rock-weir located under the bridge that funnels the stream through an opening only a few feet in width. There is extensive sedimentation occurring along the right bank just upstream of this structure. In addition to the sedimentation, there is a lack of a defined stream channel for approximately 50 feet directly upstream of the structure. It is likely that the water gets backed up behind the small rock-weir during times of heavy streamflow causing the deposition of sediment along the right side of the stream. The sediment in this location during the time of the site visit was very soft and loose and is likely easily eroded and transported downstream into Lake Hopatcong.

RECOMMENDED MEASURES: Ideally, the first recommended measure at this site would be the removal of the rock-weir to allow for the natural flow of the stream and to reduce the severity of the sedimentation. If the structure Is in place to prevent flooding downstream, we still recommend addressing the sedimentation issues occurring upstream. The streambanks should be enhanced to allow water to flow down a defined path and through the rock-weir rather than spreading out and transporting the loose sediment that is located upstream of the structure. The streambanks should be stabilized and vegetation should be enhanced in this location in order to hold the streambank sediment in place, decreasing the amount of sedimentation occurring here.




SITE 29: MEMORIAL PARK NEAR NORTH GLEN AVENUE (40.9265, -6363)

This streambank site is located upstream of Site 28 and is located in Memorial Park. This stream reach travels through the open section of the park and the majority of the right bank lacks a vegetative buffer. The few sections along the stream that have a small vegetative buffer are covered in the invasive Japanese stilt grass (*Microstegium vimineum*). In addition to the lack of a vegetative buffer, there is a section of roughly 25 linear feet along the right bank that is eroding. Specifically, the upper section of the streambank is widening, exposing tree roots and loose sediment.

RECOMMENDED MEASURES: Vegetation should be planted along the right bank of the stream in order to sequester some of the nutrients in the stormwater runoff from the park. In addition to the buffer, the section along the right bank that is currently eroding could be graded back to a gentler slope in order to allow the water to flood the adjacent floodplain without causing the bank to erode. Such an increase in conductivity would mitigate the flooding through infiltration and/or evapotranspiration. The toe of the bank currently has some rocks in place for bank protection, but the upper part of the bank is exposed and eroding. If the upper bank continues to erode, some of the trees can become dislodged and fall across the stream, causing further erosion in the streambed through a process known as head cutting.

SITE 30: UPSTREAM OF EDITH M. DECKER ELEMENTARY SCHOOL (40.9350, 74.6290)

There is a small un-named tributary that flows through a culvert before traveling across the front of the Edith M. Decker Elementary School property just east of Howard Boulevard. The stream had very minimal flow during the site visit and most of the water was collecting in a small pool upstream of the culvert. The stream channel began to lose its structure along the right bank beginning approximately 25 feet upstream of the culvert and sedimentation along the right bank was occurring.

RECOMMENDED MEASURES: The right streambank should be enhanced to allow water to flow down a defined path and through the culvert rather than spreading out just upstream of the structure. The streambanks should be stabilized and vegetation should be enhanced in this location in order to hold the streambank sediment in place, decreasing the amount of sedimentation occurring here. In addition to enhancing the streambank, replacing the current culvert with a larger one would allow for more natural streamflow and aquatic organism passage during periods of heavier flow.

ROXBURY TOWNSHIP

SITE 31: UPSTREAM OF MOUNT ARLINGTON BOULEVARD (40.9187. -74.6448)

Located just upstream of Mount Arlington Blvd. is a small un-named tributary that travels through a culvert and under Mt. Arlington Blvd. The stream had very low flow during the site visit but extensive erosion and sedimentation was observed, indicating much heavier flows during storm events. Extensive bank scouring and widening was observed along the right bank, especially just upstream of the culvert. A few localized patches of sedimentation were also present in this relatively short stream reach. The culvert opening was barely visible during the site visit and the water was starting to pool up just upstream of this location; this is likely causing some of the sedimentation issues in this stream reach. The blocked culvert may also be a sign of an undersized culvert and should be further evaluated as such.

RECOMMENDED MEASURES: The opening to the culvert should be cleared of all debris to allow for the natural flow of the stream and to reduce the severity of the sedimentation. In addition to clearing the culvert, the right bank of the stream could use some bank stabilization to prevent the bank scouring and widening that was observed. The streambanks were also lacking proper, native vegetation; this should be addressed to stabilize the banks and prevent further erosion and the associated TP and TSS release into the water. If further evaluation of the culvert after removing the debris reveals what appears to be an undersized culvert, replacing it with a larger size would allow for more natural streamflow and aquatic organism passage during periods of heavier flow.

SITE 32: INTERMITTENT STREAM SOUTH OF KING ROAD (40.9189, -74.6462)

There is a small intermittent stream that drains the wetland area between Mt. Arlington Boulevard and King Road; this small stream drains along King Road before connecting with the larger stream mentioned in Site 31. This intermittent stream had no defined streambanks and the sediment was extremely muddy and loose; a Princeton Hydro scientist sunk in over 1 foot into the streambed during the site visit. A small amount of pooling along King Road was observed during a site visit in March during a relatively dry period.

RECOMMENDED MEASURES: Because this site is located in a wetland area and appears to be a small headwater stream, this area could benefit from wetland type plantings, such as skunk cabbage *(Symplocarpus foetidus)*, in order to better stabilize the soil and increase nutrient sequestration. In addition to the wetland plantings, the placement of some larger rocks or small boulders could benefit the area by diffusing the flow, allowing for increased contact time and reduced kinetic energy and erosion.

SITE 33: MUSCONETCONG RIVER (DOWNSTREAM OF LAKE HOPATCONG DAM) (40.9170, -74.6660)

The right bank of the Musconetcong River is eroding just downstream of the dam and overhead bridge located adjacent to Hopatcong State Park. There is approximately 30 feet of severe erosion occurring along the right bank where undercutting and bank scour are evident; large tree roots are exposed. The river is channelized just upstream of this location which is likely increasing the velocity of the water before it reaches the right bank. In addition to the erosion caused by the river water, there is an outfall pipe along the right bank that drains onto a small piece of concrete. The right bank under the pipe is receding backwards a few feet past the rest of the already eroding right bank.

RECOMMENDED MEASURES: The majority of the erosion at this site is occurring along the bottom of the right bank and restoration measures should be focused on streambank toe protection. Lining the bottom of the streambank with rocks and stones will provide protection against the erosional forces currently affecting the right bank. The concrete slab that is currently collecting the drainage from the outfall pipe should also be removed and a small drainage path should be lined with rocks all the way down to the river to prevent the severe undercutting that is occurring. Some minor bank re-grading may be necessary at this location to accommodate the toe protection.

SITE 34: MUSCONETCONG RIVER SIDE CHANNEL (40.9168, -74.6661)

Just downstream of Site 36 is a side channel that has formed along the left bank of the Musconetcong River. It is difficult to tell if this side channel broke off of the main river through continued erosion along the left bank, or if a substantial amount of sediment has built up over time creating an island that split the river up. Nonetheless, extensive sedimentation is occurring in multiple locations along this side channel. In addition to the sedimentation, a number of large trees have been uprooted here; these trees were likely dislodged during storm events rather than continued erosion along the streambank because the elevation is relatively flat. The sediment is very loose and muddy throughout this whole area and there are loose logs and tree branches scattered throughout.

RECOMMENDED MEASURES: One option for addressing the erosion and sedimentation issues at this location could involve stabilizing the left bank of the main river and the small island with rooted vegetation in order to better hold the streambanks in place. Additionally, the dislodged and toppled trees in the side stream should be removed to prevent the trees from being transported down river during periods of heavy flow to prevent any potential headcuts or other erosional issues that may form.

SITE 35: MUSCONETCONG RIVER (MAIN CHANNEL) (40.9165, -74.6666)

Just downstream from Site 37 in the main channel of the Musconetcong River is a fallen tree that is lying across the entirety of the river. There were vines and vegetation growing across the tree over the river, so more than likely this tree has been in this location for some time. It appeared as though the river was flowing just under the tree for the most part during the relatively low flow of the river, but this tree may cause issues during periods of heavier flow. The tree may cause a large volume of water to be diverted out of the main channel during periods of heavier flow and also has the potential to lead to streambank erosion by creating a headcut.

RECOMMENDED MEASURES: Princeton Hydro recommends removing this fallen tree from the main channel of the river in order to prevent any potential erosion issues that may occur either directly in the river bed or along the streambanks if the tree causes a large volume of water to be diverted to the sides. An alternative option to completely remove the tree involves cutting it into smaller pieces with a chainsaw which could serve a similar purpose. If the second option Is pursued, select pieces of the tree could be removed to allow for a more natural flow, which would still leave a few pieces of the tree in the river for natural fish and macroinvertebrate habitat.

JEFFERSON TOWNSHIP

SITE 36: EAST SHORE PARK (40.9579, -74.6194)

A small un-named stream passes through East Shore Park before traveling through a culvert under East Shore Road and into Lake Hopatcong. The entire left bank of the stream lacks a vegetative buffer; this is the side of the stream that is open to the park. The stream was flowing very low during the site visit but there was an excessive amount of sedimentation occurring just upstream of the culvert. The sediment accumulation was sufficient enough in the center of the stream to support the growth of phragmites (*Phragmites australis*). There was a 30-foot stretch along the lower right bank that was eroding and is the likely source of sedimentation; the sediment was loose here and lacked any vegetation or toe protection. Most of the remaining streambank on either side of the stream was stabilized with either vegetation or rocks.

RECOMMENDED MEASURES: Although the left bank was stabilized with rocks along the entire stream reach, we recommend re-grading and a vegetative buffer to help slow the rate of runoff from the park and to sequester additional nutrients. In addition to the buffer, the right bank should be stabilized where the erosion was occurring to prevent additional sedimentation. Because the erosion was mainly occurring along the bottom of the right bank, toe protection through the placement of rocks or stones may be sufficient. In addition to stabilizing the right bank, the upstream culvert could be evaluated for proper sizing; an undersized culvert could be causing some of the sedimentation issues by not allowing for natural passage of water during periods of heavier streamflow.

SITE 37: OUTLET OF LAKE WINONA (40.9888, -74.6062)

An un-named stream between the outlet of Lake Winona and Lake Hopatcong is only approximately 150 feet in length but the erosion is extensive and the most severe that was observed during field assessments. The water was flowing relatively slowly during the site visit. The streambanks on both sides varied between approximately 6 – 10 feet in height along the stretch and severe erosion was evident to the top of the bank in multiple locations. Extensive widening and bank scouring were observed on both the right and left bank. Large tree roots were exposed and multiple trees have the potential to become dislodged from the streambank; some trees had already been dislodged and fallen across the stream. It is important to note that there are residential properties located adjacent to each streambank with houses located relatively closely to each bank.

RECOMMENDED MEASURES: Although accessibility may be difficult in this location without access to through private properties, this location should be a priority due to the extent of the erosion. Because of the close proximity to residential properties, restoration measures may be limited here. At a minimum, we recommend protecting the streambanks from further erosion through the placement of riprap or gabion walls. If possible, the streambanks should be regraded and stabilized in place of riprap, but space is likely limited here. It is important to address this erosion to reduce the amount of TP and TSS entering Lake Hopatcong but also to protect the structures on the adjacent properties. This site may also be a candidate for grade control to slow down the streamflow; the streambed is approximately 6 feet lower than Lake Winona and this drop occurs abruptly as the water drains from Lake Winona.




SITE 38: UPSTREAM OF LORETTACONG DRIVE (40.9880, -74.6117)

An un-named stream that drains a small lake located in Willow Lake Day Camp travels south before flowing through a culvert and under Lorettacong Drive before entering Lake Hopatcong. The stream reach just upstream of the culvert is showing signs of minor streambank / streambed erosion and associated sedimentation. A large tree has fallen across the stream causing headcut erosion; the streambed is more than a foot deeper downstream of the fallen tree. This is causing sediment that is eroded from the streambed to be transported downstream and into Lake Hopatcong. An excessive amount of sedimentation is also accumulated just upstream of the fallen tree; this sediment is likely transported downstream during periods of heavy flow. Most of this sedimentation is a result of eroding streambanks upstream of the fallen tree.

RECOMMENDED MEASURES: The first course of action at this location should be the removal of the fallen tree from the streambed. This tree is directly leading to streambed erosion downstream and the removal will be the first step in addressing this erosion. Minor grade control may also be necessary at the location of the removed tree to address the headcut; there is already over a foot of elevation change between the upstream and downstream portions of the streambed. In addition to addressing the fallen tree and associated headcut, minor bank stabilization upstream should also be considered to address additional erosion and sedimentation that was observed. This can be done by re-grading the right bank at the location of erosion or through the placement of riprap; the length of streambank that is eroding is not very long and the placement of riprap may be sufficient. It should be noted that the removal of a fallen tree or tree limb from a waterway in New Jersey does not require a Division of Land Use Regulation Permit, though it is encouraged to contact the local municipality to see if a plan for debris removal has already been implemented. More information on this matter can be found at the DLUR website found at: https://www.nj.gov/dep/landuse/emergencies.html




BOROUGH OF HOPATCONG

SITE 39: DRAINAGE STREAM OFF OF HOLIDAY DRIVE (40.9266, -74.6602)

There is a small drainage stream located off of Holiday Drive that receives runoff from the surrounding neighborhood and discharges into Ingram Cove. Extensive erosion was observed along both banks during the site visit, including bank scour and severe undercutting; erosion along the right bank was more severe than the left bank. The sediment along the right bank was exposed and extremely raw, and excessive sedimentation was occurring along the streambed. The inlet of this drainage stream in Ingram Cove was also probed for sediment accumulation; sediment deposition was measured at approximately 2.5 feet compared to approximately only 0.5 feet a few feet away from where the stream enters the cove.

RECOMMENDED MEASURES: The right bank of this stream is an ideal candidate for bank stabilization to help address the severe erosion and sedimentation that is occurring. Due to the severe undercutting that is occurring along the right bank, the streambank should be regraded to a gentler slope to allow for floodplain connectivity. Once re-graded, the streambank toe can be further stabilized with riprap or another stabilization method that will allow the bank to absorb the impact of the stormwater without eroding.

SITE 40: CRESCENT COVE STREAM (SOUTH OF DUPONT AVENUE) (40.9411, -74.6622)

This site is just upstream of the Crescent Cove Beach Club parking lot and just south of Dupont Avenue. It appears as though the stream reach of this un-named tributary has been modified with rocks along the base of the streambanks to minimize erosion. Although there are currently rocks present for erosion prevention, there are a few spots along both the left and right streambank without any rocks that appear to be eroding, though not severe.

RECOMMENDED MEASURES: It would be beneficial to reassess the entirety of both streambanks and place more rocks along the base of the streambanks for erosion protection. It appears some of the rocks that were placed along the stream have become dislodged and have fallen into the stream bed; replacing the small rocks with a larger size may serve a better purpose here and further reduce erosion.

SITE 41: WETLAND NEAR CRESCENT COVE (40.9402, -74.6626)

There is a wetland just west of the Crescent Cove Beach Club parking lot that drains into a culvert that travels under Crescent Road and into Crescent Cove. There is a small drainage path that travels through the wetland before discharging into the culvert. The stream flattens out and loses structure just upstream of the culvert; excessive sedimentation was observed in this location during the site visit. The sedimentation gets excessively worse as the drainage path approaches the culvert, and the culvert has a thick layer of muck and organic material building up before the culvert opening.

RECOMMENDED MEASURES: This site could benefit from extending the wetland type plantings, such as skunk cabbage *(Symplocarpus foetidus)* and other native vegetation, closer to the culvert opening in order to better stabilize the soil and increase nutrient sequestration. In addition to the wetland plantings, the placement of some larger rocks or small boulders could benefit the area by diffusing the flow, allowing for increased contact time and reduced kinetic energy and erosion and the associated sedimentation.

SITE 42: JAYNES BROOK (NORTH OF KENTUCKY AVENUE) (40.9745, -74.6301)

Jaynes Brook is one of the major tributaries of Lake Hopatcong, and empties into the lake in Henderson Cove. This stream reach is located near the mouth of the stream, just north of Kentucky Avenue. The stream is located on private property and access would need to be granted for any restoration measures. The stream was flowing relatively slow during the site visit, but signs of minor erosion were evident. Specifically, undercutting and bank scour were observed along the left bank with sediment accumulating mainly along the right bank.

RECOMMENDED MEASURES: The majority of the erosion at this site is occurring along the bottom of the left bank and restoration measures should be focused on streambank toe protection. Lining the bottom of the streambank with rocks and stones will provide protection against the erosional forces currently affecting the left bank. Because the stream is located on private property and the extent of erosion is relatively small, it is likely not feasible or necessary to regrade the stream here.




SITE 43: DRAINAGE STREAM IN WITTEN PARK (40.9554, -74.6477)

There is a drainage stream located in Witten Park that receives runoff from the surrounding neighborhood through two outfall pipes before discharging into Byram Bay. Extensive erosion was observed along both banks during the site visit, including bank scouring and severe undercutting. Both streambanks were void of any vegetation along the entire reach, and the entire park was comprised of mostly loose dirt and gravel. Tree roots were visible along both banks down the entire stream reach, and there was sediment accumulating in multiple locations. Both outfall pipes are located a few feet higher in elevation than the stream, and the water travels down scattered rocks before entering the main channel. The bigger pipe located just above the mainstream had a small flow of water during the time of the site visit.

RECOMMENDED MEASURES: This site should be a priority for restoration measures due to the extent of erosion that is occurring, and the location in a public park with easy access from a main road. This site would be an ideal location for the implementation of a Regenerative Stormwater Conveyance System (RSC). An RSC is comprised of a series of riffles, pools, native vegetation and an underlying sand and woodchip media that is designed to treat, detain, and convey stormwater in an efficient manner. Not only would an RSC address the severe erosion that is currently occurring, but it would also treat the stormwater from the surrounding neighborhood, decreasing the TP and TSS concentrations through infiltration. RSC’s can be designed in multiple ways to fit the local ecosystem and has the potential to turn this park into an aesthetically pleasing location for the community.




CANDIDATES FOR SHORELINE RESTORATION

SITE 44: LAKE MUSCONETCONG (RIVER SAINT ROW/PORT MORRIS PARK) (40.9093, -74.6851)

The entire shoreline of Lake Musconetcong at River Saint Row / Port Morris Park lacks a vegetative buffer. In addition to the lack of a shoreline buffer, the shoreline in the eastern section of the park is showing signs of erosion. The erosion along the shoreline is primarily occurring along the lower portion of the shoreline, creating some undercutting and bank scour. The tree roots of a large tree located along the shoreline in this section are also exposed.

RECOMMENDED MEASURES: A vegetative shoreline buffer in this location would provide multiple benefits, including decreased shoreline erosion and increased assimilation of nutrients from stormwater runoff. In addition to a shoreline buffer, this site would also benefit from the placement of rocks or stones along the lower bank of the shoreline to prevent further undercut erosion that was evident.

SITE 45: LAKE HOPATCONG (SOUTH OF ARTHUR J. ONDISH MEMORIAL BEACH) (40.9277, -74.6416)

This site was one of the few residential shorelines in Lake Hopatcong that did not have a bulkhead. It was difficult to tell from the boat what was causing the erosion at this location, but severe undercutting was evident on a section of shoreline that was approximately 6 feet tall. Tree roots from 2 large trees located near the shoreline were exposed at the top of the shoreline, and the erosion went back a few feet into the shoreline.

RECOMMENDED MEASURES: The extent of erosion in this localized section of shoreline was severe and should be addressed. The section of shoreline that has been undercut beneath the trees should be filled and further protected against erosion with the placement of riprap or another shoreline protection method.

SITE 46: LAKE HOPATCONG (INGRAM COVE) (40.9265, -74.6603)

This site is the shoreline of Lake Hopatcong in Ingram Cove directly adjacent to the drainage stream referenced in Site 40. The slope of the property directly behind the shoreline is relatively steep, and the shoreline lacks vegetation. The erosion along this shoreline is minimal, but the lack of any type of shoreline buffer should be addressed. At a minimum, a shoreline buffer of 20 to 50 feet wide should be installed along the sections of the shoreline not used for launching boats.

RECOMMENDED MEASURES: A vegetative shoreline buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff.

SITE 47: LAKE HOPATCONG SHORELINE (BEEBE MARINA) (40.9623, -74.6222)

This stretch of shoreline runs parallel to Brady Road, and the lake is only separated from the road by a few feet of mowed grass. The shoreline here lacks any type of vegetative buffer that would act as a nutrient filter for any stormwater that drains from Brady Road.

RECOMMENDED MEASURES: A vegetative shoreline buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff. Brady Road is a relatively busy road located close to the shoreline here, and a shoreline buffer would help filter out any pollutants that would be carried into the lake from stormwater runoff.

SITE 48: LAKE HOPATCONG (ALONG SIERRA ROAD) (40.9626, -74.6133)

This stretch of shoreline runs parallel to Sierra Road, and the lake is only separated from the road by a small gravel parking lot. The shoreline here lacks any type of vegetative buffer that would act as a nutrient filter for any stormwater that drains from Sierra Road. The parking lot between Sierra Road and the lake slopes down towards the lake, likely increasing the rate of stormwater flow from Sierra Road.

RECOMMENDED MEASURES: A vegetative shoreline buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff. A shoreline buffer in this location would help filter out any pollutants that would be carried into the lake from stormwater runoff. In addition to a shoreline buffer, it would be beneficial to change the loose gravel parking lot to a grass area to prevent any loose gravel from entering the lake.

SITE 49: LAKE HOPATCONG (ALONG CALLAGHAN ROAD) (40.9614, -74.6142)

This stretch of shoreline runs parallel to Callaghan Road, but the lake is separated from the road by a boat shop and marina. The shoreline of the boat shop here lacks any type of vegetative buffer that would act as a nutrient filter for any stormwater that drains from the road or parking lot. There is a bulkhead in place to prevent erosion, but the property consists of mowed grass down to the shoreline.

RECOMMENDED MEASURES: A vegetative shoreline buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff. A shoreline buffer in this location would help filter out any pollutants that would be carried into the lake from stormwater runoff that comes from the boat shop property.

SITE 50: LAKE HOPATCONG (ALONG YACHT CLUB DRIVE) (40.9698, -74.6090)

This stretch of shoreline is located along Yacht Club Drive, but the lake is separated from the road by the Yacht Club. The shoreline of the Yacht Club here lacks any type of vegetative buffer that would act as a nutrient filter for any stormwater that drains from the road or parking lot. There is a bulkhead in place to prevent erosion, but the property consists of mowed grass down to the shoreline.

RECOMMENDED MEASURES: A vegetative shoreline buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff. A shoreline buffer in this location would help filter out any pollutants that would be carried into the lake from stormwater runoff that comes from the Yacht Club property.

SITE 51: LAKE HOPATCONG (NEAR MASON STREET) (40.9815, -74.6164)

This stretch of shoreline is located along the parking lot of a restaurant/bar near Mason Street. The shoreline of the restaurant here lacks any type of vegetative buffer that would act as a nutrient filter for any stormwater that drains from the road or parking lot. In addition, the parking lot here appeared to be composed of loose material, either uncapped asphalt or dirt that can easily get carried into the lake with stormwater.

RECOMMENDED MEASURES: A vegetative shoreline buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff. A shoreline buffer in this location would help filter out any pollutants that would be carried into the lake from stormwater runoff that comes from the restaurant property. In addition to the shoreline buffer, it is recommended that the parking lot be cleaned up or paved to prevent the loose material from entering the lake. Porous pavement should also be considered for the parking lot.

SITE 52: HOPATCONG (GREAT COVE) (40.9427, -74.6223)

This stretch of shoreline is located along the parking lot and downgradient of a new building being built in Great Cove. The property here is steep and mostly pavement, and the shoreline lacks any type of vegetative buffer that would act as a nutrient filter for any stormwater that drains from the road or parking lot.

RECOMMENDED MEASURES: A vegetative shoreline buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff. A shoreline buffer in this location would help filter out any pollutants that would be carried into the lake from stormwater runoff that comes from the property.

ON-SITE WASTEWATER TREATMENT SYSTEMS AND SEWERING OF THE WATERSHED

The sections of the Township of Roxbury and the Borough of Mt. Arlington within the Lake Hopatcong watershed are sewered. In contrast 40% of the homes within the Borough of Hopatcong are sewered, while none of the homes are sewered in the Township of Jefferson. Based on the original Restoration Plan, septic systems accounted for a little over half of Lake Hopatcong's annual TP load (52%). However, since then 40% of the homes within the Borough of Hopatcong have been sewered. It is also expected that another approximately 50 homes will be sewered over the next few years in the Borough of Hopatcong. In addition, the Hopatcong State Park's restroom facilities will also be sewered sometime in the immediately future. While the sewering of the State Park will not direct reduce the phosphorus load entering Lake Hopatcong, it will directly benefit Lake Musconetcong. In contrast, all homes within the Township of Jefferson remain on septic systems at this time.

Given the large-scale cyanobacteria algal blooms experienced in Lake Hopatcong over the 2019 growing season, there has been serious consideration given to completely sewering the Lake Hopatcong watershed. Thus, the Township of Jefferson was recently awarded a grant from the NJ Highlands Council to conduct a Wastewater Feasibility Study for the north and northeast portion of the Lake Hopatcong watershed.

A very preliminary estimate has determined if the Township of Jefferson and the rest of the Borough of Hopatcong were sewered, the lake would be between 60 and 100% in compliance with its TMDL for TP. Note, this does not include the TP reductions associated with the stormwater, streambank and shoreline projects identified in this WIP. Thus, discussions have been initiated in the sewering the rest of the watershed and the feasibility study will be the first step in this process. However, it should be clarified that while sewering would substantially reduce the load of certain pollutants, such as phosphorus, fecal coliform, and *E. coli*, it would not reduce others such as total suspended solids.

Finally, a list of supplemental project sites can be found in Appendix VIII; these were project sites recommended by the Commission after all field assessments had taken place. It is recommended that the WIP be re-assessed and updated in five years (sometime around 2024 / 2025) to evaluate the progress being made. For example, in 2021, a study will be conducted in the monthly and seasonal quantification of the Lake Hopatcong's internal phosphorus load, to determine if addressing this source of phosphorus can be a cost-effective approach in addressing HABs as the watershed projects (stormwater and sewering) are being implemented.

Table 6: Low and high pollutant removal estimates for proposed streambank and shoreline projects.

Proposed Projects in Upper Muscontecong River WIP	Pollutant Removal (lbs)			
Proposed Streambank Projects	low P	high P	low TSS	high TSS
Memorial Park Bridge Crossing	3	54	71,700	600,800
Memorial Park near North Glen Avenue	1.5	27	35,850	300,400
Upstream of Edith M. Decker Elementary School	1.5	27	35,850	300,400
Upstream of Mount Arlington Boulevard	3	54	71,700	600,800
Intermittent Stream South of King Road	5	90	59,750	675,900
East Shore Park	1.8	32.4	43,020	360,480
Outlet of Lake Winona	18	324	430,200	3604,800
Upstream of Lorettacong Drive	3	54	71,700	600,800
Musconetcong River - just downstream of Lake Hopatcong Dam	3	54	71,700	600,800
Musconetcong River - side channel	3	54	71,700	600,800
Musconetcong River - main channel	6	108	143,400	1,201,600
Drainage Stream off Holiday Drive	3	54	71,700	600,800
Crescent Cove Stream - South of Dupont Avenue	1.8	32.4	43,020	360,480
Wetland Area near Crescent Cove	5	90	59,750	675,900
Jaynes Brook - north of Kentucky Avenue (low priority)	3	54	71,700	600,800
Drainage Stream in Witten Park (high priority)	9	162	215,100	1,802,400
Proposed Shoreline Projects				
Lake Musconetcong shoreline - River Saint Row / Port Morris Park	12	108	286,800	1,201,600
Lake Hopatcong shoreline - south of Arthur J. Ondish Memorial Beach	9	81	215,100	901,200
Lake Hopatcong shoreline - Ingram Cove	6	54	143,400	600,800
Lake Hopatcong shoreline - Beebe Marina	3	27	71,700	300,400
Lake Hopatcong shoreline - along Sierra Road	21	189	501,900	2,102,800
Lake Hopatcong shoreline - along Callaghan Road	24	216	573,600	2,403,200
Lake Hopatcong shoreline - along Yacht Club Drive	6	54	143,400	600,800
Lake Hopatcong shoreline - near Mason Street	3	27	71,700	300,400
Lake Hopatcong shoreline - Great Cove	9	81	215,100	901,200

Table 7: Low and high cost estimates for proposed streambank and shoreline projects.

Proposed Projects in Upper Musconetcong River WIP	Price Estimate		Ownership
Proposed Streambank Projects	**Low**	**High**	
Memorial Park Bridge Crossing	$2,100.00	$19,200.00	Municipal
Memorial Park near North Glen Avenue	$1,050.00	$9,600.00	Municipal
Upstream of Edith M. Decker Elementary School	$1,050.00	$9,600.00	Public
Upstream of Mount Arlington Boulevard	$2,100.00	$19,200.00	
Intermittent Stream South of King Road	$2,100.00	$19,200.00	Public
East Shore Park	$1,260.00	$11,520.00	Municipal
Outlet of Lake Winona	$12,600.00	$115,200.00	Public
Upstream of Lorettacong Drive	$2,100.00	$19,200.00	
Musconetcong River - just downstream of Lake Hopatcong Dam	$2,100.00	$19,200.00	Public
Musconetcong River - side channel	$2,100.00	$19,200.00	Public
Musconetcong River - main channel	$4,200.00	$38,400.00	Public
Drainage Stream off Holiday Drive	$2,100.00	$19,200.00	Private
Crescent Cove Stream - South of Dupont Avenue	$1,260.00	$11,520.00	
Wetland Area near Crescent Cove	$2,100.00	$19,200.00	Public
Jaynes Brook - north of Kentucky Avenue (low priority)	$2,100.00	$19,200.00	Private
Drainage Stream in Witten Park (high priority)	$6,300.00	$57,600.00	Municipal
Proposed Shoreline Projects			
Lake Musconetcong shoreline - River Saint Row / Port Morris Park	$1,600.00	$6,000.00	Municipal
Lake Hopatcong shoreline - South of Arthur J. Ondish Memorial Beach	$1,200.00	$4,500.00	Private
Lake Hopatcong shoreline - Ingram Cove	$800.00	$3,000.00	Private
Lake Hopatcong shoreline - Beebe Marina	$400.00	$1,500.00	Private
Lake Hopatcong shoreline - Along Sierra Road	$2,800.00	$10,500.00	Private
Lake Hopatcong shoreline - Along Callaghan Road	$3,200.00	$12,000.00	Private
Lake Hopatcong shoreline - Along Yacht Club Drive	$800.00	$3,000.00	Private
Lake Hopatcong shoreline - Near Mason Street	$400.00	$1,500.00	Private
Lake Hopatcong shoreline - Great Cove	$1,200.00	$4,500.00	Private

TECHNICAL AND FINANCIAL ASSISTANCE

Implementation of plan elements and project concepts is dependent on securing the funding and technical assistance to support those goals. As a crucial element of a WIP, this section addresses the fourth of the EPA nine elements.

Costs for the design, installation, and maintenance of each proposed stormwater structure are provided in this report and its associated appendices. Project specific costs are provided in Tables 5 and 6 in the previous section. The total cost of all proposed projects is estimated to cost in the range of $3.3 – 4.7 million.

FINANCIAL ASSISTANCE

From a practical perspective, one of the major limitatioins on successfully managing NPS pollution, meeting water quality standards and designated uses, and controlling stormwater is funding. The expense of these items is three-pronged: first, the management of NPS pollution requires action on a broad front because the loading by definition is diffuse and effective management requires the implementation of many projects; second, while the management measures are often simple from a conceptual perspective, the permitting, design, materials, labor, and monitoring, not to mention land acquisition and easements, all incur real and significant costs. These costs are further amplified because implementation is typically sponsored at a local level, be it municipality, landowner, or NGO, where ready access to capital may be difficult. Finally, funding and/or the infrastructure needs to be in place for the long-term management and maintenance of any BMP or green-implementation project.

Despite the costs of implementing individual projects or enacting a watershed management plan such as this document, there are a wide array of funding resources available to help offset the costs. Grants are typically the primary source of these funds, but other streams are available including the issuance of bonds, typical governmental budgeting and appropriations, and low-interest loans. These funds help defer the costs of such projects and typically carry a number of conditions to both maximize the funding and ensure the delivery of a high-quality product often requiring matching funds, in-kind contributions, and strict reporting and monitoring requirements. The availability of these funds is predicated on meeting the goals of the grantor which can range from simple environmental restoration and conservation, more focused efforts to meet the objectives of a program, regulation, or law such as the Clean Water Act, or targeted efforts to meet the needs of a specific requirement such as satisfying a TMDL. Often, these grants operate on all three levels. In addition, many of the programs provide not only financial assistance, but technical assistance. The following sections will explore some of the available funding opportunities.

SECTION 319 NON-POINT SOURCE MANAGEMENT PROGRAM

One of the best known, widely utilized, and powerful programs developed to manage NPS pollution throughout the nation is the Section 319 Nonpoint Source Management Program. This program was established in 1987 under amendments to the Clean Water Act and created a funding mechanism in which monies were allocated to the States, territories, and tribal authorities that award and administer grants for State and local level projects. According to the EPA website, billions of dollars have been allocated over the life cycle of the program, and from 2000 through 2017 (the last posted update) at least $150 million has been made available annually. While this funding covers an array of activities, the 319 grants are recognized by the EPA as particularly important in implementing TMDLs.

There are a number of requirements under federal statute and governing technical regulations. Thematically, the grants are to cover projects that provide for the management of nonpoint source pollution. There is a continued focus on watershed Implementation plans (WIP) that meet the EPA Nine Elements. As this project is meant to address loading issues for the TMDL, this WIP adheres to these requirements. There are a number of reporting and tracking requirements to ensure and document the success of the projects.
Implementation of Non-Structural Best Management Practices will also be considered but is of a lower priority. Those elements will include:

- **Monitoring, Assessment, and Trackdown Projects** – These elements are important in describing the focal points for implementation projects using a targeted approach.
- **Watershed or Statewide Education and Outreach Projects** – These types of projects are focused on increasing awareness, educating the public about the needs for these types of actions, and developing the base support and political will to implement pollutant control strategies. Some of the topics to be addressed would include pet waste, lawncare, and runoff management.
- **Land Use Management Projects** – These types of projects would support municipal or governmental management efforts and would include items such as land use evaluations, modification of regulatory programs to support green infrastructure and low impact development (LID), educating public officials, incorporating integrated pest management (IPM) and nutrient management, and other similar activities.

These priorities evolve over time and are subject to change in response to emerging issues or completion of historical objectives. The grant process is competitive and therefore those grant submissions that best address the priorities, demonstrate project understanding, and have a sound technical approach have the best chance of successful award. Fund matches are no longer required but are encouraged and help to expand the scope of a work plan. One of the benefits of preparing a WIP that adheres to the EPA Nine Elements is that the management measures and implementation projects identified within the document often conform to priority action items thus increasing the likelihood of successful award. 319 Grants are likely to play a major role in meeting the funding requirements for this WIP.

It should be noted that the Lake Hopatcong Commission was recently awarded a 319-grant in July 2020 by NJDEP to implement some additional watershed projects as well as quantify the monthly and seasonal internal phosphorus load at Lake Hopatcong.

OTHER FEDERAL FUNDING SOURCES

In addition to the 319 Grants, the federal government has enacted a host of additional programs and grants designed to address broad environmental protection goals. The origin, statutory authority, responsible agency, and objectives of these programs are variable, as are year-to-year to funding which can be Congressional appropriation, environmental damages settlements, excise taxes, or other sources. A summary table is provided below that identifies the responsible agency, the name of the grant or program, and URLs to the program web page (Table 8). A brief summary of the highlights is discussed below.

The US EPA maintains a broad portfolio of programs and responsibilities, as well as providing technical guidance to the States and other actors. As such, EPA programs run the gamut from community health initiatives to straight environmental conservation efforts and many programs in between. As such, some programs deal with meeting water quality or air quality criteria, targeting specific geographic locations or sensitive environmental features, outreach and education, and habitat improvements. As with all of the grants, while each program and grant have specific requirements to meet the stated objectives, environmental restoration, protection, and NPS pollution management broadly overlap and one project can fulfill many different goals. For instance, the creation of a stormwater wetland may be constructed to meet water quality goals but may also be viewed as habitat creation. This type of approach allows various funding avenues to be explored.

The United States Fish and Wildlife Service (USFWS) also is a major federal grantor. Unlike EPA, USFWS programs tend to have a tighter focus on habitat-oriented projects. These can include many different habitat types such as wetlands and uplands and may foster habitat improvements for various species like migratory fishes, shorebirds, or imperiled species. The United States Forest Service also has a more singular focus and implemented primarily at a landscape level. Another potential source of funding is through the National Fish and Wildlife Foundation (NFWF). The Lake Hopatcong Commission and the Lake Hopatcong Foundation are planning to submit an application to NFWF in 2021 for funding of several of the stream / river projects identified in the WIP.

In addition to Federal Sources, there may be other sources of funding. For example, in 2020, the Lake Hopatcong Commission received a $0.5 million dollar grant from NJDEP to "Prevent, Mitigate and/or Control HABs" at Lake Hopatcong. A wide variety of both in-lake and watershed-based projects have already been implemented with the rest being completed by the end of 2021.

The NJ Highlands Council may be a potential source of funding for the scientific investigations and/or engineering design work that is necessary for the implementation of the projects identified in the WIP. Funding through the Council can be used for such studies but cannot be used for implementation. In addition, applications must be submitted through the local towns and municipalities. It was previously mentioned that the Township of Jefferson was awarded a grant for a wastewater feasibility study. Additionally, the Borough of Mount Arlington also recently received a grant to conduct a Beach / Park Restoration Plan for their municipal beach. This grant will include both the beach and Memorial Park, which includes several of the project sites identified in the WIP.

There are other potential sources of grant funding that can be pursued by the Lake Hopatcong Foundation since they are a non-profit 501(c)(3) organization. Thus, the highly positive working relationship among the Commission, the Foundation, the towns and the Counites can utilized in obtaining sources of funding from a variety of sources for the common goal of implementing the projects identified in the WIP.

Finally, the Lake Hopatcong Commission is looking into the possibility of aiding the municipalities in obtaining low-interest loans from “green banks” to fund some of the projects identified in the WIP.

Table 8: Federal Grant Services

Entity	Program	Link
EPA	Urban Waters Small Grants	https://www.epa.gov/urbanwaters/urban-waters-small-grants
	Healthy Communities Grant Program	https://www3.epa.gov/region1/eco/uep/hcgp.html
	Five Star Restoration Grant Program	https://www.epa.gov/urbanwaterspartners/five-star-and-urban-waters-restoration-grant-program-2018
USFWS	North American Wetlands Conservation Act	https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php
NRCS	Conservation Stewardship Program	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/
	Emergency Watershed Protection Program	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/

TECHNICAL ASSISTANCE

Much as funding is necessary to implement management programs and projects, technical assistance is required to properly design and oversee implementation of management measures be it structural or cultural BMPs, outreach, training, or a related course of action. The following section will discuss project roles, key players, and sources of technical information and assistance.

- **Project Sponsor –** The project sponsor serves as the hub of project implementation. For many of the projects identified, the Commission will serve as the project sponsor, although non-profits (Foundation) and even landowners may also serve this role. They are responsible for all project activities, usually starting with identifying the need for a project in response to a regulatory requirement, identified problem, emergency need, or general policy. They subsequently interface with the landowner or manager and identify stakeholders to move the project forward. This is followed by securing funding or submitting grant applications. If awarded they hire consultants, contractors, and vendors, interface with regulators, oversee the financials, and ensure all steps are followed. Experience is of great benefit in navigating the complexity of the process.

- **Landowner/Manager** – Landowners or managers have a vested interest in project success, and grant permission to proceed. In some cases, they may serve as project sponsor, but more typically either approach the project sponsor to correct a problem or are approached by the project sponsor after having identified their holding to have some significance.
- **Stakeholders** – Stakeholders consist of many people, but a large component would include the community that are directly or indirectly affected by the project, but regulators, public officials, and others may all have real interests. Identifying stakeholders early in the project and soliciting their input is very important. In watershed projects, there is a strong link between project success and those located downstream and therefore stand to gain the most by its success. While technical contributions may be limited, this is not always the case, and stakeholders and residents often have the best understanding of system deficiencies, a resource that needs to be utilized.
- **Grantor** – The grantor at the most basic level is responsible for financial assistance and project awards. As noted above, financial assistance is usually not offered in a vacuum and grant awards are often associated with programs that offer technical assistance. In addition, the grantor usually imposes strict reporting requirements as a condition of the grant award that would include technical reporting, design, and financial management.
- **Regulators** – A major function of regulatory agencies is to ensure that projects, whether implementation projects, planning, or other, meet the technical regulations. In particular, implementation projects are often subject to various land use and other permitting requirements although exceptions and waivers may be offered depending on the scope and objective of the project. Besides overseeing the regulatory matters, regulators may function as the grantors or project sponsors. They typically act as contributing partners in these types of projects.
- **Professionals and Consultants** – This class includes ecologists, hydrologists, engineers, planners, geologists, and related professions that are typically hired by the project sponsor at the onset of the project. They serve multiple roles, but core functions may include monitoring, project design, preparation of permit applications, construction oversight, and reporting and interface with all other project roles. Coordinating the varied project components is a fundamental responsibility of consultants. In particular, consultants offer their project experience to navigate the various of demands of the project and thus must demonstrate technical, regulatory, outreach, and project management knowledge and the ability to identify sources of assistance.
- **Contractors and Vendors** – Contractors and vendors both offer deep technical knowledge of project implementation and necessary materials. The best contractors are also well-versed in the regulations to ensure project success.

EDUCATION AND OUTREACH

This section reviews the information and education (I/E) aspect of the WMP. Specifically, it deals with identifying and building stakeholder involvement, developing educational and outreach programs and materials, and encouraging the adoption of measures and practices to protect the watershed and water quality. This section corresponds to the fifth of the US EPA nine elements.

OUTREACH DEVELOPMENT

The protection and preservation of water quality and the ability to address the TMDL in the Upper Musconetcong River watershed is contingent upon the education of the target audience including public officials, residents, landowners, farmers, and business in the watershed. Goals of I/E programs should include:

- Improving communication, training, and coordination among local, county, and State governments and environmental and stakeholder organizations. Improve public education and raise awareness to promote stewardship of watershed resources, improve water quality, and reduce NPS pollutants, particularly TP.
- Celebrate successes to recognize continuing and noteworthy efforts, encourage participation, and continue the implementation of the WIP.
- Focusing on development of ordinances that impact water quality and impacts to the watershed, including development

One of the best and most comprehensive sources for the development of outreach programs is the US EPA's *Getting in Step: A Guide for Conducting Watershed Outreach Programs,* 3rd ed.:

https://cfpub.epa.gov/npstbx/files/getnstepguide.pdf.

This document discusses outreach program development and implementation. The EPA also maintains the *Nonpoint Source Outreach Digital Toolbox* (https://cfpub.epa.gov/npstbx/index.html), a clearinghouse for various educational materials including surveys, evaluations, and media campaigns.
Some of the key outreach methods include:

- Demonstration projects
- Watershed tours and hikes
- Workshops and staff training seminars
- Volunteer opportunities for cleanups, planting, and monitoring
- Planning efforts and local ordinance

The groups identified in the financial and technical assistance section should be consulted. Other groups or sources that may provide appropriate materials are:

- The Groundwater Foundation: https://www.groundwater.org/
- The River Network: https://www.rivernetwork.org/
- Green Values Stormwater Toolbox: http://greenvalues.cnt.org/
- Center for Invasive Species and Ecosystem Health: https://www.invasive.org/

Continuing to identify stakeholders is also an important component of this project. Specifically, efforts need to be made to engage not only the community at large, but a targeted pro-active effort to include property owners or managers that contain or are adjacent to waterways, ponds, wetlands, and floodplains. These are the areas most susceptible to degradation of aquatic ecosystems, but also in the best position to implement projects that can mitigate these problems.

PUBLIC PARTICIPATION THROUGH STREAMBANK MONITORING

As part of the development of this WIP, volunteers from the Commission and the Foundation will have the opportunity to be directly involved in monitoring for streambank erosion throughout the watershed. Additionally, the Lake Hopatcong Foundation has been working with the Jefferson Township High School's Academy for Environmental Science in the development of their volunteer monitoring programs, who are very interested in learning how to conduct streambank assessments.

Although Princeton Hydro already conducted the streambank and shoreline monitoring in preparation of this document, volunteers will have the opportunity to be trained in streambank monitoring this fall. While Princeton Hydro field staff were collecting the necessary data for the development of this document, they were searching for stream locations in public areas that would have enough space to accommodate additional volunteers. Conducting the stream monitoring training with volunteers during the fall will allow for easier access to sites as the vegetation starts to die out. This training session will provide a set of local stakeholders with the tools and the training to conduct such Visual Assessment at other locations throughout the Upper Musconetcong River watershed in the future. As stated in a previous section, the volunteers will be trained using the New Jersey Department of Environmental Protection Habitat Assessment Scorecards developed as part of the NJDEP Volunteer Monitoring Program. An example of this scorecard can be found in Appendix VI.

In addition to the streambank monitoring, Princeton Hydro will conduct two public presentations, hosted by the Commission and/or Foundation, as well as producing educational material for general distribution and posting on stakeholder websites. The public presentations will focus on what the landowner can do to contribute toward reducing the NPS pollutant loading to the lakes, with an emphasis on phosphorus. The first presentation will focus more on behavioral changes in general land use/ homeowner practices that will aid in protecting the lakes, such as septic management, use of non-phosphorus fertilizers, expansion of buffers and simple land / soil stabilization techniques. The second presentation will focus more on projects that can be actively implemented to contribute toward reducing NPS pollution such as rain gardens, creating shoreline / streambank buffers and using rain barrels. Educational material will be developed for each presentation that can be distributed to the public and make available on stakeholder websites.

In summary, the public information and aspect component of this WIP includes:

1. Training local stakeholder volunteers on how to conduct stream / shoreline visual assessments.

2. Two public presentations with an emphasis on stormwater management.

3. The distribution of educational material with information related to each of the presentations.

Finally, it should be noted that since the large-scale HAB event that impacted Lake Hopatcong over the summer of 2019, there has been an extremely productive working relationship among the Commission, the Foundation, the municipalities and the Counties in the watershed. In addition to representatives attending the Commission's monthly public meetings (either in person or virtually), there is a monthly meeting of the mayors of the four towns surrounding Lake Hopatcong to discuss projects and provide local updates.

IMPLEMENTATION SCHEDULE

As required by the sixth US EPA element, this document contains an implementation schedule. This is intended to provide a timeline such that measurable actions are implemented in a reasonably expeditious way.

From a practical perspective, one of the major limiters on successfully managing NPS pollution, meeting water quality standards and designated uses, and simply implementing a comprehensive watershed management plan is funding. Without question, project implementation is not an inexpensive proposition, especially where watershed-wide implementation is necessary to meet pollution reduction goals and align with the TMDL as in the Upper Musconetcong River watershed. As such, there will likely be a heavy reliance on grants and other financial vehicles. In turn, securing such funding is difficult for a number of reasons. Assistance programs are subject to changing appropriations from year to year and may be entirely defunded. Grant programs often have relatively low levels of funding relative to demand, and as a consequence the process tends to be quite competitive. Further, funding and management priorities change over time.

It should be noted that the projects outlined in each of the following timeframes are suggestions to be used as guidance while applying for grants and planning implementation projects. Due to the high number of implementation projects recommended in this report, it is not feasible to implement all of the projects. Thus, each of the projects outlined in the following timeframes were picked based on both feasibility of implantation as well as the overall impact towards TMDL compliance, and act as examples that should be considered over the following 10+ years throughout the watershed.

YEARS 1 AND 2

In the short term, approximately Years 1 and 2, the focus should be on addressing the highest priority projects that have a strong likelihood of being approved and implemented, **such as the installation of Biochar in pre-existing structures and location within the lake known to experience elevated nutrient loading, evaluating HAB related management techniques, and shoreline plantings and modifications**. These projects represent locations throughout the watershed. The focus, especially in the early going, is to research grant availability, prepare grant submissions, and initiate the projects when funding becomes available. Realistically, all grant applications will not be awarded and therefore it is recommended that multiple applications are submitted. If a grant application is denied a different source of funding should be investigated or the project should be resubmitted in the next funding cycle. When possible and capacity allows, it is recommended that multiple projects be worked on concurrently. The life cycle of each project will naturally vary, but the cradle to grave duration of each individual project is likely to span two to three years from grant award to post-construction monitoring, even if the construction phase is brief.

In addition to the highest priority project sites with a strong likelihood of being approved and implemented, some of the lower priority items should also be initiated at this time. This would include measures that include low-cost solutions like community outreach efforts and promotion of projects, procedures, and BMPs that should be adopted by homeowners and land managers. These are the types of projects that have lower technical requirements, but also keep the community engaged and harness their efforts to meet pollution abatement goals. The short-term implementation schedule is provided below.

Table 9: Implementation Schedule – Years 1 to 2		
Site ID	**Location**	**BMP**
7	Hopatcong State Park	Revegetate rain garden
11	Mt. Arlington Blvd	Detention basin retrofit
12	Mt. Arlington Blvd	Retention basin retrofit
13	Memorial Park/Beach	Biochar in existing BMP Vegetated shoreline buffer
27	East Shore Park/Road	Biochar in existing BMP
29	Memorial Park near Glenn Avenue	Streambank restoration/vegetation
33	Musconetcong River	Streambank restoration
46	Lake Hopatcong Shoreline (Ingram Cove)	Shoreline buffer
48	Lake Hopatcong Shoreline (Sierra Road)	Shoreline buffer

It should also be noted that the Commission was awarded a 319-grant in July of 2020, which will be initiated in 2021. It will include more stormwater projects with Biochar, the installation of Floating Wetland Islands and an assessment of the lake's monthly and seasonal internal phosphorus load to determine if it would be a cost effective strategy to address this source of phosphorus while the watershed projects are underway.

YEARS 3 TO 5

This phase of project implementation is primarily focused on the development of projects that have been identified as being of highest priority due to their potential nutrient reductions. These areas have been identified as the most problematic sources of TP and other NPS pollutants by virtue of load or concentration, size, and development characteristics. They are also associated with measured impairments in water quality in both lakes. The focus on implementing these types of projects should provide the greatest benefit in meeting reduction goals.

There is an expectation that project implementation rates should accelerate in this phase of the project, in part building off the project experience gained in the first phase. As such, much of the focus will be on initiating the remaining highest priority sites. At the same time, many of the projects initiated in years 1 and 2 are anticipated to be nearing completion or have been completed or constructed but have continuing monitoring and reporting requirements.

Realistically, some of the initial projects forwarded, those with conceptual designs, likely have not been started and these will continue to hold priority in this phase of the project. As always, funding will be a major control in the execution of these projects. The medium-term implementation schedule is provided below.

It is also recommended that the WIP be updated after the fifth year to re-assess the status of in-lake conditions and determine if additional projects should be added and/or if new nutrient management technologies should be considered.

Table 10: Implementation Schedule – Years 3 to 5

Site ID	Location	BMP
2	West Side Methodist Church	Bioretention system (2) Cistern Aqua-Guardian
4	Bell Avenue	Three chambered baffle box Vegetates swales
5	QuickChek (40 Lakeside Blvd)	Retrofit detention basin
6	Vale Way and Cove Road	Three chambered baffle box tree box (2)
9	Auriemma Court	Retrofit detention basin
15	Edith M Decker School	Bioretention system Aqua-Guardian (2)
16	Howard Blvd	Three chambered baffle box Aqua-Guardian (2)
18	Alabama Ave and New Jersey Ave	Three chambered baffle box
20	Brady Road	Three chambered baffle box
22	Quarry Stream	Under review
26	Lakeside Fields Parking Lot	Three chambered baffle box
28	Memorial Park Bridge Crossing	Stream restoration
31	Upstream of Mt. Arlington Blvd	Stream restoration
36	East Shore Park	Shoreline buffer
37	Outlet of Lake Winona	Stream restoration
39	Drainage stream off of Holiday Drive	Stream restoration
41	Wetland area near Crescent Cove	Wetland restoration
44	River Saint Row / Port Morris Park	Shoreline buffer

YEARS 6 TO 10

This phase is focused on the implementation of the longer-term projects and some of the lower priority projects. These projects may include areas owned by private entities or more complex projects from a logistical and stakeholder standpoint. Projects that have less of a direct effect on TMDL compliance may also be implemented in this phase. It is also expected that some of the longer-term projects that have been initiated in the previous 6 years will still be ongoing and/or beginning the implementation phase.

Again, after the tenth year, the WIP should be re-assessed.

Table 11: Implementation Schedule – Years 6 to 10		
Site ID	**Location**	**BMP**
1	St. Jude Parish	Bioretention system Planter boxes
3	Defiance Engine #3	Aqua-Guardians (3)
8	Verizon Building	Bioretention system
10	Ridgeview Lane	Tree box (6) Retrofit detention basin (2)
14	Altenbrand Avenue and Windermere Avenue	Aqua-Guardian tree box
17	Kentucky Avenue	Aqua-Guardian (2)
19	New Jersey Avenue	Aqua-Guardian
21	Oakwood Road and Shore Road	Aqua-Guardian
23	Lorettacong Dr and Route 181	Tree box (2)
24	Lorettacong Dr and Lake Winona Stream Crossing	Aqua-guardian
25	Alps Lane	Three chambered baffle box
30	Upstream of Edith Decker School	Stream restoration
32	Intermittent Stream (King Road)	Stream restoration
34	Musconetcong River Side Channel	Stream restoration
38	Upstream of Lorettacong Dr	Stream restoration
40	Crescent Cove Stream	Stream restoration
42	Jaynes Brook	Stream restoration
45	Lake Hopatcong Shoreline (South of Memorial Beach)	Shoreline restoration
47	Lake Hopatcong Shoreline (South of Beebee Marina)	Shoreline restoration
49	Lake Hopatcong Shoreline (Along Callaghan Road)	Shoreline buffer
50	Lake Hopatcong Shoreline (Along Yacht Club Drive)	Shoreline buffer
51	Lake Hopatcong Shoreline (Near Mason Street)	Shoreline buffer
52	Lake Hopatcong (Great Cove)	Shoreline Buffer

POST YEAR-10

This phase is focused on much longer-term projects that would likely require considerable coordination between property owners and regulatory authorities.

Table 12: Implementation Schedule – Post Year 10		
Site ID	**Location**	**BMP**
-	Lake Hopatcong Watershed (Jefferson and 60% of Hopatcong)	Sewering of the watershed

INTERIM MEASURABLE MILESTONES

In order to track implementation progress and assess how implementation compares with the schedule a set of interim milestones needs to be developed. These milestones are distinct from water quality monitoring, load reductions, and performance metrics. This corresponds to seventh of the nine US EPA plan elements.

MILESTONES

Milestone metrics are meant to function as tracking tools or program indicators. In most cases, individual projects will be subject to a number of reporting requirements often involving various monitoring programs. It is recommended that TP load reductions be used as the main assessment of how the various watershed measures that are implemented work towards achieving compliance with the TMDL. An empirical approach can be taken by monitoring TP concentrations at site locations pre and post implementation of a BMP or other restoration measure. In addition to quantifying annual nutrient reductions through water sampling, there are a variety of other milestones can be used to encapsulate individual project data within the framework of the larger WIP program. Some of the milestones that should be tracked include:

- Number of grant application packages developed and submitted
- Successful grant awards
- Funding secured
- Outreach programs implemented
- Number of project demonstrations, watershed walks, cleanup events and similar
- Mailers sent, event attendees, volunteers, trainees and related
- Number of septic management projects in-progress or completed
- Tanks pumped, systems repaired, malfunctions corrected, and new sanitary sewer connections and related measures
- Number of stormwater projects in-progress and completed
- Acres of runoff managed, number of retrofits, number of BMPs installed
- Bank stabilization and riparian buffer enhancement projects in-progress and completed
- Number of stream feet stabilized, acres of buffer improved, trees and shrubs installed, in-stream grade controls installed, and other related metrics
- Pet waste and wildlife management projects in-progress and completed
- Signage erected, waste receptacles installed, waste bags provided, geese managed, and similar items

- Number of tracts and acres of land preserved
- Changes to land use regulations, adoption of new ordinance, dedication of funds, modification of operations, and similar local government initiatives enacted
- Attainment of designated uses, de-listing of impaired waters, and similar compliance with environmental quality standards

EVALUATION CRITERIA

While the milestones serve as programmatic indicators, evaluation criteria are performance metrics used to ascertain load reductions, concentrations, flows, and similar evaluations. This corresponds to the eighth US EPA element.

Similar to the original Restoration Plan, the indictors used to measure progress towards TMDL compliance will be of two types. The first will be based on the specific water quality criteria that have already been established for Lake Hopatcong for TMDL compliance; a targeted mean, growing season TP concentration of 0.03 mg/L and mean (growing season) and maximum chlorophyll-a values of 8 and 14 µg/L, respectively. These indicators will be based on the collection of empirical, in-lake water quality data. Similar criteria have been established for Lake Musconetcong and any future monitoring of the lake will provide a means of assessing the lake's current status.

The second indicator will be the amount of TP removed through each implemented stormwater BMP or watershed action. Typically, with each completed project, the amount of TP removed through that project is quantified on an annual basis. The resulting removed amount of TP can then be deducted from the lake's TP load targeted for reduction under the TMDL. In turn, the indicator will be the percent reduction associated with complete compliance with each lake's TMDL. Currently. The Lake Hopatcong TMDL is approximately 33% in compliance, while at this point the percent compliance in the Lake Musconetcong's TMDL is not known; recent inventories of completed BMPs is not up to date. The project-based, estimated TP removal rates are usually based on the collection of water quality data and/or the implementation of some relatively simple pollutant loading models.

In addition to the specific indicators listed above, additional metrics may be monitored and quantified based on the requirements of specific grants. These evaluation criteria can be applied to three basic levels regarding watershed management: project specific criteria, field measurements of surface waters, and regulatory requirements including water quality standards. The following section discusses these three elements.

PROJECT SPECIFIC CRITERIA

At a project specific level evaluation criterion will be formulated to address the objectives of that individual project. Therefore, evaluation criteria cannot be uniformly applied across project types. Criteria are likely to also be dictated by the technical assistance program if employed, conditions of the funding source, and regulatory and permit conditions. A list of some of the likely evaluation criteria are provided for each of the generalized management measures. Most of the criteria are anticipated to be directly measured, although modeling will likely play an important role as well due to the scope of the project or difficulty in obtaining measurements.

STORMWATER MANAGEMENT CRITERIA

Stormwater management projects encompass a wide range of project types, but generally address either stormwater quality or stormwater quantity with wide overlap between the two as addressing hydrology and hydraulics often results in quality improvements.

Many of the commonly measured or modeled stormwater quality metrics include:

- Solids, particularly total suspended solids, total solids, or total settleable solids
- Nutrient pollutants including various phosphorus species such as total phosphorus, orthophosphates, and nitrogen species including total nitrogen, nitrate, total Kjeldahl nitrogen
- In urbanized settings or associations with transportation infrastructure hydrocarbons are often measured as these are associated with fuels
- In the same areas and industrial facilities metals, particularly the RCRA metals like chromium, lead, mercury, may be explored

Because the TMDL for each river is based on TP concentrations, TP will be the stormwater quality metric that is most heavily relied upon.

Stormwater quantity criteria focus on the hydrology and hydraulics of the catchment and project and include:

- Peak flows
- Average flow
- Volume reduction
- Recharge
- Storage volumes

A subset of the hydrology and hydraulics metrics would include projects that address instability in which metrics like channel geometry and channel protections would be evaluated.

STREAMBANK STABILIZATION AND RIPARIAN BUFFER ENHANCEMENTS

This class of management measures includes in-stream and riparian area projects to address instability, erosion and sedimentation, hydraulics, habitat quality, and aquatic organism passage.

Measures related to modifying local hydraulics are typically evaluated on the following metrics:

- Channel and floodplain hydraulic geometry
- Flows including peak flow

- Velocity
- Flood storage capacity
- Channel roughness
- Shear stress

Substrate and solids characterization include:

- Particle size metrics such as D_{50} and D_{84}
- Bed load
- Solids metrics including total suspended solids and total solids

Riparian buffer enhancements have many benefits including cooling, improved habitat quality, enhanced pollutant and nutrient trapping, and soil stability. Criteria to evaluate these benefits include:

- Vegetative cover
- Water temperature
- Canopy cover/insolation
- Infiltration

Measuring localized nutrient and solids loads can be difficult because runoff is not necessarily concentrated in these areas. Biological surveys can be useful indicators for both these projects and may include:

- Fishery composition and related community metrics
- Macroinvertebrate community metrics
- Mussel surveys
- Plant and periphyton metrics

PET WASTES AND WILDLIFE MANAGEMENT CRITERIA

These types of management measures are designed to specifically reduce bacterial and pollutant loading, accomplished through behavioral modification and other techniques. The following criteria can be used to evaluate these programs:

- Bacteria concentrations
- Nutrient concentrations
- Waste density
- Wildlife use metrics including frequency, density, and duration

SURFACE WATERS EVALUATION CRITERIA

Monitoring surface waters is where the cumulative effect of the various management measures and implemented projects is best expressed and consequently measured. This watershed management plan is particularly focused on the management of TP in the Upper

Musconetcong River watershed, with a secondary focus on associated NPS pollution, particularly total suspended solids.

Of course, concerns regarding pollutants and their generation within the watershed, as well as their impact on the environment demand evaluation through a broad suite of criteria. Many of these criteria are already employed at Lake Hopatcong and Lake Musconetcong, although some additional criteria may be added, as necessary.

Regarding water quality sampling, there are field measured parameters collected *in-situ* and the collection of water quality samples for discrete laboratory analysis. In-situ criteria should include:

- Water temperature
- Dissolved oxygen
- Specific conductance
- pH
- Clarity or Secchi depth where appropriate
- Chlorophyll-a and phycocyanin (a pigment only cyanobacteria produce)

Discrete water quality criteria would include:

- Phosphorus species including total phosphorus, soluble reactive phosphorus, organic phosphorus, etc.
- Nitrogen species including total nitrogen, nitrate, nitrate, ammonia, total Kjeldahl nitrogen
- Solids including total solids, total dissolved solids, total suspended solids, and total settleable solids
- Standard limnological parameters such as alkalinity and hardness
- Additional discrete analytes as necessary including hydrocarbons, metals, semi-volatile organic compounds

Hydrology is a key concern regarding the functions of rivers, as well as an important factor in pollutant loading. It is therefore important to monitor:

- Discharge
- Precipitation

Biological sampling, within both lakes and their contributing tributaries, can be important in evaluating system function. This may include:

- Fishery community metrics
- Submerged aquatic vegetation composition
- Chlorophyll-a, a proxy measure of algal biomass
- Phytoplankton and zooplankton metrics

- Cyanotoxin concentrations produced by cyanobacteria
- Wetland plant composition
- Vegetative coverage
- Presence of invasive species

REGULATORY CRITERIA

The regulatory criteria provide not only a statutory standard, but a means to evaluate the field sampling and modeling activities. Here, the *New Jersey Surface Water Quality Standards* are of primary concern. These include classifications of surface and groundwaters with accompanying designated uses. There are also assigned water quality standards, both numerical and narrative. For Lake Hopatcong and Lake Musconetcong the following criteria are especially important:

- Dissolved oxygen
- Turbidity
- pH
- Nutrients (total phosphorus)
- Biological Condition

Note, since 2017 NJDEP has had a set of recommended guidelines and criteria in the management of recreational waterbodies, relative to algae that have the potential to produce Harmful Algal Blooms (HABs). In the case of freshwater systems, almost all HABs are associated with cyanobacteria. Key criteria in making management decisions relative to HABs include the identification of cyanobacteria, measured cell counts of cyanobacteria and *in-situ* measurements of chlorophyll-a and phycocyanin. While such data is used by both NJDEP and local stakeholders in making management decisions relative to recreational use of waterbodies, the associated criteria are NOT regulatory in nature.

MONITORING

Monitoring is used to supply the data necessary to evaluate pollution reduction goals. Following the criteria cited above, monitoring occurs at two levels, project specific and larger watershed-scale surface water monitoring efforts. This section corresponds to the last of the US EPA nine elements.

PROJECT SITE MONITORING

Monitoring at project sites is often a condition of project funding. There are several basic monitoring program designs that can be employed at the site level. All of these varying monitoring program designs may require the preparation of a quality assurance project plan or QAPP to ensure the correct criteria are being evaluated, the proper methods employed, and the program is consistent with quality assurance standards.

INFLUENT AND EFFLUENT

The most basic site monitoring program, particularly those for stormwater management designs, consists of monitoring the influent and effluent streams. This allows direct comparisons of concentrations to determine removal rates. If paired with flow data, concentrations can be integrated to determine load removals. The criteria monitored will depend on the objectives of the project, as well as the dictates of funding and regulatory requirements.

PRE- AND POST-MONITORING

Another common method of determining reductions and adherence to water quality or other standards is to conduct monitoring prior to project implementation and again after completion. This may be a particularly useful methodology in situations where influent concentrations are hard to measure because they are not neatly concentrated or where there was no influent concentration prior to project implementation. In any case, monitoring prior to construction or other implementation, and again afterward provides an effective means of determining concentration and load reductions specific to the project.

LONGITUDINAL MONITORING

Monitoring over time can also be important in assessing design performance. This is particularly true where the project contains an element of site evolution. This would be especially true in situations where there is a biological element, such as increasing vegetative coverage over time or the development of the macroinvertebrate community for stream grade controls. There may also be a reason for event-based sampling, such as assessing erosion after a channel forming flow event or a flood. These sampling programs may rely on quarterly sampling or some other set frequency, or by a triggering environmental condition or event.

CONTROL-IMPACT

Comparative monitoring can also be useful, by monitoring within a control area and an impact area corresponding to the project site. Monitoring of reference conditions can also be useful in the design phase. When paired with a time element this type of sampling design is called BACI, before, after, control, impact, and is especially powerful from a statistical perspective in determining project efficacy.

MODELING

Modeling is also a valid way to ascertain site specific function. Simple models like STEPL are endorsed by the US EPA for use in determining BMP removal rates. Certainly, a host of other models of varying complexity exist that are used in a similar role. Modeling presents an alternative to in-field sampling, can reduce costs, and is useful for projects where measurable changes in water quality are difficult to sample, such as when infiltration is enhanced.

SURFACE WATERS MONITORING

In-lake monitoring will also be conducted to gauge how Lake Hopatcong and Lake Musconetcong are responding to the reductions in pollutant loads. Such large-scale in-lake and watershed-based monitoring will continue in the future, using a similar monitoring program as was established after the completion of the Restoration Plan. This provides an ever-increasing inter-annual database to identify long-term trends in water quality. Eleven (11) in-lake monitoring stations are typically monitored in Lake Hopatcong for a variety of physical, chemical, and biological parameters; *in-situ* (dissolved oxygen, temperature, pH, and conductivity) data and discrete samples are collected from 9 of the in-lake stations. Five in-lake stations are monitored in Lake Musconetcong for the same parameters, including discrete samples at each in-lake station. The discrete samples are typically collected and analyzed for total phosphorus-P, nitrate-N, ammonia-N, TSS, and chlorophyll-a. Typically, Princeton Hydro is responsible for the standard in-lake monitoring, which usually involves one spring, one early summer, and one late summer sampling event.

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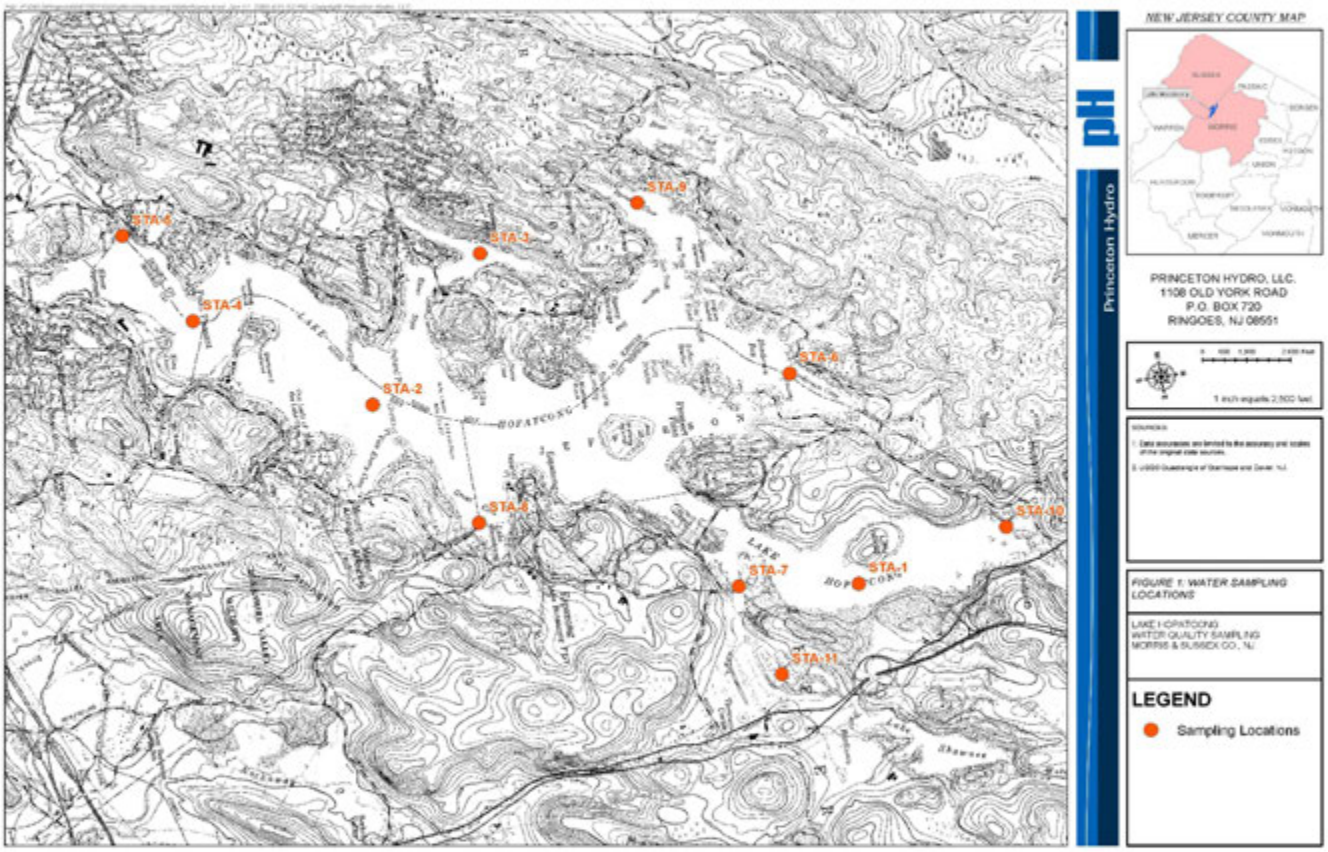
APPENDIX I

Project Maps


STA-9
STA-5
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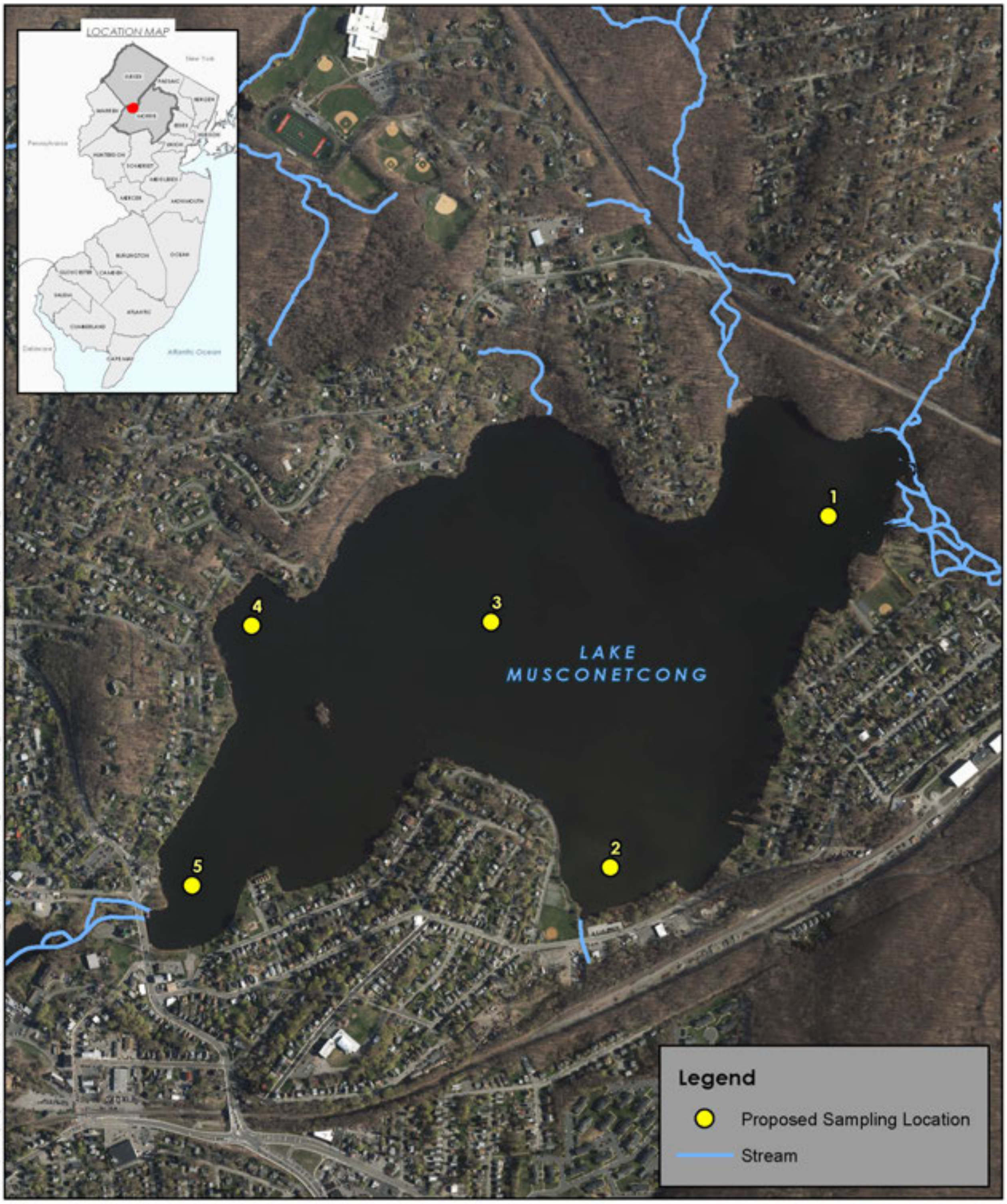
STA-2
STA-8
STA-10
STA-7
STA-1
STA-11
Princeton Hydro
NEW JERSEY COUNTY MAP
PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
FIGURE 1: WATER SAMPLING LOCATIONS
LAKE HOPATCONG
WATER QUALITY SAMPLING
MORRIS & SUSSEX CO., NJ
LEGEND
Sampling Locations



NOTES:
1. Proposed sampling locations are approximate
2. Streams obtained from NJDEP GIS website: www.state.nj.us/dep/gis/
3. 2015 orthoimagery obtained from NJ Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS).

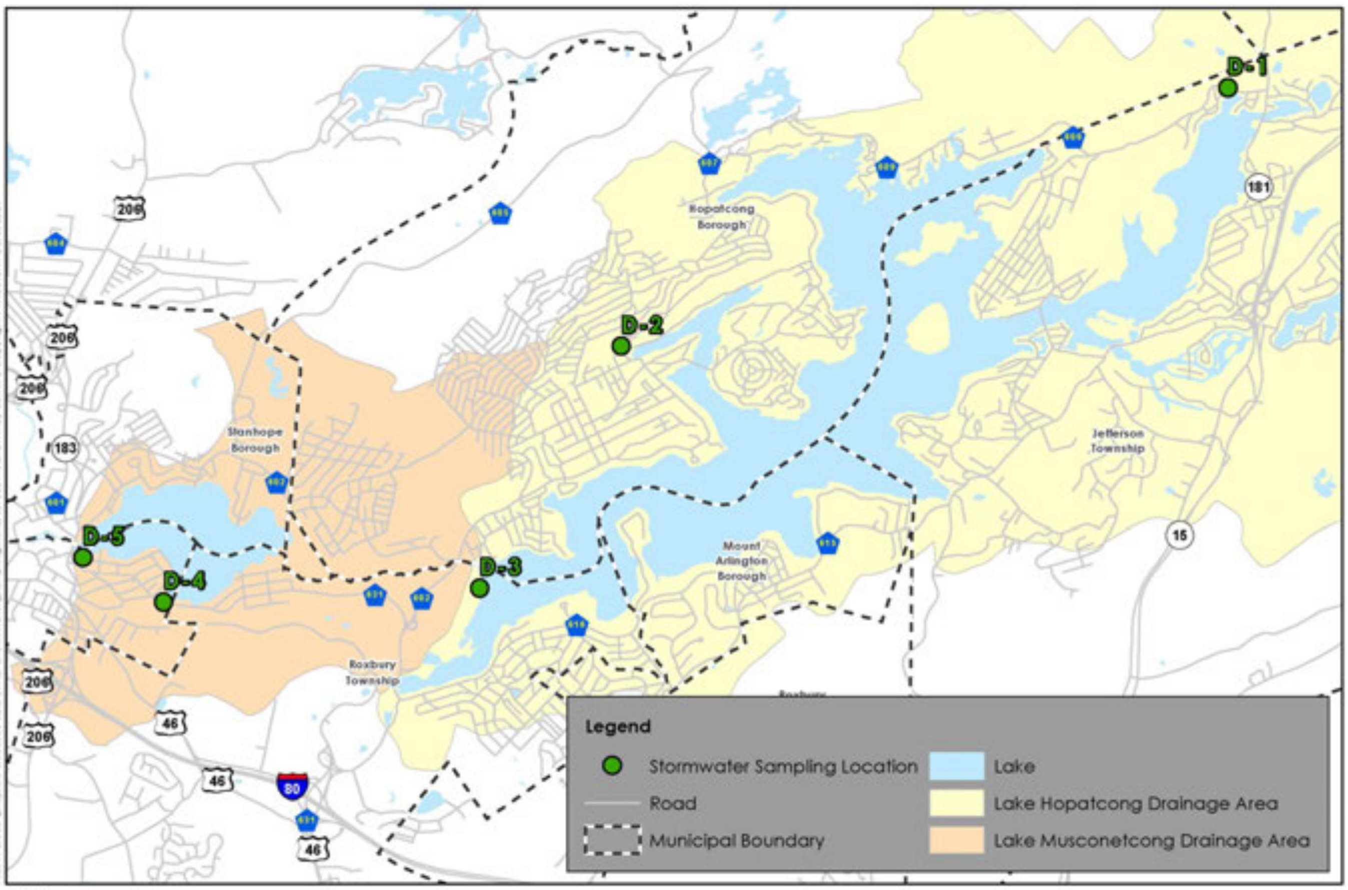
0 500 1,000 Feet

Map Projection: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

PROPOSED SAMPLING LOCATION MAP

LAKE HOPATCONG COMMISSION
MORRIS AND SUSSEX COUNTIES
NEW JERSEY

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING
www.PrincetonHydro.com



NOTES:
1. Stormwater sampling sites are approximate.
2. Drainage areas derived from HUC 14 data, obtained from NJGIN Information Warehouse website: https://njgin.state.nj.us/NJ_NJGINExplorer.

0 2,000 4,000 Feet

Map Projection: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

STORMWATER SAMPLING LOCATIONS

UPPER MUSCONETCONG UPDATED WIP
LAKE HOPATCONG COMMISSION
SUSSEX AND MORRIS COUNTIES, NEW JERSEY

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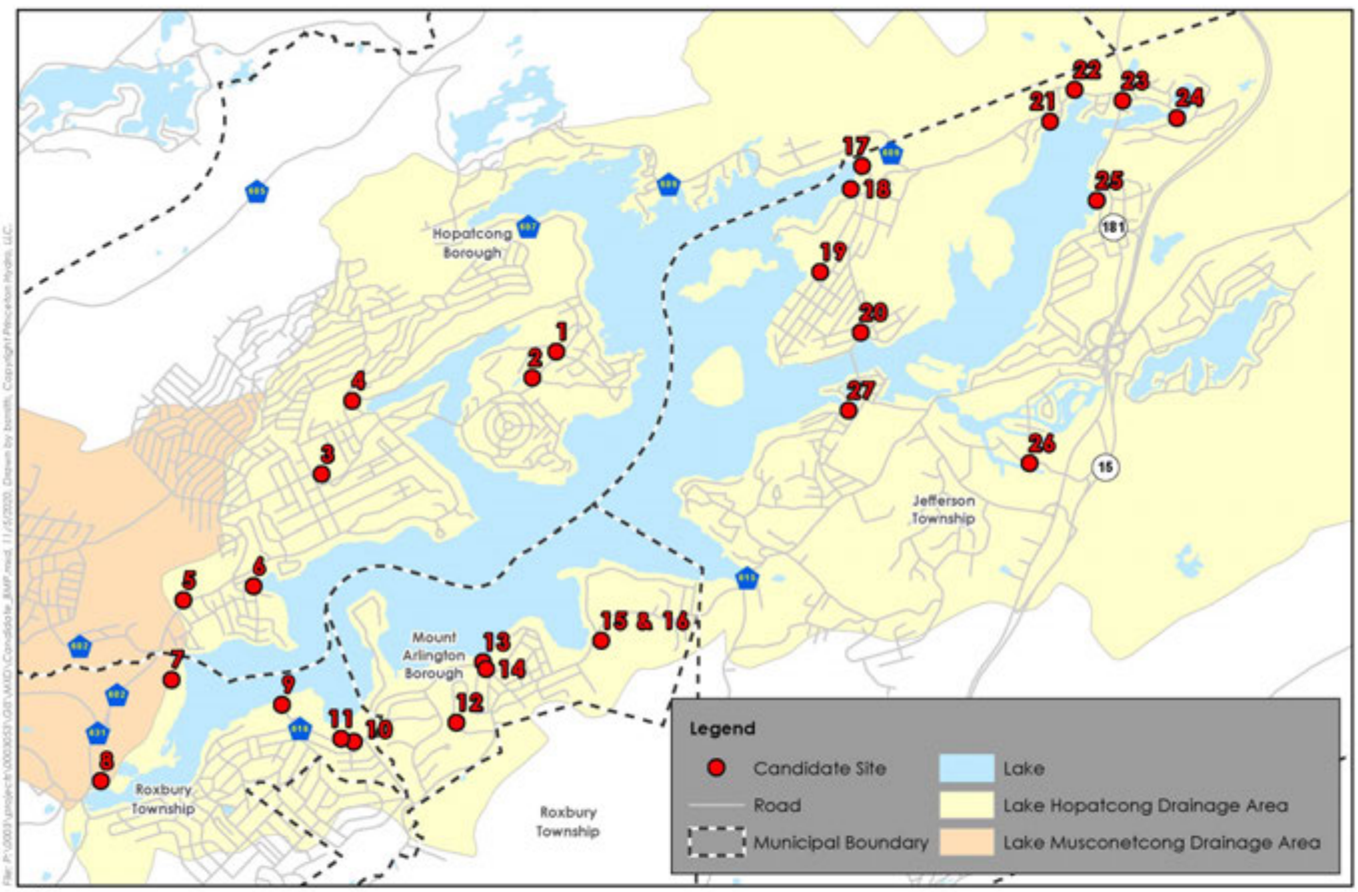


NOTES:
1. Candidate sites are approximate.
2. Drainage areas derived from HUC 14 data, obtained from NJGIN Information Warehouse website: https://njgin.state.nj.us/NJ_NJGINExplorer.

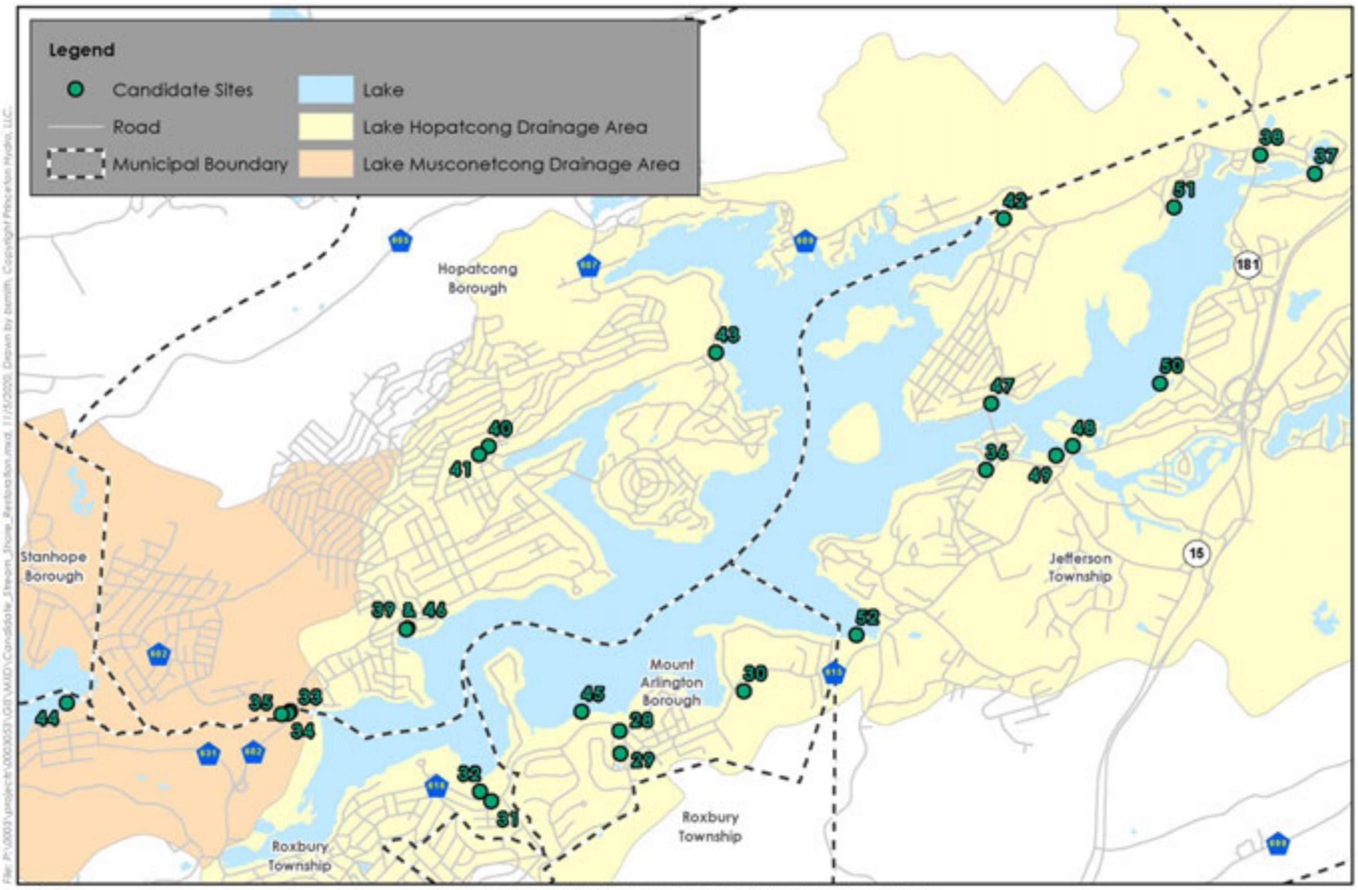
0 2,000 4,000 Feet

Map Projection: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

CANDIDATE SITES FOR RETROFITS OR BMPS

UPPER MUSCONETCONG UPDATED WIP
LAKE HOPATCONG COMMISSION
SUSSEX AND MORRIS COUNTIES, NEW JERSEY

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING
www.PrincetonHydro.com



NOTES:
1. Candidate sites are approximate.
2. Drainage areas derived from HUC 14 data, obtained from NJGIN Information Warehouse website: https://njgin.state.nj.us/NJ_NJGINExplorer.

0 2,000 4,000 Feet

CANDIDATE SITES FOR STREAMBANK AND SHORELINE RESTORATION

UPPER MUSCONETCONG UPDATED WIP
LAKE HOPATCONG COMMISSION
SUSSEX AND MORRIS COUNTIES, NEW JERSEY

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING