GREENWOOD LAKE WATERSHED IMPLEMENTATION PLAN

WEST MILFORD TOWNSHIP, PASSAIC COUNTY, NEW JERSEY

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EXECUTIVE SUMMARY

Greenwood Lake is a 1,920-acre waterbody located in both Passaic County, New Jersey and Orange County, New York. The watershed encompasses approximately 16,036 acres and most of the development within the watershed occurs on the northern and southern ends of the lake. Belcher Creek is the main tributary of the lake and empties into the southern end of Greenwood Lake in New Jersey. The lake is a highly valued resource for both states and has a substantial impact on the local economies. Although highly valued, the lake has been documented to experience declined water quality conditions such as blue-green algal blooms. 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 2004 by the New Jersey Department of Environmental Protection (NJDEP) for the annual TP load entering Greenwood Lake. To address this issue, a Stormwater Implementation Plan (SIP) was developed for the New Jersey end of the Greenwood Lake Watershed in 2006 for the Greenwood Lake Commission (the Commission) and the Township of West Milford by Princeton Hydro, which linked the existing TP TMDL to existing and targeted loads from the New Jersey end of the watershed. The resulting SIP was an outline for a series of projects to be implemented within the New Jersey end of the Greenwood Lake watershed to comply with the regulatory requirements as detailed in the TMDL for TP. The SIP was approved by NJDEP in 2006 and was subsequently used to obtain funding for the implementation of a 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; one of which was the same grant (SFY2004 319-grant) that funded the SIP. To date, these projects have addressed approximately 50% of the required reduction to be in compliance with the TMDL in the New Jersey portion of the watershed.

While the original SIP for the NJ end of the Greenwood Lake watershed 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 US Environmental Protection Agency (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 program for monitoring to track progress.

A sub-watershed analysis was conducted for the New Jersey end of the watershed during the creation of the original SIP to rank sub-watersheds from highest to lowest relative to the amount of human-generated TP. The sub-watersheds that drain directly into Belcher Creek, the main inlet to Greenwood Lake, generate the highest human-produced TP loads. These are also the highest developed sub-watersheds relative to land use and population. Thus, the majority of monitoring and sampling associated with this project focused primarily on these three sub-watersheds and Belcher Creek itself.

The early stages of this project focused on evaluating the TMDL compliance progress 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 Greenwood Lake. The first approach involved field assessments of each of the BMPs that have been implemented with 319 funds since the completion of the original SIP to determine their existing status and if any maintenance or clean-outs are required. Princeton Hydro coordinated with the Town of West Milford to access and inspect each project site. Stormwater samples were also taken from four (4) of these BMPs for the quantification of TP and TSS.

The second approach included general water quality monitoring of Greenwood Lake and its tributaries during the 2019 growing season (May through September) to provide an up-to-date water quality and ecological assessment of conditions within Greenwood Lake. It was critical that a set of growing season water quality sampling events, similar to those implemented back in 2005 and 2006 as part of the original SIP, were conducted so any changes or shifts in either in-lake or watershed (e.g. the tributaries) water quality conditions are documented. As such, an updated QAPP, an up-to-date water quality and ecological assessment of conditions in Greenwood Lake, and a comparison between the current (2019) and 2005 – 2006 datasets to identify any changes or shifts in water quality were completed.

After the completion of the various evaluation metrics, the focus was shifted towards determining the remaining watershed-based TP load that needs to be reduced for TMDL compliance and the various management measures necessary to achieve these reductions. 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 Greenwood Lake. 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.

As mentioned above, it has been previously determined that the sub-watersheds that drain directly into Belcher Creek generate the highest human-produced TP loads. Thus, the majority of the field assessments conducted were focused on these sub-watersheds. While the majority of the recommended projects are watershed-based and involve the implementation of various BMPs and/or MTDs in the areas surrounding Belcher Creek, many of the small streams that feed Greenwood Lake were also assessed for potential streambank/shoreline restoration projects. Finally, a field survey of Belcher Creek from where the Creek enters the lake up to the dam on Pinecliff Lake was conducted to identify potential problems that contribute to water quality issues in Greenwood Lake.

For each of the 22 identified locations, a proposed BMP/restoration measure is proposed 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, constructed wetlands, pervious pavement, vegetated filters, bioengineered streambank stabilization, and MTDs that incorporate green infrastructure where possible, among others. In order to streamline the process of project acceptance and 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 was provided, including interim measurable milestones such as the number of project demonstrations, evaluation criteria such as the amount of TP removed, and both project site and surface water monitoring components.

INTRODUCTION

Greenwood Lake is a 1,920-acre waterbody located in both Passaic County, New Jersey and Orange County, New York (Appendix I). The watershed encompasses approximately 16,036 acres and most of the development within the watershed occurs on the northern and southern ends of the lake. The lake is highly valued as an ecological, water quality and recreational resource for both New Jersey and New York. Given this high value, the lake has a substantially positive impact on the local economies of both States. In addition, the lake serves as a headwater supply of potable water that flows to the Monksville Reservoir and eventually into the Wanaque Reservoir, where it supplies over 2.3 million people with drinking water.

As a result of algal blooms and excessive densities of nuisance aquatic plants, a Phase I Diagnostic/ Feasibility Study was conducted of Greenwood Lake and its watershed in the early 1980's. Funds for this study were provided through the US EPA Clean Lakes Program (Section 314 of the Clean Water Act); subsequent funds were obtained through the Clean Lakes Program for a Phase II Implementation Program to eliminate point sources, conduct mechanical weed harvesting, and install several stormwater structures and retrofits to reduce the NPS pollutant load. Water quality improvements were documented in the first half of the 1990's, relative to conditions in the early 1980's. However, more recently collected water quality data documented Greenwood Lake's impaired condition, particularly in the New Jersey end of the lake.

A Stormwater Implementation Plan (SIP) was developed for the New Jersey end of the Greenwood Lake Watershed for the Greenwood Lake Commission (the Commission) and the Township of West Milford in the mid- 2000's (Princeton Hydro, 2006). Funding for the Plan was provided through the New Jersey Department of Environmental Protection's (NJDEP) Non-Point Source 319(h) Program and Princeton Hydro was hired to develop it. The watershed-based plan linked the existing total phosphorus (TP) Total Maximum Daily Load (TMDL), developed by NJDEP in 2004, to existing and targeted loads from the New Jersey end of the watershed (Appendix II). In turn, the NJ end of the watershed was divided into a series of sub-watersheds and a phosphorus loading priority analysis was conducted to rank the sub-watersheds from "high" to "low" relative to stormwater and watershed restoration needs.

The sub-watersheds that produce the highest human-related (e.g. residential, commercial, farmland, transportation, etc.) TP loads were ranked highest in terms of the prioritization of stormwater and other watershed-based projects. Not surprising, the three highest ranked sub-watersheds were those that immediately surround Belcher Creek, the main inlet of Greenwood Lake (Appendix I). Thus, this Watershed Implementation Plan (WIP) for the New Jersey side of the Greenwood Lake watershed will focus on, but not be limited to, these three sub-watersheds.

It should be noted that the original TMDL identified the targeted reductions in TP for both the New Jersey and New York ends of the Greenwood Lake watershed, in order achieve full water quality compliance. However, the 2006 SIP was funded through an NPS 319(h) grant by the NJDEP and so it focused on the New Jersey end of the watershed relative to watershed-based recommendations. Despite this, the water quality monitoring associated with the SIP did include locations in both states, although the focus was mostly the New Jersey side of the lake. As will be described in greater depth in this report, the in-lake and stream monitoring associated with this WIP mirrored that implemented back in 2005 and 2006 but is slightly expanded to include some limited monitoring associated with cyanotoxins.

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 Greenwood Lake. 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 TP loads for the New Jersey end of the watershed were established, the SIP identified prioritized locations where potential stormwater treatment measures, also known as Best Management Practices (BMPs), could be installed.

The resulting SIP was an outline for a series of projects to be implemented within the New Jersey end of the Greenwood Lake watershed to comply with the regulatory requirements as detailed in the TMDL for TP. The SIP was approved by NJDEP in 2006 and was subsequently used to obtain funding for the implementation of a variety of stormwater control and watershed management projects. The grants used to complete the projects around Greenwood Lake include two Clean Water Act Section 319 Non-Point Source pollution grants from NJDEP; one of these 319 grants was the same grant (SFY2004 319-grant) that funded the SIP. Additionally, the Township of West Milford received a grant under the federal Clean Water Act program 604(b) to create an "Onsite Wastewater Treatment System (OWTS) Management Plan" in 2006 for the New Jersey portion of the watershed. This OWTS Management Plan included passing an ordinance in 2008 for the mandatory pump-out of all septic system at least once every three years and have a State-certified contractor conduct a general inspection of the system at that time to obtain a license of operation from the Township.

While the original SIP for the NJ end of the Greenwood Lake watershed was extremely useful over the last decade as a guide in the implementation of projects to reduce TP loads, it should be updated 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 US EPA Nine Elements approach to develop a Watershed Implementation Plan (WIP). Thus, those watersheds that have an approved WIP, including the 9 elements, have a substantially higher chance of obtaining State and Federal funding. Although some changes in land use may have occurred in the NJ end of the watershed, such changes are not expected to be substantial over the last 10 years. However, 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 Greenwood Lake over the summer of 2019 placed additional emphasis on the need to continue in the long-term efforts of reducing the TP loads in the lake and comply with the TMDL.

This document will 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 WIP 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

SUMMARY OF THE NINE ELEMENT WATERSHED IMPLEMENTATION PLAN

This project includes a set of eight deliverables that are inter-connected but serve to develop a 9 element-based WIP for the NJ end of the Greenwood Lake watershed:

1. Conducting a detailed in-lake and watershed-based water quality monitoring program and compare the data to that collected in 2004 and 2005 to document changes or shifts in water quality
2. Meetings with the Township of West Milford, Passaic County and other stakeholders to conduct an inventory of recently completed BMPs and other watershed measures
3. Conduct a field-based evaluation of existing stormwater project that have been completed since the original Restoration Plan with 319-grant funds
4. Field site assessments to identify potential stormwater / watershed BMP projects
5. Field site assessment of Belcher Creek to identify potential projects to reduce the NPS pollutant loads that enter Greenwood Lake
6. Assembling the WIP with the 9 elements
7. Public and project meetings
8. Submission of final version of WIP and public presentation

These elements were all addressed while developing this WIP and will be presented in this document, although not necessarily in the above order.

1. IDENTIFICATION OF SOURCES OF POLLUTUON

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 Greenwood Lake, a summary of completed watershed measures, an updated pollutant loading estimate of the NJ end of the watershed, and a synopsis of water quality data in the lake. As previously stated, the TMDL developed in 2004 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 Greenwood Lake.

A number of studies and projects have been conducted in the Greenwood Lake watershed over the last 15 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:

BRIEF SUMMARY OF THE TMDL AND THE STORMWATER IMPLEMENTATION PLAN

The total phosphorus TMDL for the New Jersey end of Greenwood Lake was established in September 2004 and subsequently established for the New York end of the lake by NYS DEC in 2005. TP was the primary pollutant of concern since it has been well established that Greenwood Lake is a phosphorus limited system, which means it takes very little phosphorus to stimulate substantial amounts of algal and aquatic plant growth. For example, one pound of phosphorus has the potential to generate up to 1,100 lbs of wet algae biomass. Thus, even moderate reductions in TP will have a measurable improvement in water quality. While the TMDL for Greenwood Lake focuses solely on TP, total suspended solids (TSS) was another pollutant of concern when designing and implementing the stormwater projects.

It was previously determined in 2004 that the single largest source of TP for Greenwood Lake originates from internal loading, which accounted for 42% of the annual TP load when the TMDL was created (Table 1). However, stormwater-based surface runoff and on-site wastewater treatment systems (i.e. septic systems) combined to account for over half of the lake's annual phosphorus load (Table 1). Of the surface runoff load, low density residential, high density residential, and commercial/industrial/transportation land types accounted for the highest, second, and third highest sources of stormwater-based TP, respectively. Together, these three land types accounted for approximately 64% of the total surface runoff load. The percent contribution of the various pollutant sources entering Greenwood Lake as of the TMDL creation in 2004 is presented in Table 1.

Table 1: Annual Total Phosphorus Load Entering Greenwood Lake, NJ-NY, as of 2004.

Source of Pollutant	TP Load (kg)	Percent Contribution
Surface Runoff	1,580	38
Septic Systems	710	17
Internal Loading	1,739	42
Point Sources	70	2
Atmospheric Sources	53	1
Total	**3,088**	**100**

Based on NJDEP's phosphorus TMDL analysis in 2004, the surface runoff TP load entering Greenwood Lake was 1,580 kg while the **targeted surface runoff TP load should be 1,088 kg** (NJDEP, 2004). Thus, in order to attain the targeted TP load, the required reduction was 492 kg. To assign these reductions in an objective, fair, and equitable manner, the TP load targeted for reduction was divided based on the area of land covered within each State's watershed. New Jersey accounts for 62% of the total watershed while New York accounts for 38%. Therefore, **New Jersey is responsible for reducing its existing surface runoff load by 305 kg**, while New York is responsible for reducing its existing surface runoff load by 187 kg, based off of the loading calculations in 2004. **The surface runoff TP load in the NJ end of the lake has since been reduced, and the current load and necessary reductions will be quantified and discussed at the end of this section and the beginning of the following section.**

Since addressing the surface runoff NPS pollutant load will reduce other pollutants such as TSS, NJDEP recommended that any implementation phase of the TMDL should focus on watershed management. Any serious consideration to address the internal phosphorus load will only be made after stormwater/ surface runoff pollutant contributions have been addressed.

While the TMDL quantified how much the existing TP load needs to be reduced 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, as part of a previous 319-grant (RP04-081), a Stormwater Implementation Plan, essentially structured as a Watershed Implementation Plan, was developed for the New Jersey end of the Greenwood Lake watershed. This Plan was approved by NJDEP in April of 2006 and a similar plan was developed for the New York end of the watershed (Town of Warwick / Village of Greenwood Lake, Orange County, New York). Thus, the SIP was used as a guide in the selection of the projects that were identified for design and implementation. To briefly summarize, a sub-watershed analysis was conducted for the New Jersey end of the watershed to rank them from highest to lowest relative to the amount of human-generated TP. Obviously, sub-watersheds that have the highest amount of developed or agricultural-based lands would be ranked high, while those dominated by forested and wetlands would be ranked lower. Not surprising, sub-watersheds G, H and I, lands that drain directly into Belcher Creek the main inlet to Greenwood Lake, generate the highest human-produced TP loads (Appendix I). These are also the highest developed sub-watersheds relative to land use and population. Thus, the stormwater projects selected for design and implementation focused primarily on these three sub-watersheds. **The sub-watershed analysis and related pollutant loads will be discussed in greater detail in the following section.**

One of the first major steps in moving the SIP 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 15 years for the implementation of watershed-based projects to reduce the TP loads entering Greenwood Lake; one in 2004 and one in 2007, as detailed below (Princeton Hydro, 2014).

NON-POINT SOURCE (319) IMPLEMENTATION PROJECTS

The Township of West Milford (Passaic County, NJ) and the Greenwood Lake Commission were awarded a Non-Point Source (NPS) (Section 319(h) of the Clean Water Act) grant by the New Jersey Department of Environmental Protection (NJDEP) to continue in their long-term efforts to reduce the non-point source (NPS) pollution entering the New Jersey-end of Greenwood Lake. The grant was awarded in SFY 2007 (RP07-052) and stormwater installation activities were completed in May of 2014. A total of six stormwater projects were designed and implemented. In addition to these six projects, two more additional projects were implemented as part of an older 319(h) grant (SFY2004; RP04-081). These projects mainly 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, include technologies that may be exclusively manufactured by one or several companies. Green infrastructure was also incorporated into these projects wherever possible.

PROJECTS INSTALLED UNDER THE 2007 319 GRANT:

- Installation of a nutrient separating baffle box (NSBB) MTD with a polisher unit within an easement off of Beaver Avenue between Greenbrook Drive and Belcher Creek. The NSBB simply allows particulate material to settle out in a series of multi-chambered basins. Thus, this BMP focuses primarily on addressing solids (TSS) and that portion of the phosphorus load adsorbed onto sediment particles. The polisher unit adds an extra step for the removal of dissolved forms of phosphorous. This MTD treats approximately 11 acres of land and the structures were installed in April of 2011.

- Installation of a 4' x 4' BaySeparator SV MTD along Birch Avenue at the intersection with Greenbrook Drive. This MTD treats approximately 7 acres of land and the structure was installed in April of 2011.

- Installation of a 4' x 4' BaySeparator SV MTD along Rutgers Avenue. This MTD treats approximately 3.4 acres of land and the structure was installed in April of 2011.

- Installation of a NSBB MTD along Adelaide Terrace near an unnamed tributary of Belcher Creek. This MTD treats approximately 6 acres of land and construction was completed in December of 2013.

- Installation of a NSBB MTD and vegetative filter along Durant Road near Belcher Creek. This MTD treats approximately 5 acres of land and construction was completed in December of 2013.

- Installation of a 6' x 6' Filterra tree box MTD at the intersection of Reidy Place and Millington Avenue. The Filterra is a smaller retrofit that can be integrated into existing stormwater infrastructure and combines a settling basin with an organic media / native vegetation mix to remove dissolved pollutants. The drainage area to this Filterra unit is approximately 0.5 acre; this project was completed in December of 2013.

In addition to these six projects, a Vortechnics MTD was installed at Greenwood Lake Turnpike and two vegetative filters were planted along Morestown Brook as part of an older 319(h) grant (SFY2004; RP04-081).

ESTIMATED ANNUAL POLLUTANT REMOVAL EFFICIENCY OF PROJECT BMPS AND MTDS

Some relatively simple modeling was used to quantify the annual pollutant TP and total suspended solids (TSS) removal rates associated with the installed BMPs / MTDs. The same NJDEP-selected, land-use, pollutant loading coefficients that were used to quantify the annual stormwater / surface runoff pollutant loads in the TMDL (NJDEP, 2004) were used in this modeling exercise. Specifically, both the land use type and the surface area of each land type were quantified for the drainage area of each installed stormwater structure. It should be noted that the two dominant land types for these structures were typically forested and medium / high residential, which are very typical of a land community in the Mid-Atlantic States. Using the land type loading coefficients and the associated land areas, the annual TP and TSS loads were calculated for each project site's drainage area, using methodology that was similar to that used by NJDEP in the TMDL. Percent loading removals were then ascribed to each MTD or BMP, based on other studies or identified in NJDEP's Stormwater Manual. These percent removals were used to calculate how much of the annual TP and TSS load was removed as a result of the installed MTDs or BMPs.

While the primary pollutant of concern for the TMDL is TP, the amount of TSS removed as a result of the installed stormwater structure was also quantified; a substantial portion of the phosphorus entering a waterbody from stormwater can be adsorbed onto sediment particles. Thus, since phosphorus does not have a gaseous phase, reducing the stormwater-based TSS load will directly contribute to reducing the TP load as well. In addition, elevated TSS loads negatively impact water quality, producing turbid, muddy conditions, reducing water depths which exacerbates rooted plant growth, and destroys spawning habitat for many desirable fish. Given the water quality and habitat impacts of TSS, reductions in TSS loads associated with the installed stormwater projects were also quantified as part of this study.

Based on information provided by the manufacturer, the BaySeparator SV MTDs have TP and TSS pollutant removal rates of 30% and 80%, respectively. The Vortechnics MTD device that was installed along Greenwood Lake Turnpike (as part of the SFY2004 319-grant) is estimated to have TP and TSS removal rates of 30% and 64%, respectively. In contrast to these other MTDs, the Filterra unit incorporates vegetation into its design, which assimilates dissolved forms of phosphorus, and TP and TSS removal rates for this MTD are reported by the manufacturer to be 65% and 85%, respectively.

For those stormwater structures that included a vegetated filter strip (Durant Road) the TP removal rate was increased by 10%. In contrast the TSS removal rate was not altered since the vegetated filter strip was composed of meadow cover and planted woody vegetation. If the filter strip was composed of an existing forested area, it would have been increased by approximately 10%. Finally, the two vegetated filter strips that were planted along Morestown Brook, again as part of the SFY2004 319-grant, were both ascribed TP and TSS removal rates of 30% and 70%, respectively.

Again, using a simplified pollutant modeling approach and the TP and TSS removal rates associated with each stormwater BMP / MTD, the amount of TP and TSS removed by each structure was calculated. The results for these TP and TSS analyses are shown below in Tables 2 and 3, respectively.

Table 2 - Summary of the Annual TP Removal Rates for West Milford, Passaic County Stormwater Projects Installed Under the Two Non-Point Source 319-grants.

Location	Source of 319(h) Funding	BMP / Action	Kg/yr	Lbs/yr
Reidy Place	SFY2007, RP07-052	Filterra Unit	0.5	1.1
Adelaide	SFY2007, RP07-052	NSBB	1.5	3.3
Durant Road	SFY2007, RP07-052	NSBB + vegetated filter strip	1.6	3.5
Rutgers Avenue	SFY2007, RP07-052	Bay Separator	0.7	1.5
Birch Avenue	SFY2007, RP07-052	Bay Separator	1.4	3.1
Beaver Avenue	SFY2007, RP07-052	NSBB + polishing unit	5.4	11.9
Greenwood Turnpike	SFY2004, RP04-081	Vortech unit	0.2	0.4
Morsetown Brook	SFY2004, RP04-081	Vegetated filter strips	0.3	0.7
Stormwater TP Removal Total Per Year			**11.6**	**25.5**

Table 3 - Summary of the Annual TSS Removal Rates for West Milford, Passaic County Stormwater Projects Installed Under the Two Non-Point Source 319-grants.

Location	Source of Funding	BMP / Action	kg/yr	lbs/yr
Reidy Place	SFY2007, RP07-052	Filterra Unit	798	1,755
Adelaide	SFY2007, RP07-052	NSBB	3,447	7,583
Durant Road	SFY2007, RP07-052	NSBB + vegetated filter strip	2,815	6,193
Rutgers Avenue	SFY2007, RP07-052	Bay Separator	2,168	4,770
Birch Avenue	SFY2007, RP07-052	Bay Separator	4,518	9,940
Beaver Avenue	SFY2007, RP07-052	NSBB + polishing unit	6,273	13,801
Greenwood Turnpike	SFY2004, RP04-081	Vortech unit	518	1,139
Morsetown Brook	SFY2004, RP04-081	Vegetated filter strips	956	2,103
Stormwater TSS Removal Total Per Year			**21,493**	**47,284**

FIELD-BASED ASSESSMENT OF EXISTING WATERSHED PROJECTS / BMPS

As mentioned above, after the New Jersey Restoration Plan for Greenwood Lake was completed, the Commission and the Township of West Milford received funds through the State's NPS, 319(h) program to design and implement a variety of watershed projects / BMPs to reduce the NPS pollutant load entering the lake, with an emphasis on TP. Princeton Hydro conducted field assessments of each of the aforementioned project sites to determine their existing status and if any maintenance or clean-outs are required. Princeton Hydro coordinated with the Town of West Milford to access and inspect each project site.

During an assessment on 10 April 2019, it was determined that all of the MTDs implemented under the 319 grants should be cleaned out, as they had not yet been cleaned this year. Princeton Hydro recommends that all the MTDs be cleaned out at least once a year to remove the accumulated sediment, organic matter, and garbage. The routine maintenance of these devices will ensure they function properly and remove the expected TP and TSS loads. Each of the MTDs exhibited different sediment and organic accumulations. It should be noted that all of the sites were inspected, although the Filterra unit on Reidy Place could not be opened and inspected due to the nature of the MTD. Also, the filter strips on Morestown Brook were visually inspected, but there is not much of a maintenance requirement with the filter strips. Princeton Hydro also conducted three storm sampling events at four MTD locations to quantify the pollutant removal efficiency of the different MTD types; **the results from the stormwater sampling will be provided in the Estimates of Load Reductions section of this report**. A brief description of the field assessments of the MTDs are included in Table 4 Below.

Table 4 – Field Based Assessments of Existing MTDs, 10 April 2019.

Location	MTD	Sediment Accumulation	Additional Notes
Adelaide Terrace	NSBB	1st Chamber: ~0.5 ft. 2nd Chamber: No accumulation	Not much sediment accumulation.
Durant Road	NSBB + vegetated filter strip	1st Chamber: ~2 ft. 2nd Chamber: ~0.5 ft.	Leaf litter accumulated in outlet.
Rutgers Avenue	Bay Separator	1st Chamber: 2 – 4 ft.	4 ft. sediment accumulation directly after pipe; 2 ft. accumulation in rest of chamber.
Birch Avenue	Bay Separator	1st Chamber: 2 – 4 ft. across 2nd Chamber: ~0.5 ft.	This MTD may have never been cleaned out since installation. Accumulation of garbage and floatables in 2nd chamber.
Beaver Avenue	NSBB + polishing unit	**First Box:** 1st Chamber: 1 – 2.5 ft. across 2nd Chamber: ~0.5 ft. **Second Box:** 1st Chamber: ~1.5 ft. 2nd Chamber: No accumulation	First chamber accumulation varied between 1" – 2.5". Garbage and floatables accumulated in 2nd chamber of first box.
Greenwood Turnpike	Vortech unit	1st Chamber: ~ 1 ft. 2nd Chamber: < 0.5 ft. 3rd Chamber: <0.5 ft.	Normally cleaned yearly. Accumulation of garbage and floatables in 2nd chamber.

ADDITIONAL WATERSHED MEASURES

Since the completion of the Restoration Plan a variety of watershed projects have been completed with State grants and other sources funding. However, other stormwater / watershed projects may have been completed since the establishment of the Restoration Plan that were not identified. It is important to identify and recognize these additional measures so that their contributing reductions for TP and TSS can be quantified and recorded toward the TMDL.

Two of these measures include the use of non-P fertilizers on residential lands and mechanical weed harvesting, both of which on the New Jersey side of the watershed and lake, which combined account for the removal of 66 kg of TP (Table 5).

Other measures include:

STREET SWEEPING

Increases in impervious cover within watersheds are often associated with increased pollutant loading due to the reduction of pervious land that naturally drains stormwater and removes pollutants. Increased populations that are often associated with increased impervious area tend to produce more trash that ends up in the streets. There are numerous street-sweeping technologies that provide varying sediment and nutrient reduction rates. West Milford Township employs the use of a mechanical broom sweeper and vacuum sweeper to clean the streets of West Milford.

Specifically, an Elgin Eagle Mechanical sweeper and an Elgin Whirlwind Vacuum sweeper are utilized to clean the streets of West Milford. The streets are swept once a year, directly after every winter season. Overall, this street sweeper cleans 120 miles of street total each run. This waste includes leaf waste, branches, road sand and garbage that has collected along the streets of West Milford.

Through the use of street sweeping as a BMP measure, nutrient and sediment loads are removed prior to entering the lake, as a watershed-based proactive measure. Street sweeping reduces approximately 1.0 kg TP and 680 kg TSS from entering the Greenwood Lake ecosystem per year (Table 5).

MANDATORY PUMP-OUTS FOR ALL ONSITE WASTEWATER TREATMENT SYSTEMS

This measure is a result of a Clean Water Act program 604(b) grant that the township of West Milford received to create an “Onsite Wastewater Treatment System (OWTS) Management Plan” in 2006 for the New Jersey portion of the watershed.

As stated in Ordinance No. 2008 – 050, the Township established a Management Program for OWTSs “in order to ensure the proper operation and maintenance of such systems.” A key component of this Program is that all OWTSs be pumped out at least once every three (3) years in order to minimize future malfunction. Removing the accumulated sludge from a septic tank on a regular basis will minimize the amount of particulate material that flows into the drain field. Particulate material in the drain field severely reduces its capacity to properly treat wastewater and remove pollutants such as phosphorus. Thus, regular pump-outs of a septic tank are a very cost-effective means of maximizing an existing system’s ability to remove pollutants.

While the Township’s ordinance pertains to all operating OWTSs, the OWTS Management Plan focuses only on those systems within the established Zone of Influence (ZOI). Based on the Township’s GIS database, there are 1,632 OWTSs within the ZOI; approximately 84% of these systems are within the Targeted Zone (sub-watersheds G, H, and I; Appendix I). It should be noted the ordinance pertains to all OWTSs since a system can still have undesirable impacts related to local health (i.e. contamination of wells).

Pumping out the OWTSs within the ZOI should contribute toward reducing the TP load entering the waterways within the New Jersey end of the Greenwood Lake watershed. In order to quantify this for the TMDL, a number of studies were reviewed. For example, it has been stated that a properly functioning septic tank retains up to 48% of the phosphorus that enters the tank (Gold, 2006). However, studies conducted in the Cannonsville Reservoir watershed, New York, have estimated that between 20 - 30% of the TP from raw wastewater is separated out as sludge, which accumulates in the bottom of the septic tank (Day, 2011). Thus, for the OWTS Management Plan, a conservative removal rate of 10% per tank was used to calculate how much TP would be removed from the annual load once all tanks are pumped out on a routine schedule of at least once every 3 years. The removal rate was lowered to 10% for two reasons. First, there are large data gaps in the OWTS database and many of the existing systems are known to be at least 35 to 50 years old. In the absence of an extensive database, it is prudent to assume that many of these systems are operating on a sub-optimal capacity and lowering the removal rate to 10% will account for some of this in the model. Second, lowering the removal rate to 10% also contributes toward accounting for an implicit margin of safety for the TMDL analysis.

Since, as per the Township's ordinance, all septic tanks are required to be pumped out at least once every three years, with subsequent proof of action through certification, it was assumed that all OWTSs within the ZOI will participate in this management action. The median TP concentration down gradient of the municipal septic leach field and estimated water consumption were used to calculate a median per tank load of 0.44 kg of TP per year. In turn, this loading rate was multiplied by the number of OWTSs within the ZOI and then by 0.1 to calculate how much TP would be removed on an annual basis once all of the residents are in compliance with the three-year mandatory pump-outs. The resulting annual removal rate was 73 kg (Table 5).

TMDL PROGRESS

Based on all of the in-lake and watershed projects completed after the TMDL was established and the original Stormwater Implementation Plan was implemented, the amount of TP removed from the NJ end of the watershed on an annual basis is estimated to be 151.6 kg. This accounts for approximately 49.7% of the amount of TP targeted for removal under the existing TMDL for Greenwood Lake. Thus, the New Jersey end of Greenwood Lake still needs to reduce the TP load by 153.4 kg to be in compliance with the TMDL. In contrast, a similar analysis has not been completed for the NY end of the watershed, and any reductions in TP loading from NY are unknown at this time. Thus, it will be assumed that the TP load entering Greenwood Lake from NY is the same as it was when the TMDL was established in 2004, and any reductions in TP loading discussed in this report will be referring to the NJ end of the watershed. Table 5 quantifies the total amount of TP removed on an annual basis from NJ.

Table 5 – Summary of the Management Activities in the NJ end of the Greenwood Lake Watershed (Passaic County, NJ) and their associated annual Total Phosphorus Removal Rates.

Location	BMP / Action	kg/yr	Lbs/yr
Reidy Place	Filterra Unit	0.5	1.1
Adelaide Terrace	NSBB	1.5	3.3
Durant Road	NSBB + vegetated filter strip	1.6	3.5
Rutgers Avenue	Bay Separator	0.7	1.5
Birch Avenue	Bay Separator	1.4	3.1
Beaver Avenue	NSBB + polishing unit	5.4	11.9
Greenwood Lake Turnpike	Vortech unit	0.2	0.4
Morsetown Brook	Vegetated filter strips	0.3	0.7
NJ end of the watershed	non-P fertilizers on residential lands	47	103.4
NJ end of the watershed	mandatory pump-outs of OWTSs	73	160.6
NJ end of the lake	mechanical weed harvesting	19	41.8
NJ end of watershed	street sweeping	1.0	2.2
Total		**151.6**	**333.5**

SYNOPSIS OF WATER QUALITY DATA

Princeton Hydro, LLC conducted general water quality monitoring of Greenwood Lake during the 2019 growing season (May through September) to provide an up-to-date water quality and ecological assessment of conditions within Greenwood Lake. Greenwood Lake had not been monitored under a State-approved Quality Assurance Protection Plan (QAPP) since 2005. Thus, it was absolutely critical that a set of growing season water quality sampling events, similar to those implemented back in 2005 and 2006, were conducted so any changes or shifts in either in-lake or watershed (e.g. the tributaries) water quality conditions are documented. This task included an updated QAPP (Appendix III), an up-to-date water quality and ecological assessment of conditions in Greenwood Lake, and a comparison between the current (2019) and 2005 – 2006 datasets to identify any changes or shifts in water quality (Appendix IV).

The current water quality monitoring program is valuable in terms of assessing the overall "health" of the lake, identifying long-term trends or changes in water quality, and quantifying and objectively assessing the success and potential impacts of restoration efforts. In addition, the in-lake water quality monitoring program continues to be an important component in the evaluation of the long-term success of the implementation of the phosphorus TMDL-based Restoration Plan. Finally, the monitoring program provides the data necessary to support the Commission's requests for grant funding to implement both watershed-based and in-lake projects to improve the water quality of Greenwood Lake.

This section will include the materials and methods associated with the 2019 water quality sampling, a summary of the 2019 findings, and a comparison between the 2005 – 2006 and 2019 data. The full 2019 QAPP can be found in Appendix III. Additionally, the full Greenwood Lake Water Quality Report 2019 is included in Appendix IV.

MATERIALS AND METHODS

In-lake water quality monitoring was conducted at the following five (5) locations in Greenwood Lake (represented in Figures 1 and 2, Appendix A of the full water quality report):

Station Number	Description
L1	New York, northernmost mid-lake station
L2*	New York, mid-lake station
L3	New Jersey, mid-lake station
L4	New Jersey, near-shore outlet station at mouth of Belcher Creek
L5	New Jersey, southern near-shore station

* *In-situ* monitoring only

The 2019 sampling dates were 13 May, 11 July, and 23 September. A Eureka Amphibian Personal Digital Assistant (PDA) with Manta multi-probe unit was used to monitor the *in-situ* parameters: dissolved oxygen (DO), temperature, pH, and specific conductance during each sampling event. Data were recorded at 1.0 m increments starting at 0.25 m below the water's surface and continued to within 0.5-1.0 m of the lake sediments at each station during each sampling date. In addition, water clarity was measured at each sampling station with a Secchi disk. *In-situ* data can be found in Appendix B at the end of the full water quality report.

Discrete water quality samples were collected with a Van Dorn sampling device at 0.5 m below the lake surface, at mid-depth and 0.5 m above the sediments at the mid-lake stations L1 and L3. Discrete samples were collected from a sub-surface (0.5 m) position at the remaining two (2) shallow sampling stations (L4 and L5). Discrete water samples were appropriately preserved, stored on ice, and transported to a State-certified laboratory for the analysis of the following parameters:

- total suspended solids
- total phosphorus-P
- total dissolved phosphorus-P
- soluble reactive phosphorus-P
- nitrate-N
- ammonia-N
- chlorophyll *a*

Monitoring at station L2 consisted of collecting *in-situ* and Secchi disk data; no discrete water samples were collected from this station for laboratory analyses. Discrete data can be found in Appendix C at the end of the full water quality report.

During each sampling event, surface and mid-depth grabs well collected at stations L1 and L3 for phytoplankton quantification. A Schindler trap was also used to sample zooplankton densities at surface and mid-depths at these stations. Surface grab samples were also taken at near-shore or beach areas on both the New Jersey and New York ends for phytoplankton quantification and cyanotoxin testing. Phytoplankton data can be found in Appendix D at the end of the full water quality report.

Tributary monitoring was also conducted at eight (8) tributaries entering Greenwood Lake, with two established at the NY end and six at the NJ end. These eight stations were monitored during the 2004-2006 monitoring program. *In-situ* and discrete monitoring for TP and TSS were conducted at each stream sampling.

2019 SUMMARY

This section provides a summary of the 2019 water quality conditions observed at Greenwood Lake.

1. Thermally stratified waters were noted in the deeper waters by the first sampling event, which then persisted throughout the remainder of the growing season. The waters were well oxygenated during the first sampling event, only dropping below the recommended DO threshold at the sediments. By the July event, the deep-water stations became anoxic at 5 meters. Anoxic conditions persisted at L1 and L2 through the September sampling, while ample DO was noted at the shallower stations.

2. A TMDL was established for TP in the New Jersey end of Greenwood Lake. TP concentrations in the surface waters of Greenwood Lake varied between non-detectable concentrations and 0.05 mg/L. TP concentrations contravened the TMDL upper limits during both the May and July sampling events. Deep water concentrations consistently exceeded the TMDL target during the 2019 season. Extremely elevated TP was noted in the deep waters of L1 due to extended periods of anoxia causing internal loading of P.

3. Elevated cyanobacteria densities were noted throughout the 2019 season at Greenwood Lake. Stations L1 and L3 both yielded algal densities above the NJDEP Health Advisory Guidance Level and were characterized as Moderate or High by WHO criteria throughout the season. During the July monitoring event, both the NJ and NY beach shoreline exceeded the NJ Health Advisory Guidance Level, characterized as High and Moderate, respectively, by WHO criteria. By the final sampling, both the NY and NJ beaches were characterized as "Moderate" by WHO standards. However, overall microcystin and cylindrospermopsin levels remained below their respective NJDEP draft recreational health advisories at each station during each sampling events.

4. Stream sampling showed elevated TP throughout the season. TP contravened TMDL standards during each sampling event. T6 yielded the most elevated TP throughout the season with maximum concentrations of 1.80 mg/L.

INTERANNUAL ANALYSIS OF WATER QUALITY DATA

A similar monitoring program was conducted during the 2005 - 2006 season. Data collected during the 2005 and 2006 seasons will be utilized for comparison to those in 2019. The main focus for this interannual comparison will be placed on the 24 August 2005, 1 August 2006 and 11 July 2019 sampling data. The reason for focusing on these mid-summer dates is because this is the most consistent time of year with sampling data available from the two different timeframes. The water quality data from 2005 – 2006 has additional data from April and November, but these months are at the very beginning and end of the growing seasons and won't necessarily provide a consistent comparison to the 2019 sampling dates. Similarly, mean values taken from April, August, and November from 2005 – 2006 would not provide a consistent comparison to mean values calculated from the 2019 sampling months of May, July, and September. Nutrient concentrations, especially TP, are going to be higher during the peak growing season months, and the most accurate comparison with the available data series includes a comparison of the peak growing season months of August and July.

Thermal stratification was noted during each of these three sampling events, with strong stratification noted at the deeper stations. L3 was well-mixed during the 2005 and 2006 sampling seasons, only exhibiting slight stratification in the bottom meter of the lake during the 2019 sampling. Persistent thermal stratification in the deeper stations caused anoxic conditions starting at 5-7 meters during each of the three sampling events at L1 and L2. During the 2005 and 2006 samplings, DO declined below the 5.0 mg/L threshold above the sediments at L3. In contrast, ample DO was noted throughout the water column at L3 during the 2019 sampling. Water clarity was variable throughout the sampling period. The deep-water station L1 exceeded the 1.0 m threshold during each sampling season, with maximum Secchi depth noted in 2006 (2.4 m). The shallower L3 had Secchi depths ranging from 0.5 m during 2005 to 1.3 m during 2006. Clarity dropped below the 1.0 m threshold during both 2005 and 2019 (0.9 m).

TP concentrations at the surface of both mid-lake stations L1 and L3 declined as time progressed (Figure 1). TP dropped from 0.05 mg/L and 0.07 mg/L during the 2005 season, to 0.02 mg/L and 0.03 mg/L in 2006, down to non-detectable concentrations (ND < 0.01 mg/L) and 0.01 mg/L, respectively, during the 2019 season. Surface TP concentrations were at or below the TMDL upper limit of 0.03 mg/L at both of these stations in 2006 and 2019. Surface TP concentrations were slightly higher at the shallower near-shore stations L-4 and L-5 during each year, though 2005 concentrations were much higher than 2006 and 2019, similar to the trend observed at the mid-lake stations.

Both mid-depth and deep-water TP concentrations at L1 were very similar in each year, varying between 0.02 mg/L and 0.03 mg/L (Figure 1). Deep water TP was variable at L3 during this sampling period, ranging from a minimum of 0.04 mg/L during 2006 up to 0.07 mg/L during 2005; the 2019 deep sample was in between those values at 0.06 mg/L. Deep TP concentrations are not likely to be as affected by watershed measures as surface TP concentrations, especially in the relatively short timeframe of 14 years; growing season TP concentrations in the hypolimnion of a stratified lake are usually higher than surface TP concentrations as a result of the internal cycling of phosphorus from anoxic bottom sediments. The bottom sediment contains legacy phosphorus that has built up over time and can continue to release from the bottom sediment during periods of hypolimnetic anoxia for years to come.

Surface soluble reactive phosphorus (SRP) concentrations during each year were relatively low, only exceeding 0.002 mg/L one time at L-5 in 2019 (Figure 2). Deep SRP concentrations were much higher at L-1 but decreased with time, from 0.011 mg/L in 2005 down to 0.004 mg/L in 2019. Similarly, deep SRP at L-3 was high in 2005 with a concentration 0.009 mg/L, but low during 2006 and 2019 with a concentration of 0.001 mg/L (Figure 2). Surface total dissolved phosphorus (TDP) concentrations were below the detection limit of 0.01 mg/L at all stations in 2019; surface concentrations in the previous years were much higher, varying between 0.01 mg/L and 0.02 mg/L. Deep TDP concentrations were much higher at L-1, but decreased with time, from 0.03 mg/L in 2005 down to 0.01 mg/L in 2019 (Figure 3). Deep concentrations at L-3 followed a similar trend, from a concentration of 0.02 mg/L in 2005, down to < 0.01 mg/L in 2019.

Surface chlorophyll *a* concentrations were variable from year to year but were highest in 2005 and lowest in 2006 (Figure 4). It is not surprising that chlorophyll *a* concentrations were highest in 2005, as TP concentrations were much higher at all stations during this year. Chlorophyll *a* is a pigment possessed by all algal groups that is used in the process of photosynthesis. Chlorophyll *a* concentrations are used as a means of quantifying algal biomass in a waterbody. In general, chlorophyll *a* concentrations greater than 20 µg/L are considered unfavorable for recreational water use. Chlorophyll *a* concentrations are directly linked to algal biomass, and therefore can often be correlated with TP concentrations. Chlorophyll *a* concentrations were elevated at all stations other than L-1 during the 2019 season (Figure 4). Similar to 2005, this is not surprising as TP concentrations were also elevated at these stations in 2019. The spring of 2019 was very wet, followed by hot temperatures throughout the summer and short but intense rainstorms; these conditions are favorable for phytoplankton, and especially cyanobacteria as was witnessed in Greenwood Lake and many lakes in the northeast this past year. The heavy precipitation continually washed nutrients and other allochthonous material from the watershed into the lake, providing a source of nutrients for the cyanobacteria to feed on early in the season.

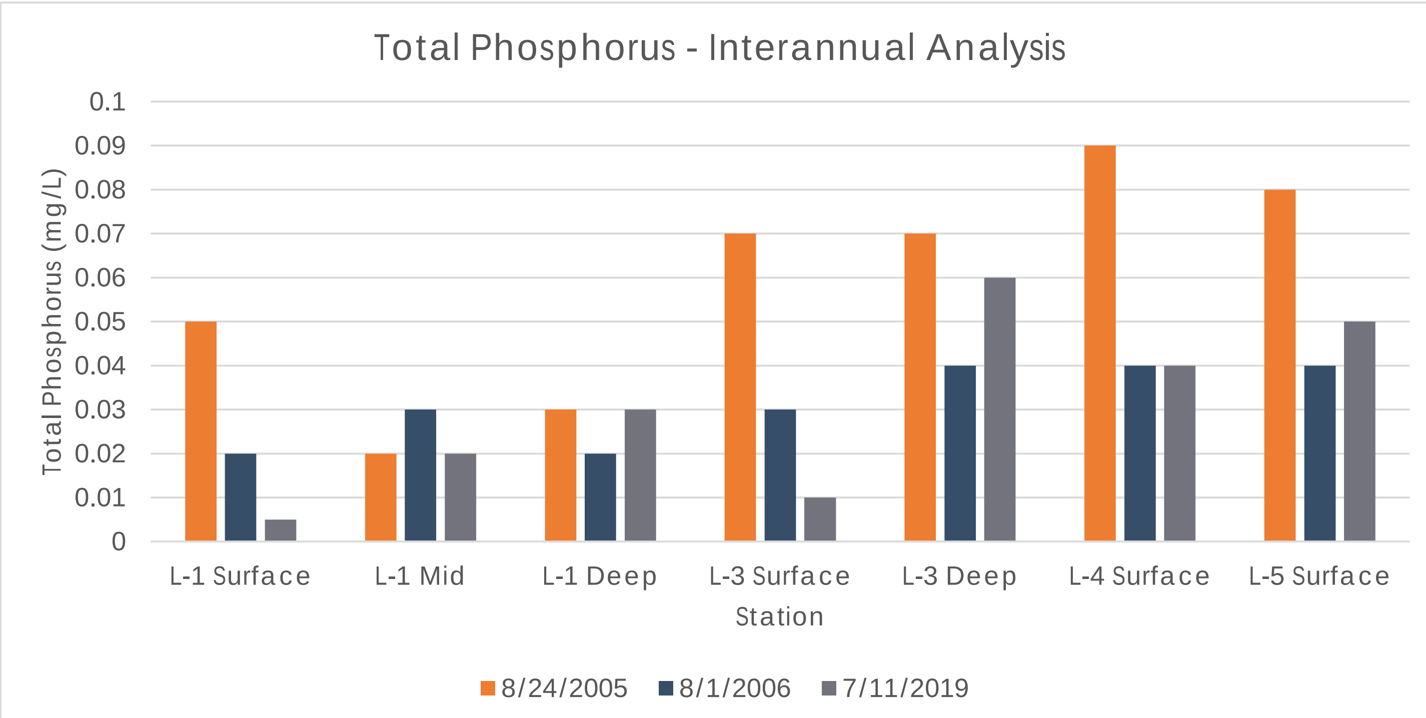


Figure 1: Total phosphorus concentrations in Greenwood Lake from 2005, 2006, and 2019.

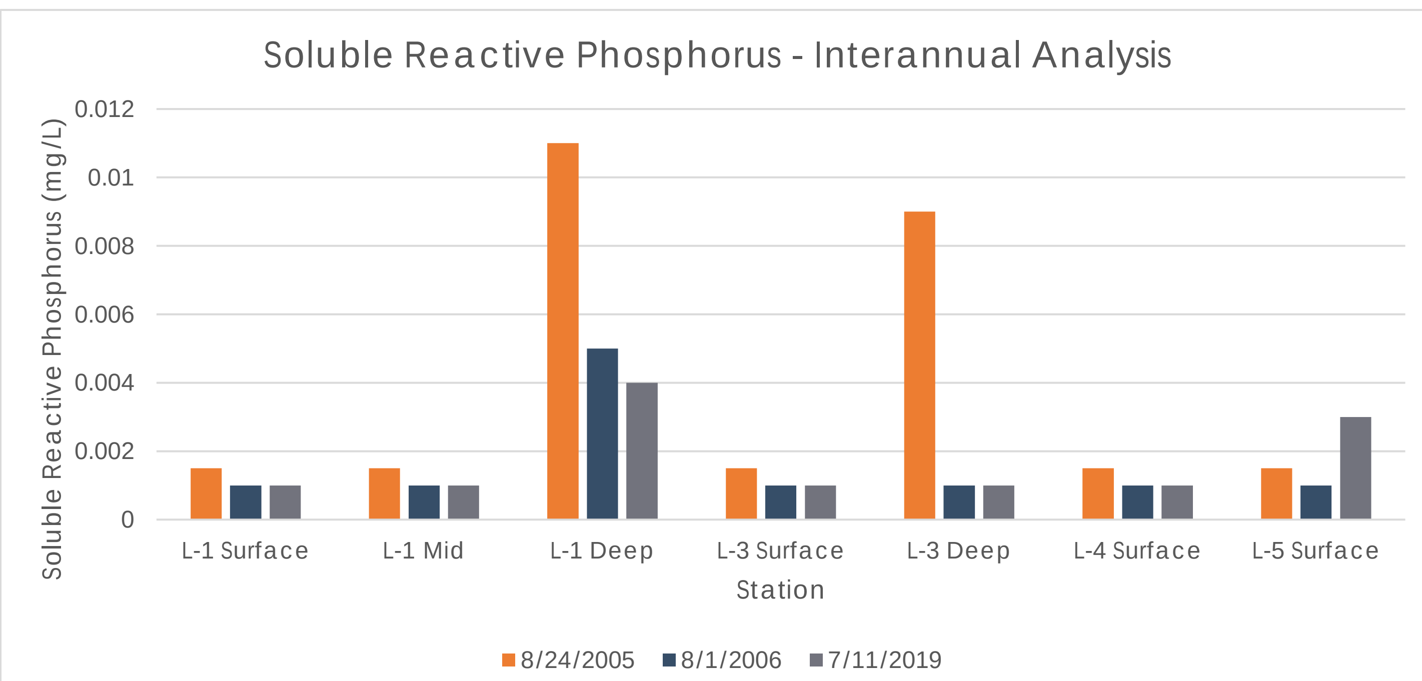


Figure 2: Soluble reactive phosphorus concentrations in Greenwood Lake from 2005, 2006, and 2019

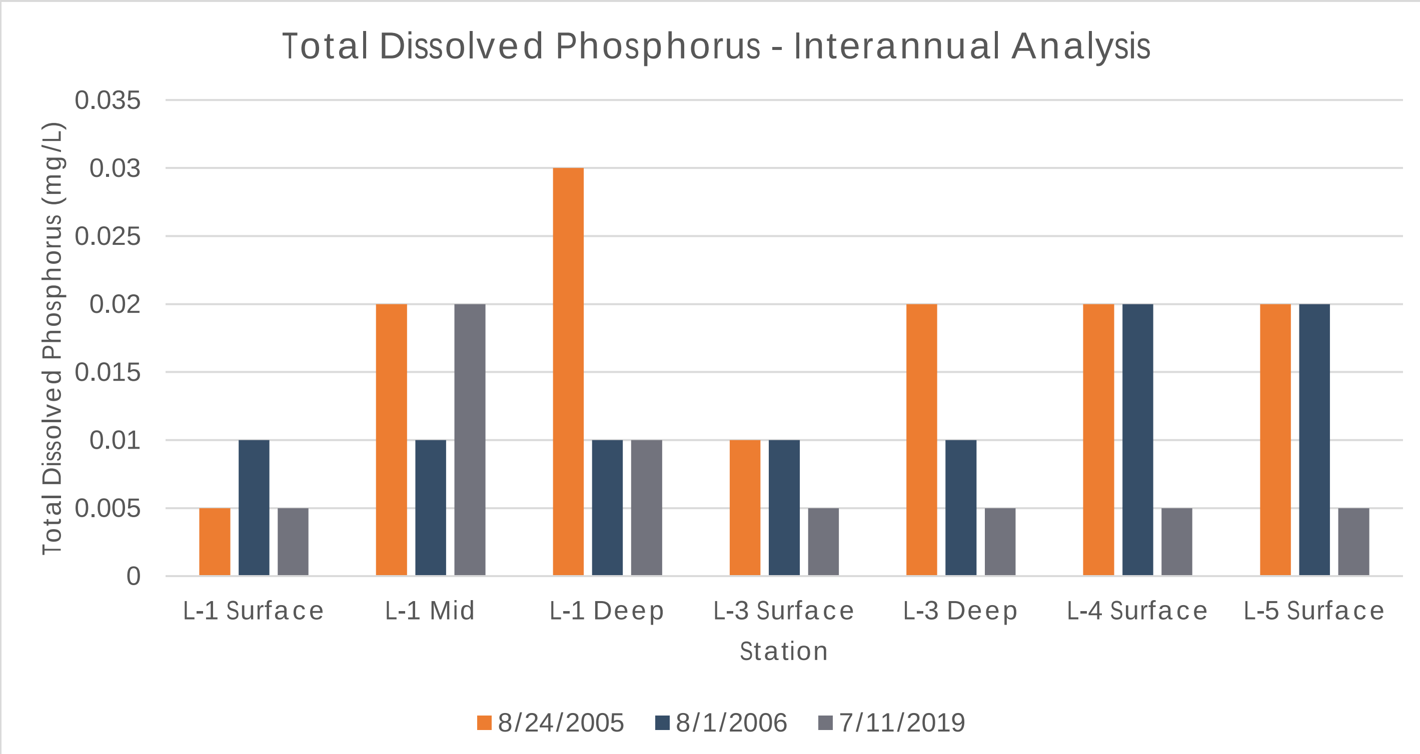


Figure 3: Total dissolved phosphorus in Greenwood Lake in 2005, 2006, and 2019.

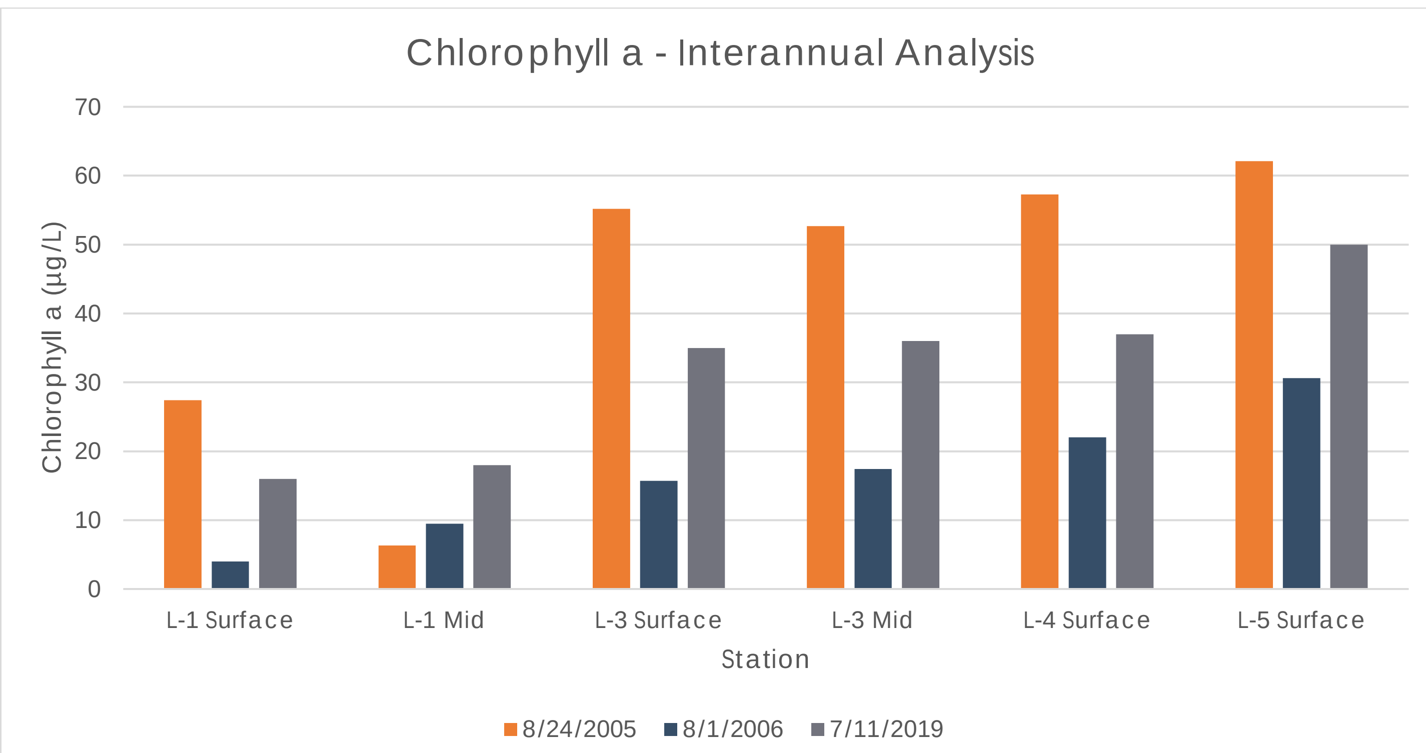


Figure 4: Chlorophyll *a* concentrations in Greenwood Lake in 2005, 2006, and 2019.

In addition to lake monitoring throughout the 2019 season, Princeton Hydro conducted sampling of various tributaries of Greenwood Lake (Appendix A at the end of the full water quality report). The purpose of this sampling was to determine sources of nutrient loading throughout the watershed in order to locate areas which may be prioritized for management efforts. Similar to the in-lake sampling, the tributary sampling in 2019 was conducted at the same sites that were sampled during the 2005 – 2006 season. Locations of all tributary sampling sites can be found in Appendices A and B at the end of the full water quality report. The tributaries were all sampled and analyzed for TP, and the results are presented in Figure 5 for 2005 – 2006 and Figure 6 for 2019.

Overall, nutrient loading in the various tributaries followed similar trends in 2019 to those observed in 2005 – 2006. For example, T-6 had the highest nutrient concentrations during both time periods, although the July and September sampling events in 2019 were much higher than those observed in 2005 – 2006; TP concentrations reached a maximum of 1.8 mg/L on 11 July 2019. Sampling site T-5 had the second highest TP concentrations during both time periods, although the July event was again much higher in 2019. All other tributaries were much lower in TP concentrations than T-5 and T-6 during both time periods, with nutrient concentrations varying between 0.005 mg/L – 0.1 mg/L. All other tributaries did not necessarily exhibit a reduction in TP concentrations between the time periods, and in many locations were often slightly higher in 2019. TP concentrations in all tributaries besides T-5 and T-6 were slightly elevated at times, although never exceeded the New Jersey Surface Water Quality Standard of 0.1 mg/L for TP in streams. It is clear that tributary locations T-5 and T-6, located at the outlet from the former West Milford Lake at Marshall Hill Road and Morestown Brook at Marshall Hill Road, respectively, are significant sources of TP loading to Greenwood Lake and are ideal locations for the implementation of BMPs.

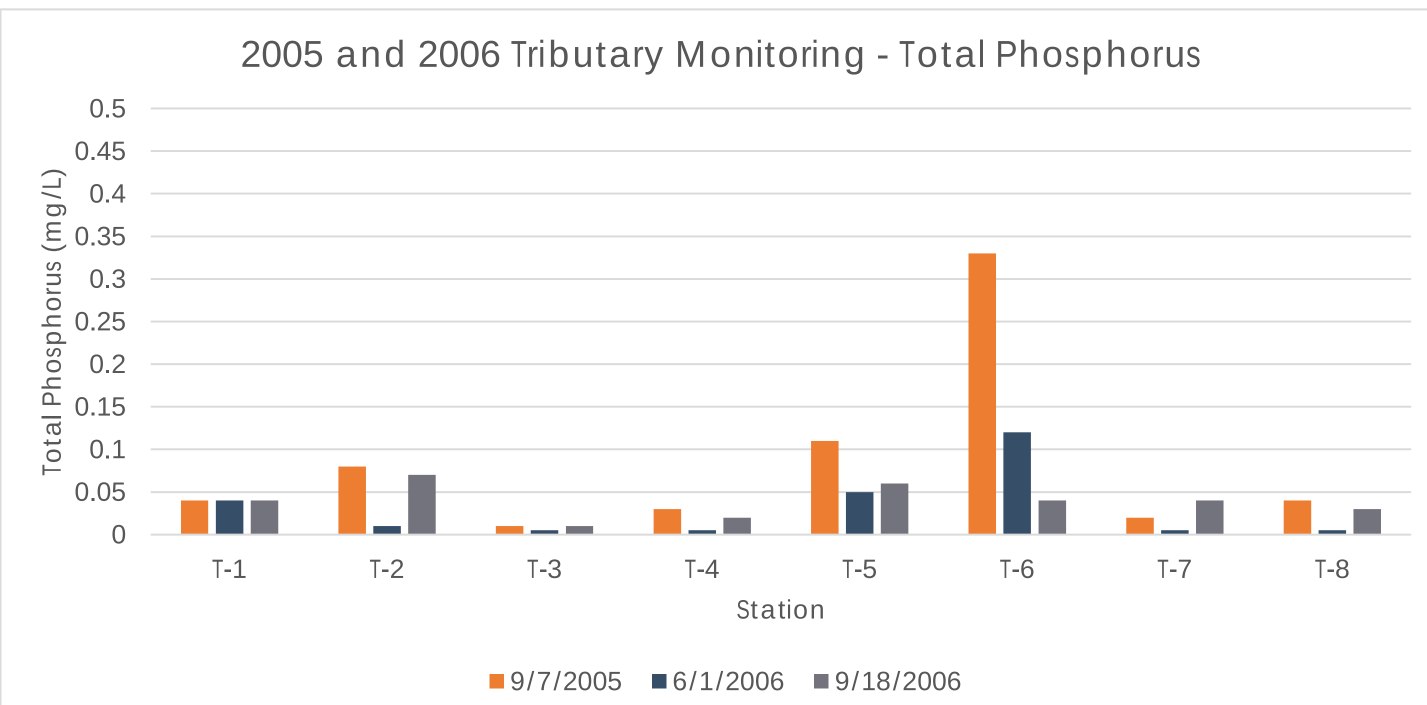


Figure 5: Total phosphorus concentrations in tributaries of Greenwood Lake on 7 September 2005, 1 June 2006, and 18 September 2006.

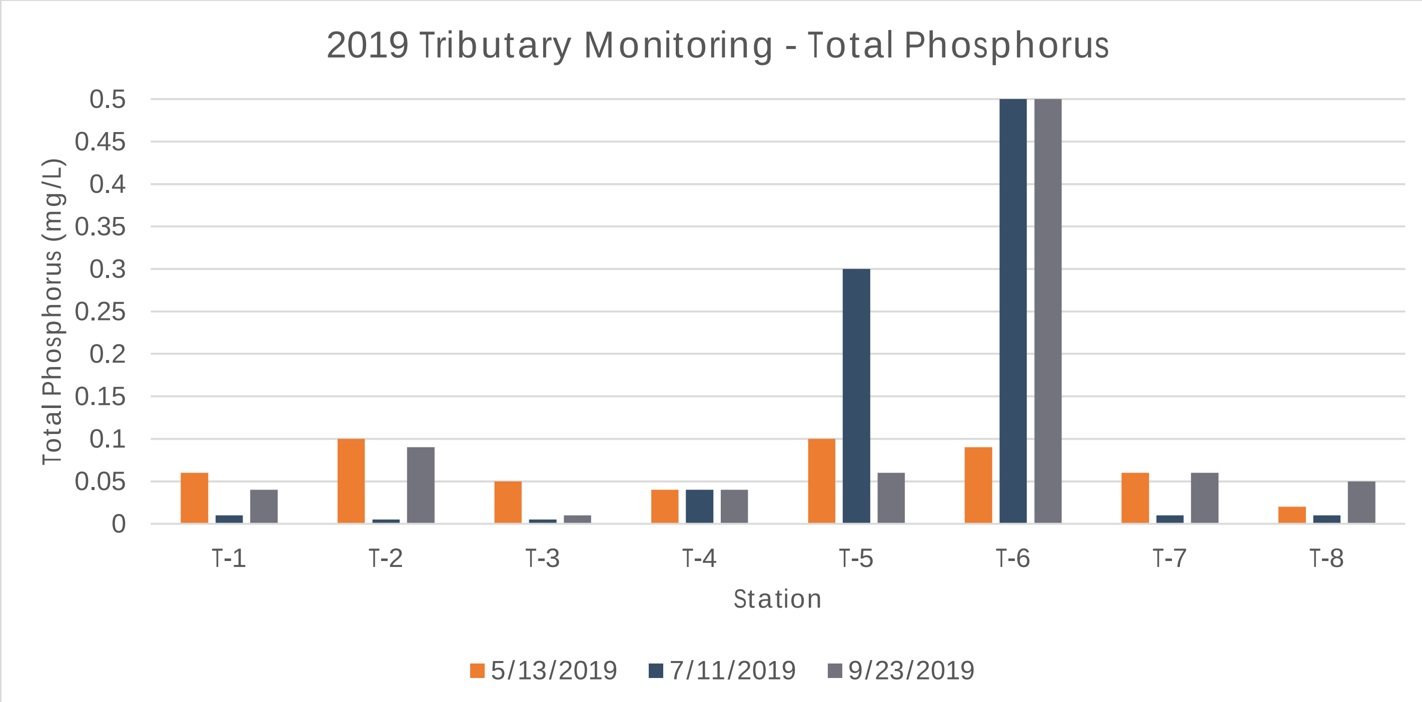


Figure 6: Total phosphorus concentrations in tributaries of Greenwood Lake on 13 May 2019, 11 July 2019, and 23 September 2019.

***Note that the actual values for 11 July 2019 and 23 September 2019 are 1.8 mg/L and 0.89 mg/L, respectively. The x-axis stops at 0.5 mg/L so all other values can be visually represented.**

INTERANNUAL TROPHIC STATE INDEX

Carlson's Trophic State index is a commonly used tool by lake managers to assess lake productivity and to track changes in eutrophication over time. Carlson's Trophic Index is a log based, single variable trophic index that uses chlorophyll *a* concentration, total phosphorus concentration, or Secchi depth to calculate an index value, from 0 to 100, to designate the productivity status of a lake.

The index was calculated by Dr. Robert Carlson through the use of regression equations on a robust dataset of North American lakes. The basic assumptions of this index are that suspended particulate matter is the primary determinant of Secchi depth and that algal particles are the sole source of this suspended matter. Given these assumptions TSI values calculated for chlorophyll *a*, total phosphorus, and Secchi disk should all be equal. Frequently they are not and systematic differences in productivity may therefore be determined through residuals analysis.

Index values greater than 50 are generally associated with eutrophic conditions and are correlated with chlorophyll *a* concentrations of 7.3 µg/L and greater. Tracking TSI values over time may provide great insight as to the rate of lake eutrophication and the benefits of management measures which serve to reduce excessive algal growth. Carlson's trophic state index for L1 and L3, as based on chlorophyll *a*, total phosphorus concentrations and Secchi disk depths are hereby presented in Table 6.

Table 6 - Historic TSI at Greenwood Lake				
Parameter	**Station**	**8/24/2005**	**8/1/2006**	**7/11/2019**
TP	L1	59	47	37
	L3	65	53	37
Chl *a*	L1	63	44	58
	L3	70	58	65
Secchi	L1	59	47	54
	L3	67	56	62

TSI was highest during the 2005 season, with TSI values ranging from 59 to 70 at L1 and L3. Values noted during the 2005 sampling year were indicative of eutrophic waterbodies and blue-green and macrophyte dominated communities. Chlorophyll *a* concentrations were greater than Secchi depth and TP, which is suggestive of large particulates like *Aphanizomenon* colonies. TSI declined at both L1 and L3 by 2006, ranging from 44 to 58. Mesotrophic conditions were noted at the deep station, as L1 yielded a marked decline in TSI with measures of 44 and 47 noted. Eutrophic conditions were still noted at L3 during this event. TSI was variable by the 2019 sampling season, with values ranging from 37 to 65. Overall, TP values were low, yielding a TSI of 37 at both L1 and L3. Both TSI based on Secchi and Chlorophyll *a* were indicative of eutrophic conditions, with slightly elevated TSI at L3 comparatively due to high cyanobacteria and macrophyte densities. Overall, TSI values were continuously elevated in the New Jersey end of the lake compared to the New York end during each sampling year.

SUMMARY OF INTERANNUAL DATA

Overall, 2005 had the highest values for all of the major trophic state indices, including TP, Secchi depth, and chlorophyll *a*; 2005 also had higher concentrations of SRP and TDP than 2006 and 2019. The trophic state indices for 2006 and 2019 were rather variable, although surface TP concentrations in the mid-lake stations were much lower in 2019. Conversely, chlorophyll *a* values were higher and Secchi depths lower in 2019 relative to 2005; these two indices are directly related, as increased algal densities (chlorophyll *a*) results in reduced water clarity (Secchi depth).

As far as progress between the two time periods stands, surface TP concentrations at the mid-lake stations in 2019 were clearly lower than the 2005 – 2006 values. As mentioned earlier, the increased algal densities (chlorophyll *a*) and related decreases in Secchi depths in 2019 are likely in part due to the climatic conditions experienced in northern New Jersey during the 2019 season. The spring of 2019 was very wet, followed by hot temperatures and short but intense rainstorms throughout the summer; these are considered to be favorable conditions for phytoplankton, and especially cyanobacteria, as witnessed in Greenwood Lake and many lakes in the northeast this past year. The heavy precipitation in the spring continually washed nutrients and other allochthonous material from the watershed into the lake, providing a source of nutrients for the cyanobacteria to feed on early in the season. A review of the full 2019 sampling data available in Appendix IV reveals that mid-lake TP concentrations were much higher (0.04 mg/L) at the surface stations during the wet spring, before dropping back down to levels that did not exceed 0.01 mg/L in July. Essentially, the blue-greens likely established a dominance over the algal community early in the season, and because of the climatic conditions mentioned above (short, intense summer rain storms), were able to dominate the algal community throughout the entirety of the 2019 season, even with relatively low TP concentrations; this in turn resulted in increased chlorophyll *a* concentrations and decreased Secchi depths. The TP concentrations were high enough early in the season to establish the community, and the other 'healthy' genera, such as the greens and diatoms, were never able to establish themselves at the same level that the blue-greens did. The intense rain storms during the summer resulted in pulses of TP loading from the watershed into the lake, which likely got assimilated rather quickly by the algae present in the surface waters.

In summary, surface TP values at the mid-lake stations during the peak summer months were lower in 2019 relative to the 2005 – 2006 values, a positive sign regarding the watershed measures that have been implemented during this time period with the intension of reducing TP loading to the lake. Unfortunately, chlorophyll *a* and Secchi depth values did not respond accordingly in 2019, but as mentioned above, this is likely in part due to the prevailing weather patterns experienced during the spring and summer. It is important to note that comparisons based on single sampling dates is limited in utility because water quality conditions fluctuate throughout the season, but as mentioned earlier in this section, the mid-summer dates of July and August provide the most consistent comparison in our database. It would be greatly beneficial to continue a monitoring program similar to that of 2019 for consecutive years in order to build a long-term database; this would make it possible to confirm that the 2019 season was indeed largely influenced by the weather and would allow for consistent seasonal means to be calculated and compared between years.

2. ESTIMATES 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 sub-watershed for Greenwood Lake that have been outlined in the TMDL and the original Stormwater Implementation Plan. **As previously mentioned, this section of the report will focus on the NJ end of the watershed.**

GENERAL APPROACH FOR ADDRESSING STORMWATER TOTAL PHOSPHORUS LOADS ENTERING GREENWOOD LAKE

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 49.7% or approximately 151.6 kg per year (334 lbs / year) (Table 7). While these reductions in phosphorus have resulted in improvements in some sections of the lake and watershed, overall water quality conditions in the lake still need improvement. This was particularly obvious during the 2019 growing season when elevated TP concentrations in May 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 7: Existing and Targeted Total Phosphorus TMDL for Greenwood Lake as of 2019.

Described Scenarios	TP in kgs (lbs) per year
Annual TP load targeted for removal	305 kg (672 lbs)
Amount of TP removed between 2006 and 2018	151.6 kg (337 lbs)
Required percent reduction to attain targeted TP load	50.3 %
Amount of TP remaining to be removed	153.4 kg (335 lbs)

OBJECTIVE PRIORTIZATION OF SUB-WATERSHEDS FOR THE WATERSHED IMPLEMENTATION PLAN

As part of the creation of the original Stormwater Implementation Plan, The New Jersey end of the Greenwood Lake watershed was divided into sub-watersheds, identified as A through P (Appendix I). Again, for the sake of this analysis and this Plan, the focus is on the New Jersey end of the watershed, including sub-watersheds A through N. While sub-watersheds O and P are located in both New York and New Jersey, the majority of their land is located in New York. In addition, forested land accounts for a substantial proportion of sub-watersheds; more than 65% in sub-watershed O and almost 90% in sub-watershed P. Given these conditions, these two sub-watersheds were not included in the New Jersey sub-watershed prioritization analysis.

Using the land use / land cover database described in the New Jersey TMDL for Greenwood Lake (NJDEP, 2004) and the Unit Areal Loading (UAL) model, NJDEP calculated the annual total phosphorus (TP) loads for the Greenwood Lake watershed. GIS software was used to divide these calculated TP loads based on the sub-watershed boundaries shown in Appendix I. Sub-watersheds A through N were then ranked from the highest TP loads to the lowest.

Ranking the sub-watershed simply based on the magnitude of their TP loads can be misleading relative to the development of a Watershed Implementation Plan. For example, a large, forested sub-watershed may have a larger TP load relative to a smaller sub-watershed with a high amount of human activities (i.e. suburban development, farming). Therefore, the sub-watersheds were also ranked based on the "developed" TP loads. Essentially, for each sub-watershed the annual TP load originating from land associated with human activities was calculated. These land types included residential, industrial, transportation, commercial, and agricultural. This sub-set of each sub- watershed's complete TP load was defined as the "developed" TP load. The sub- watersheds were then ranked from the highest TP loads to the lowest.

Finally, given the size of Pinecliff Lake, its phosphorus retention coefficient was used to quantify how much of the stormwater phosphorus that enters it is retained and does not flow into Greenwood Lake. Based on an analysis conducted as part of the original Phase I Clean Lakes Diagnostic / Feasibility Study, the phosphorus retention coefficient for Pinecliff Lake is 56%. This phosphorus retention coefficient was taken into account with sub-watersheds A through F, which account for the portion of the Greenwood Lake watershed that drains directly into Pinecliff Lake (Appendix I). The concluding results of this priority ranking analysis are provided in Table 8.

As described above, Table 8 ranks the sub-watersheds of the New Jersey side of the Greenwood Lake watershed from highest to lowest in developed TP load, taking the Pinecliff Lake phosphorus retention coefficient into consideration for sub-watersheds A through F. **This sub-watershed ranking has been updated based on the nutrient reductions from the 8 watershed projects / BMPs that have been implemented with 319 funds since the creation of the original SIP. These updated rankings do not include the watershed-wide measures, such as the use of non-P fertilizers and septic pumping, as these are not specific to individual sub-watersheds and will not change their relative rankings.** Based on this analysis, sub-watershed I still has the largest developed TP load, while sub-watershed D has the smallest TP load on the New Jersey end of the Greenwood Lake watershed. These results are strongly correlated to the land use patterns within the watershed; developed land accounts for approximately 36% of the total land area in sub-watershed I, while less than 0.1% of the land is identified as developed in sub-watershed D.

As shown in Table 8, the median value of the New Jersey developed TP load dataset was 32.9 kg. In order to further rank the sub-watersheds for the prioritization of stormwater projects, those sub-watersheds that have developed TP loads below the median value of 32.9 kg, were ranked "low". That is, sites or locations targeted for stormwater projects would be low on the prioritization list.

In contrast, those sub-watersheds that had developed TP loads twice the median value, 65.9 kg, were ranked "high". Thus, potential restoration sites or locations within those sub-watersheds that have developed TP load greater than 65.9 kg would be first of the prioritization list of projects to implement. The remaining sub-watersheds that had developed TP loads greater than 32.9 kg but lower than 65.9 kg were ranked "moderate". Thus, these projects would be implemented after most of the high-ranking projects were at least considered for implementations.

It should be emphasized that the prioritization of the sub-watersheds based on their developed TP loads is a guidance tool to aid in making long-term management and planning decisions on the selection of sites of restoration. Thus, other issues such as property ownership, potential of obtaining required easements, ownership of adjacent roadways, existing environmental constraints (wetlands, steep slopes, etc.) and actual costs for design and installation need to be taken into account when making final decisions on the selection of project sites. However, the data presented here in the Watershed Implementation Plan is a site-specific and objective strategy in initiating the TMDL-based long-term management of Greenwood Lake.

Table 8: Prioritized ranking of the sub-watersheds on the New Jersey end of the Greenwood Lake watershed.

Prioritized Sub-Watershed	Developed TP Load Per Year
Sub-Watershed I	145.4 kg
Sub-Watershed G	143.9 kg
Sub-Watershed H	74.1 kg
Sub-Watershed A	59.2 kg
Sub-Watershed F	46.0 kg
Sub-Watershed C	36.4 kg
Sub-Watershed M	36.3 kg
Sub-Watershed N	29.6 kg
Sub-Watershed L	28.9 kg
Sub-Watershed J	24.1 kg
Sub-Watershed K	23.9 kg
Sub-Watershed B	14.4 kg
Sub-Watershed E	0.2 kg
Sub-Watershed D	0.1 kg
Median	**32.9 kg**

SELECTIVE STORMWATER MONITORING

A component of this revised WIP included the collection of stormwater samples, during three separate storm events, from a sub-set of the previously implemented 319(h) grant MTDs / MBPs throughout the sub-watersheds to better quantify the pollutant removal efficiency of the various structures. The goal of this component is to use the gathered data to determine if similar projects should be considered for future implementation. During each event, downgradient samples were collected for TP and TSS at four of the eight project sights:

- Reidy Place
- Durant Road
- Beaver Avenue
- Adelaide Terrace

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 7 & 8). 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 III). Three stormwater events were completed after the sampling sites were chosen: 13 May 2019, 11 July 2019, and 9 December 2019. Results from all three stormwater events can be found in Figure 5 and Figure 6. It should be noted that a stormwater sample from Durant Road was not able to be collected on 9 December 2019 due to excessive snowpack throughout the filter strip where the sample would be taken from. There was no flowing water during the time of the site visit due to the snowpack and cold temperatures.

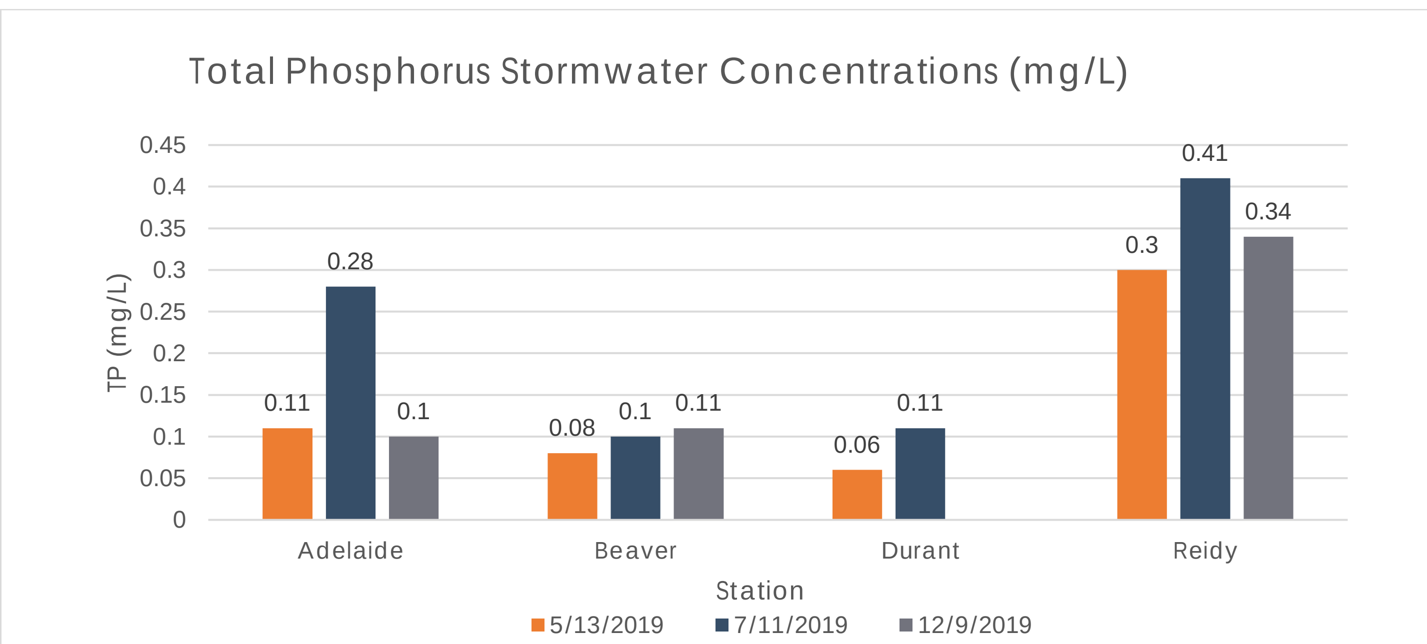


Figure 7: TP concentrations at all stormwater sampling sites on 13 May 2019, 11 July 2019, and 9 December 2019.

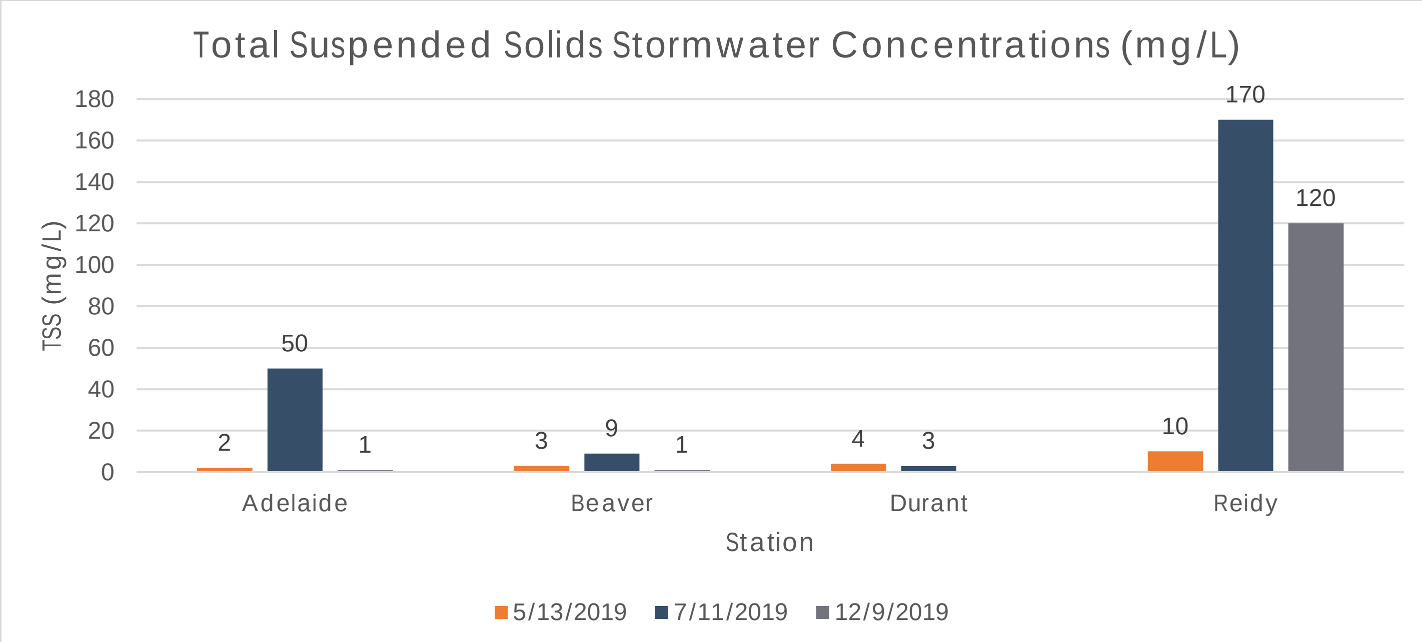


Figure 8: TSS concentrations at all stormwater sampling sites on 13 May 2019, 11 July 2019, and 9 December 2019.

DISCUSSION

Stormwater samples at Adelaide Terrace were taken directly from the outflow pipe of the nutrient separating baffle box. The samples from 11 July 2019 were elevated for both TP and TSS with concentrations of 0.28 mg/L and 50 mg/L, respectively. The other two sampling dates had similar concentrations for both parameters and were extremely low for TSS; TP concentrations remained around 0.1 mg/L. One possible explanation for the elevated concentrations in July could be that the samples were taken closer to the first flush when pollutant concentrations are expected to be the highest. TSS removals were exceptional for the other two sampling events and TP concentrations were also relatively low but would benefit from the further treatment of stormwater. As such, future recommendations for MTDs will be coupled with green infrastructure, such as bioretention systems or filter strips, wherever possible.

Stormwater samples at Beaver Avenue were taken directly from the outflow pipe of the nutrient separating baffle box at Belcher Creek. TP and TSS concentrations were similar to those at Adelaide Terrace, although concentrations during the July sampling event were not elevated to the degree that was observed at Adelaide Terrace. TP concentrations ranged from 0.08 mg/L – 0.11 mg/L and TSS concentrations ranged from 1.0 mg/L – 9.0 mg/L. Similar to what was observed at Adelaide Terrace, TSS removals in the MTD appear to be great and while TP concentrations were not extremely elevated, this site would remove more phosphorus if the MTD were coupled with green infrastructure. It is not always possible to incorporate green infrastructure, as was the case with the Adelaide Terrace and Beaver Avenue MTDs but will be incorporated wherever possible moving forward.

Samples were taken from the outflow of the filter strip at Durant Road after passing through the nutrient separating baffle box. The mean concentrations of both TP and TSS from the two sampling events at

Durant Road were the lowest of the four sites. TP concentrations ranged from 0.06 mg/L – 0.11 mg/L and TSS concentrations from 3.0 mg/L – 4.0 mg/L. The reason for the reduction in TP concentration relative to the other sites is likely due to the extra treatment that the stormwater receives when passing through the filter strip. In addition to the lower nutrient concentrations, the filter strip also reduces the quantity of stormwater that enters Belcher Creek via surface flow due to the associated infiltrative properties, further lowering the nutrient load. As such, this set of BMPs appears to be the most effective of the four sites that were sampled and will be considered for future implementation wherever applicable.

Stormwater samples at Reidy Place were taken from the catch basin that the curbside storm drain with the Filterra tree box empties into. It is important to note that the stormwater samples are not fully representative of this BMP because multiple storm drains empty into the catch basin that was sampled which do not have associated BMPs. Measures were taken for the samples to be taken directly from the pipe in the catch basin associated with the Filterra, but this was not always applicable due to flow rates. As such, these samples also included water that was draining directly off the street and into the catch basin where the sampling was conducted. Not surprisingly, both TP and TSS concentrations were the highest here compared with the other sampling sites. While this is not ideal for the sake of quantifying nutrient reductions associated with the Filterra unit, the stormwater samples give a relative idea of unfiltered pollutant concentrations from a residential street, similar to the locations where the other BMPs are located. It can then be inferred from these concentrations that the other three BMPs are efficiently reducing pollutant concentrations.

It should also be noted that during the field assessments of each of these project sites to observe their existing status, it was determined that all of the MTDs implemented under the 319 grants should be cleaned out, as they had not yet been cleaned this year and were showing varying signs of in-filling. Thus, the nutrient separating baffle boxes associated with the stormwater sampling are likely not functioning to their full capacity and would further reduce pollutant loads if properly maintained. It is not currently known if the MTDs had been cleaned out by the final stormwater sampling event in December; the MTDs would need to be opened for this assessment.

3. 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 the 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.

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 Greenwood Lake. 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 9).

The location of all sites can be found on the Candidate BMP Site 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.

The cost estimates provided below are estimates for the entire project phase, including design, engineering, possible permitting, and implementation / installation. While the cost estimates are predicted based on the entire project phase, final costs will almost certainly vary based off of the many components that are involved in project implementation. Some of these components include, but are not limited to:

- **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 costs 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. While general permitting costs were estimated in the proposed cost for each project, these do not include permits specific to the Highlands Region. Due to the location of West Milford in the protected Highlands Region, additional permitting may be required.

- **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 prior to the initiation of a project.

It should also be noted that due to the location of West Milford in the New Jersey Highlands Region, Highlands Act exemptions may be required for certain projects depending on the type of property. These potential Highlands Act exemptions were not considered during the creation of this document, and thus will need to be considered during the next phase of project development.

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 riparian restoration along Belcher Creek and will include recommended restoration measures and very general price estimates.

SUB-WATERSHED G

SITE 1: FORMER WEST MILFORD LAKE AND DAM

Due to New Jersey Dam Safety compliance requirements, West Milford Lake has been lowered and is maintained in this state with siphons and pumps. The impoundment previously served as a forebay to Belcher Creek and Greenwood Lake where energy would be dissipated and nutrient-laden sediment would settle out of the water. In the lowered condition, it is not providing these benefits. The site of the former West Milford Lake still receives a large portion of stormwater runoff from sub-watershed G and the water is currently being siphoned near the dam. Drainage areas calculated from StreamStats reveal that runoff from the two major residential areas located south of the former lake drain almost entirely to this site, eventually flowing into a small tributary of Belcher Creek.

Recommended Measures: The former lake could be converted into a wetland BMP for sub-watershed G. Such a BMP would have the capacity to remove a substantial portion of the TP load that eventually flows into Belcher Creek and, in turn, Greenwood Lake. The concept would be to grade a channel through the impoundment, provide access to the floodplain in small stormwater events, provide a stable and natural connection to the downstream channel and plant native vegetation optimal for the hydrology within the impoundment. These improvements would lengthen the flow path, reduce the channel slope, provide flood storage, filter sediment and nutrients and sequester nutrients.

In addition to converting the site into a functional wetland BMP, the stabilization of the discharge channel and removal of the spillway and/or portion of the earthen embankment would be necessary to provide a connection of the channels. An additional benefit to the project is that it would deregulate the dam. While such a project has the potential to address a substantial portion of the phosphorus load entering Greenwood Lake, a considerable amount of planning, design work and public education would be required for its successful implementation.

Estimated Costs: To convert the existing site into a wetland BMP is estimated to cost approximately $2.5 million.

SITE 2: SHOP-RITE PARKING LOT (ACROSS FROM WEST MILFORD LAKE DAM)

The Shop-Rite and other retail stores are located at the intersection of Union Valley Road and Marshall Hill Road has a large paved parking lot with several catch basins located throughout. These catch basins are connected subsurface, eventually draining into an unnamed tributary of Belcher Creek located near the northeast corner of the parking lot. In addition to a large catch basin that is located in the northeast corner of the parking near the discharge point, there is also a large grassy area in the vicinity of the discharge pipe and the creek.

Recommended Measures: This site would be an ideal candidate for the connection of a manufactured treatment device (MTD) with a bioretention system located just downgradient, also referred to as a treatment train. The MTD would be located just upstream of the existing inlet box and serve as pretreatment for the bioretention system. It is anticipated that the existing inlet would need to be replaced to accommodate the MTD discharge and include a diversion of flows into the bioretention system. The project may also include curb cuts, invasive species control and stabilization of the pipe discharge location. This treatment train will provide removal of sediment and trash from the pipe network and filtration of the stormwater before being discharged back into the creek.

There are other catch basins and storm drains around the parking lot that could also be retrofit with smaller MTDs and/or Filterra tree boxes.

Estimated Costs: The estimated cost of the design and installation of a nutrient separating baffle box and the bioretention system is approximately $406,300. The estimated cost of the design and installation of a filterras is approximately $130,000 per unit.

SITE 3: TRIBUTARY AT THE END OF ADELAIDE TERRACE

A nutrient separating baffle box has already been installed at the end of Adelaide Terrace through previous 319 funds. As such, there is not much left to be done on the road itself, but the unnamed tributary that the baffle box discharges into is located at the terminus of the road. There is a landscaped area between the edge of pavement and the stream bank which is currently mulched with a few trees. Additionally, the streambank on river right is disconnected from the woody floodplain and is approximately vertical.

Recommended Measures: The first recommended measure at this location is the enhancement of the riparian buffer between the bank and Adelaide Terrace to better filter stormwater runoff and filter nutrients and sediment.

The streambank on the opposite side could be stabilized to include floodplain benches in addition to toe protection. This streambank can be graded back to a gentler slope, allowing for more flood storage during periods of heavy precipitation and could act as a wetland storage area, filtering nutrients and other pollutants.

Estimated Costs: The estimated cost of the enhanced riparian buffer is approximately $42,600. The river right bank stabilization is estimated to cost approximately $138,300.




SITE 4: REAR PARKING LOT ON NEW JERSEY AVENUE

The rear parking lot behind the small strip of stores on the corner of New Jersey Avenue and Union Valley Road is located directly next to Belcher Creek and is almost entirely made of loose gravel. The rear half of the parking lot was not being utilized during the two site visits that Princeton Hydro made to this site and appears to be unfinished due to the curbing within the vegetation. There is a lack of a riparian buffer between the parking lot and Belcher Creek and there is a large patch of the invasive *Phragmites australis* (phragmites) near the back corner of the parking lot where pollution from trash and other debris is extensive.

Recommended Measures: The rear gravel parking lot would be an ideal location for the conversion into a vegetative filter strip. This would involve replacing the loose gravel with grass and native meadow vegetation that would act as a nutrient reducing buffer between the remaining parking lot and Belcher Creek. This process would remove the loose gravel and sediment in this location that gets carried into Belcher Creek during storm events, and the vegetative buffer would filter out additional pollutants.

The patch of phragmites in the back corner of the parking lot should also be removed and replaced with native vegetation that would function as a rain garden. The installation of the rain garden could possibly require some minor modifications to deepen the depression but would work to further reduce the nutrient load into Belcher Creek.

Estimated Costs: The estimated cost of the design and implementation of the extended filter strip is approximately $203,500 and the rain garden is approximately $105,500.

SITE 5: FRONT PARKING LOT ON NEW JERSEY AVENUE

The parking lot on Union Valley Road in front of the small strip of stores located across from the Pinecliff Lake Dam has a substantial amount of sediment/road grit built up throughout. This parking lot is located directly adjacent to Belcher Creek and has a curbside storm drain that drains directly into the creek (see photo below). The right bank of Belcher Creek on the same side of the parking lot is eroding and is a source of sediment and nutrients to Belcher Creek.

Recommended Measures: All of the sediment/road grit should be cleared out of the parking lot before any further work is done to this site. This location appears to be the primary point where snow would be pushed and would benefit from a curb to stop the plows from pushing snow and sediment right to the bank of the creek as well as minor adjustment to the pavement grades so grit could accumulate in a location/system that is more maintainable. These improvements would be further beneficial if installed with nutrient separating baffle box MTD along the existing pipe at the end of the parking lot that drains directly into Belcher Creek. Additionally, the streambank in the vicinity of the pipe discharge should be stabilized to prevent future erosion. Bank stabilization methods could include the planting of vegetation where the slope allows and through the installation of rip-rap to prevent further bank scour.

Estimated Costs: The estimated cost of the design and installation of a nutrient separating baffle box and the streambank stabilization work is approximately $293,800.

SITE 6: PARKING LOT BEHIND BAGEL TOWN CAFÉ

This parking lot located between a small strip of stores and Belcher Creek already has two existing stormwater basins that can be modified and enhanced to reduce the nutrient loads to Belcher Creek and Greenwood Lake. There is currently a dry detention basin located in the middle of the parking lot that receives stormwater from this site. In addition to the dry detention basin, there is also a wet pond located just behind the parking spots in the southern end of the parking lot. This wet pond is located in close proximity to Belcher Creek and appeared to be discolored and in poor condition during the site visit. The wet pond receives that discharge from the dry detention basin in addition to overland flow from the adjacent parking lot. It is understood that the combination of these two basins provides compliance with the NJ stormwater regulations for the property and therefore the proposed imports shall restore the system to meet or exceed the minimum requirements for water quality, quantity and recharge if applicable.

Recommended Measures: There are multiple recommendations that will complement each other and can be completed as a single large project or multiple smaller projects.

1. Retrofit the dry detention basin in the middle of the property to function as a bioretention basin that would provide increased nutrient sequestration. This retrofit would likely include modifications of the existing pipe system to ensure the runoff enters the basin, minor regarding in the basin, possible curb cuts, and a berm along the down gradient edge of the basin to provide the necessary storage volume. Pending further investigation, installation of bioretention media with an underdrain will complete the conversion to a bioretention system. The basin area would be tilled and stabilized with native vegetation.
2. The wet pond located at the south end of the property would be improved to increase nutrient sequestration through the addition of vegetation and the likely elimination of a potential HABs source. The wet pond would likely be converted into a wetland basin. This conversion will likely include modifications to or replacement of the basin outlet structure, regrading of the basin side slopes, and vegetating the basins with native plant species. This project would benefit from the conversion of some parking spaces to allow the basin to be enlarged or alternatively, parking spots could be turned into vegetated pavers, allowing for increased filtration of stormwater while preserving the parking spots.

Pictures can be found on the following page.

Estimated Costs: The estimated cost of the design and implementation of the bioretention basin is approximately $253,100. The estimated cost of the design and implementation of the conversion of the wet pond to wetland basin is approximately $280,900.

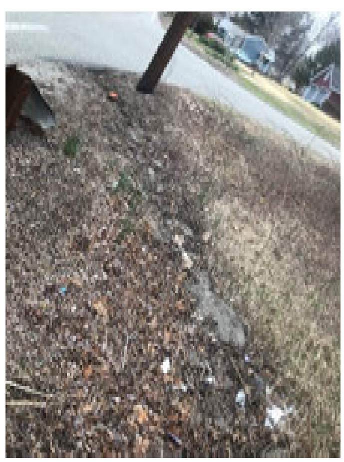
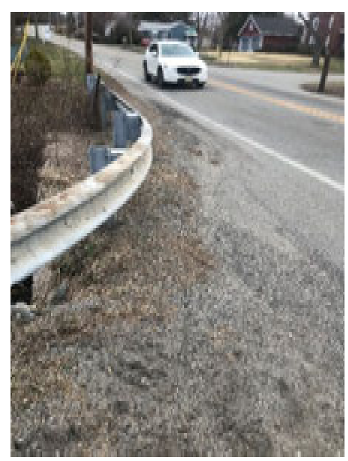
SITE 7: POND AT THE CORNER OF EDGECUMB ROAD AND UNION VALLEY ROAD

There is a pond located on the corner of Edgecumb Road and Union Valley Road that receives water from a small unnamed stream as well as stormwater from Union Valley Road and the adjacent intersection before eventually emptying into Belcher Creek. There is a small forebay where the stream enters the pond that is at capacity with sediment and organic matter. The drainage area immediately surrounding the forebay is eroding and sediment/road grit from the streets has built up because there are no curbs on Union Valley Road or Edgecumb Road to direct the stormwater towards the catch basin that is located directly in front of the forebay. This forebay needs to be cleared out and the loose sediment on the adjacent road should be cleaned up if the forebay is to efficiently reduce the TSS and nutrient loads entering Belcher Creek and Greenwood Lake.

Recommended Measures: The first recommended measure at this site involves the reconstruction of the forebay to better handle the sediment and associated nutrient loads before the pond discharges to Belcher Creek. This reconstruction would involve the removal of accumulated sediment and organic material from the forebay. Additionally, some boulders or other hard substrate could be added to better maintain the structure of the forebay and prolong the functionality. In addition to reconstructing the forebay, the current catch basin should be replaced with deep drop inlets that would capture sediment from the surrounding streets before it was to enter the forebay. It should be noted that the removal of accumulated materials from a drop inlet can more easily be completed with a vacuum truck. Curbs should be added to Union Valley Road and into Edgecumb Road to direct the stormwater into the deep drop inlet and prevent future erosion of the area surrounding the forebay. While these measures are largely directed at reducing TSS loads, the TP load would also be reduced in the process, and these measures have the potential to greatly reduce sediment loads.

Estimated Costs: The estimated cost of the forebay reconstruction and associated catch basin work is approximately $422,000.



SITE 8: GWYNETH ROAD AND GLENCROSS ROAD

There is a catch basin at the corner of Gwyneth Road and Glencross road that drains to Belcher Creek located behind Glencross Road. This catch basin is the last inlet on Gwyneth Road prior to a pipe connection to the existing floodplain. This inlet accommodates all of the stormwater runoff from this street. There is also a large grassy area directly behind the catch basin that is located between two separate properties on the corner of the two roads.

Recommended Measures: This site is an ideal candidate for the installation of an MTD that discharges into a vegetative filter strip, allowing for the further treatment of stormwater. The nutrient separating baffle box should be installed in the pavement between the inlet and the grassed buffer as this is the most down gradient catch basin to the discharge point and would therefore treat the largest quantity of stormwater from this community. Additionally, the discharge pipe could be daylighted closer to the edge of pavement and converted into a vegetated buffer or swale.

Estimated Costs: The estimated cost of the design and installation of a nutrient separating baffle box and the vegetated filter is approximately $217,700.

SITE 9: HEADWALL OF BELCHER CREEK AT GLENCROSS ROAD

The downstream side of Glencross Road at the Belcher Creek stream crossing is actively eroding from runoff and is creating a sediment bar just downstream in the channel to Belcher Creek. There are currently sandbags installed as a method to control the erosion and stabilize the area. The erosion of the bank is creating a sizeable hole in the road that is already a safety concern and will only get worse if not addressed. While this site is not a huge priority for nutrient reductions, the eroding road should be addressed as a safety concern.

Recommended Measures: This site would benefit from the construction of a headwall along Glencross Road to prevent the future erosion into Belcher Creek.

Estimated Costs: The estimated cost of the design and installation of a headwall is approximately $115,000.

SUB-WATERSHED H

SITE 10: ATHLETIC FIELDS AND FAMILY PUMP TRACK

The athletic fields and family pump track (bike course) are located behind a paved parking lot. The stormwater from the parking lot and approximately half of the athletic fields drains to a “swale” located between the two before draining to a small tributary of Morestown Brook on the west side of the property. There was pooling of water in the “swale” during the site visit and the drainage appeared to be extremely poor, with a large portion of the drainage path lacking any grass or other vegetation.

Recommended Measures: This site would be an ideal candidate for replacing the current “swale” with a bioretention swale that would capture, treat/filter, and convey the stormwater in a much more efficient manner. The bioretention swale would greatly reduce nutrient loads that drain to Morestown Brook and eventually Belcher Creek and Greenwood Lake. This site would also be a great location to incorporate educational material on a sign highlighting the importance of stormwater management because of all the foot traffic associated with the athletic fields and bike course. The slope from the athletic fields should be vegetated with meadow or similar lower maintenance vegetation with specified paths from the parking lot to the facilities.

Estimated Costs: The estimated cost of the design and installation of a bioretention swale, vegetated filter, and associated education materials is approximately $272,100.

SITE 11: MARSHALL HILL ELEMENTARY SCHOOL AND ROAD

This set of projects had already been designed under a previous 319 grant but was never implemented due to logistical complications relative to property ownership logistics with the Green Acres program and the related timing constraints as well as regulatory review. However, the plans were retained and currently make an excellent candidate for future grant funding under the 319 program. This set of plans is essentially shovel ready from a design standpoint.

Recommended Measures: The Marshall Hill Road and Marshall Hill School project would involve a series of activities including the enlargement of a culvert, the diversion of stormwater and vegetated conveyance, and some additional streambank stabilization work. In addition, a rain garden / biofiltration system would be installed in front of Marshall Hill School. The rain garden / biofiltration system would include some signage and would be used for educational purposes as well.

Estimated Costs: The estimated cost for the completion of the Marshall Hill Road and Marshall Hill School project is approximately $790,000. However, this does not account for any updating to the engineering design or permitting.

SITE 12: ALMOND BRANCH CHURCH

Almond Branch Church is located on Marshall Hill Road just west of Marshall Hill Elementary School and Morestown Brook. The church has a few grassy areas in front of the building along Marshall Hill Road. There are also a few catch basins located on Marshall Hill Road along the grassy area in front of the church property. The parking lot is paved in the front entrance area, but the back half of the parking lot is gravel. There are signs of accumulated gravel on the grass, likely a result of snow removal activities. There is a row of trees along Morestown Brook but there is room between the parking lot and the stream to extend the riparian buffer. This site would be an optimal demonstration site to showcase a few different BMPs due to the multiple locations on site that show relatively low daily traffic.

Recommended Measures: As mentioned above, this site has the potential to showcase a few different types of BMPs; the demonstration projects would reduce the pollutant load to Morestown Brook at this site and would exhibit different BMPs to the public.

1. The first recommended BMP at this site would be the installation of a bioretention system in the large grass area at the front of the property. There is another smaller grass area to the east of the large one, and it may be possible to create a second bioretention system here and connect it to the larger one; Morestown Brook is located just to the east of this smaller area.
2. The second recommendation at this site and the focus of the demonstration project would be the installation of pervious and/or vegetated pavers in the gravel section of the parking lot. This would eliminate the loose gravel that is accumulating along the side of the parking lot where Morestown Brook is located and would allow for most of the runoff in the parking lot to be filtered by the soil and vegetation instead of carrying pollutants into Morestown Brook. As part of the demonstration project, multiple types of pervious/porous/grass pavers could be implemented in different parts of the parking lot.

Estimated Costs: The estimated costs for the design and installation of the bioretention system(s) and pervious paver demonstration project is approximately $985,000.

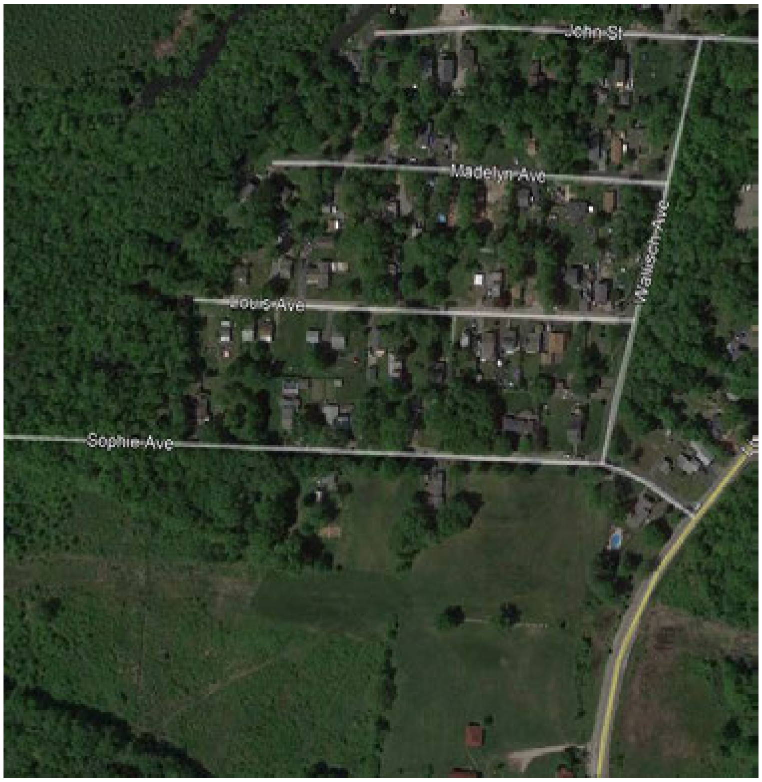
SUB-WATERSHED I

SITE 13: DEVELOPMENT WEST OF LINCOLN AVENUE (LOUIS, MADELYN, SOPHIE AVENUES AND JOHN STREET)

This entire area was included in the original SIP as a potential candidate for the installation of multiple BMPs although nothing was ever implemented due to complications with shallow groundwater and minimal public property. Due to the close proximity to Belcher Creek, this community is still viewed as a strong candidate for an implementation project. This entire community has individual onsite septic systems, and because of the proximity to Belcher Creek, even systems that are pumped regularly still release phosphorus to Belcher Creek and Greenwood Lake. It is understood that stormwater is not necessarily the primary nutrient source in this community as road side swales are vegetated with minimal signs of erosion, and minimal gradient. It should be noted that a large publicly owned upland property is located to the south this community. This proposed project would require a Highlands Preservation Area Approval Waiver from DEP, in which a public health and safety concern would need to be proved. While this would likely be an involved project, this site is still considered a strong candidate for the localized reduction of a large amount of phosphorus.

Recommended Measures: This community as well as Belcher Creek and Greenwood Lake would benefit from becoming a sewered community. The sewering would be not be connected to the other sewered sections of West Milford Township but instead have its own community treatment system located to the south of the community. The proposed system is anticipated to connect to the existing watertight septic tanks at each residence, flow via gravity pipes to the mains in each of the streets, a lift or pump station near the intersection of Sophie and Wallisch Avenues. The pump station would discharge to a treatment facility and ultimately be discharged via land application. It has also been suggested that this community might be well served by being connected to an existing plant like Birch Hill.

Estimated Costs: The estimated cost for the design and implementation of a community wastewater treatment system in the open green space is approximately $5.6 million. Connection to an existing plant has not yet been estimated.



SITE 14: UNION VALLEY ROAD AND WARWICK TURNPIKE

This was another site that was included in the original SIP as a potential candidate for the installation of multiple MTDs although nothing was ever implemented. This site is still viewed as a strong candidate for restoration work, although focused on the stream, Cooley Brook, rather than retrofitting the catch basins. The focus is the stream reach located between Union Valley Road and Warwick Turnpike, directly next to 3 Roads Deli and Grill. The streambanks on both sides are rather steep, lack sufficient vegetation and are eroding in multiple locations, with some of the erosion approaching the parking lot. Some of the drainage paths that lead from the road to the stream are also eroding. The stream is lacking a vegetated buffer, especially directly downstream and upstream of the wooden foot bridge.

Recommended Measures: This site is an ideal candidate for bioengineered streambank stabilization from Warwick Turnpike to Union Valley Road and on both streambanks. This could include boulder toe with vegetated soil wraps. This will require regrading of the slopes and excavation in order for proper placement of the stabilization measures. The increased vegetative cover along the streambanks will better hold the soil in place and the installation of boulder toe protection with vegetation will prevent future erosion. In addition to the stream, the drainage path between Warwick Turnpike and Cooley Brook could also be addressed to prevent the future erosion and to assist in nutrient removal from stormwater runoff. This work could consist of bioengineered stream bank with stabilized conveyance systems on both sides of the stream. It may be possible to replace the outflow pipe that drains water from Warwick Turnpike along the left bank of Cooley Stream with vegetated conveyance system that would aid in nutrient removal, but further investigations would be required.

Pictures can be found on the following page.

Estimated Costs: The estimated cost for the design and implementation of road to road bioengineered streambank stabilization is approximately $570,000.

The estimated cost for the design and implementation the bioengineered bank stabilization with vegetated conveyance systems is approximately $150,000.

SITE 15: OUR LADY QUEEN OF PEACE CHURCH

Our Lady Queen of Peace church is located on the corner of Union Valley Road and Elm Street. There is a catch basin located in a small depression on the grassy area of this corner. The concrete structure of the catch basin appeared to be in poor condition during the site visit and organic debris was built up on top of the grate. There are no curbs or swales on the adjacent road, and the grass area between the road and catch basin was also showing signs of erosion and sedimentation.

Recommended Measures: The catch basin in the grassy area on the corner of Union Valley Road and Elm Street is an ideal candidate for the installation of a rain garden. The rain garden would receive runoff from both Union Valley Road and Elm Street and would reduce the discharge rate of stormwater by allowing the water to infiltrate into the soil, and the plants would utilize some of the available nutrients.

Estimated Costs: The estimated cost of the design and installation of a rain garden on the corner of Union Valley Road and Elm street would be approximately $176,300.

SUB-WATERSHED J

SITE 16: ELKS LODGE

Cooley Brook passes across the back of the Elks Lodge property right before it empties into Green Brook. The streambanks appeared to be in relatively good condition, although the right bank lacked a sufficient vegetative buffer between the stream and the Elks Lodge property. Minor erosion is occurring under the foot bridge that is causing a widening of the stream here. There is also a downed tree just upstream of the foot bridge that is likely causing head cut erosion on the streambed.

Recommended Measures: The first recommended measure at this site is to enhance the riparian buffer between the stream and Elks Lodge from a grass to meadow buffer to help intercept stormwater and reduce the nutrient loads. The downed tree in the stream should also be removed to allow for the natural flow of water under the bridge.

Estimated Costs: The estimated cost for the enhancement of the riparian buffer and the removal of the downed tree is approximately $75,000.

Table 9: Proposed Stormwater Projects Summary

Site and Recommendations	Total P Removed (kg/yr)	Total Suspended Solids Removed (kg/yr)	Estimated Costs
West Milford Lake Constructed Wetland	15.0	54,000	$2,519,000
Shop Rite Nutrient separating baffle box Bioretention system	2.50	1,700	$536,300
Adelaide Terrace Stream Riparian buffer enhancement Right bank grade control	5.0	40,000	$180,900
New Jersey Avenue – Rear Lot Extended vegetative filter strip Rain garden	0.75	700	$308,500
New Jersey Avenue – Front Lot Nutrient separating baffle box Streambank stabilization	0.5	300	$293,800
Bagel Town Café Rear Lot Retrofit dry detention basin Retrofit wet pond Grade control / enhanced filter strip	1.0	650	$534,000
Union Valley and Edgecumb Rd Pond Forebay reconstruction Deep drop inlet and road curbs	2.0	6,500	$422,000
Gwyneth Road and Glencross Road Nutrient separating baffle box Bioretention system	0.75	1,000	$217,700
Belcher Creek at Glencross Road Headwall installation	-	-	$115,000
Athletic Fields Bioretention swale	1.0	1,000	$272,100
Marshall Hill Road and School Stream stabilization / water diversion Vegetated Swale Rain garden	5.5	20,000	$790,000
Almond Branch Church Bioretention system(s) Pervious pavement	1.0	1,000	$985,000
Development West of Lincoln Avenue Community wastewater system	23.0	-	$5,600,000
Union Valley Road and Warwick Tpk Bioengineered streambank stabilization Bioengineered stabilized conveyance systems	6.0	20,000	$570,000
Our Lady Queen of Peace Church Rain garden	0.5	150	$176,300
Elks Lodge Stream Enhanced riparian buffer Removal of downed tree	3.0	20,000	$75,000
Totals	**67.5**	**167,000**	**$13,745,600**

BELCHER CREEK ASSESSMENT

As numerous empirically and model-based studies have confirmed, Belcher Creek and its immediate drainage areas are the largest sources of TP and other pollutants (e.g. TSS) to Greenwood Lake. As such, Belcher Creek and the sub-watersheds immediately surrounding it were the main focus of the field assessments conducted to find potential project sites. In order to further assess Belcher Creek, a detailed field-based assessment of Belcher Creek was conducted to identify potential problems that contribute to water quality issues in Greenwood Lake. The survey was conducted from where the Creek enters the lake up to the dam of Pinecliff Lake.

This sub-section outlines a number of potential sites for streambank and riparian zone restoration. To aid in the survey of the stream sites, Princeton Hydro utilized stream visual assessment (SVA) scorecards that are largely based on the NJDEP Stream Visual Assessment Protocol. An example of the scorecards that were used can be found in Appendix VI. Assessment factors include the following habitat parameters:

- Vegetated buffer width
- Vegetated buffer condition
- Canopy cover
- Bank stability
- Channel condition
- Hydrologic alterations
- Aquatic plant community
- Invertebrate habitat
- Instream fish cover
- Barriers to fish movement
- Velocity / depth variability
- Pool variability

In addition to the above parameters, the streamside land use of each stream reach and any potential outfalls were also noted. The purpose of these stream assessments was to assess potential sites for streambank/riparian zone restoration that would reduce the TP and TSS loads entering Greenwood Lake. 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 scorecards were filled out for 10 separate stream reaches in Belcher Creek. While there were 10 stream reaches that were formally assessed with a scorecard, a full day was spent traveling from the mouth of Belcher Creek in Greenwood Lake up to the dam at Pinecliff Lake, and back downstream to the mouth of Belcher Creek. During this time in the Creek, the entire creek was visually assessed on-site and again back in the office through photograph documentation.

Again, while there were 10 sites that were formally assessed with a scorecard, there are not 10 sites in Belcher Creek that are included as potential candidates for stream restoration. **It was determined during the assessment that the majority of the excess sediment and nutrients found in the creek originate in the sub-watersheds that directly surround the creek. Because of this, the majority of the recommended projects throughout the watershed are located immediately surrounding Belcher Creek.** For example, streambank erosion throughout the majority of Belcher Creek was not severe and is likely not a major source of sediment and phosphorus to Greenwood Lake. Additionally, outfalls in

Belcher Creek were traced to their origin wherever applicable and were recommended to be retrofit with MTDs or other BMPs in the previous section. Access to Belcher Creek is also limited in many locations, especially the middle portion that is not located near a major road. This was taken into account during the survey, as heavy machinery, trucks/vehicles, etc. are often needed for major restoration measures. Because of this, restoration measures at some sites were limited and the in-stream / riparian measures often involve smaller scale projects such as vegetative plantings that can be done by homeowners and volunteers and don't require large equipment.

In summary, 10 stream reaches along Belcher Creek were formally assessed using SVA scorecards that are largely based on the NJDEP Stream Visual Assessment Protocol. Restoration measures that will aid in the reduction of the TP and TSS load to Greenwood Lake are provided at these sites wherever applicable, but the sub-watersheds directly surrounding Belcher Creek were the main focus of the recommended restoration measures and BMP implementation. The main reason for focusing on the sub-watersheds is because this is where the majority of the TP in the Greenwood Lake watershed originates.

VISUAL ASSESSMENT RESULTS

The Belcher Creek visual assessment was conducted on 16 July 2019 by two members of Princeton Hydro. The data collected includes the semi-quantitative dataset gathered for each stream station whereby scores were assigned for specific parameters, as well as qualitative data which discusses the presence of erosion, land uses adjacent to the selected stream reach, presence and types of invasive species. Each criterion was scored from 0-10, with 10 typically representing an optimal condition, and lower scores representing some form of impairment. In some situations, not all criteria could be assessed, therefore, the final station score was divided by the number of criteria assessed.

Following scoring, each stream segment was ranked amongst all others in order to prioritize those segments that have shown impairment for active management while providing necessary information for those reaches which are in excellent condition.

Table 10: General SVA scores in Belcher Creek.

Stations	SVA Score	General Health	% of Stations
4	>7.5	Good	40%
2	6-7.5	Fair	20%
4	4-6	Some Impairment	40%
0	<4	Serious Impairment	0%

Table 11: Summary of all stream reaches assessed in Belcher Creek.

Station	SVA Score	General Health
B-1	4.0	Some Impairment
B-2	8.1	Good
B-3	5.1	Some Impairment
B-4	5.1	Some Impairment
B-5	7.3	Fair
B-6	6.5	Fair
B-7	8.4	Good
B-8	9.0	Good
B-9	8.5	Good
B-10	4.5	Some Impairment

CANDIDATES FOR STREAM RESTORATION

Estimating prices and load reductions for streambank 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 12 and 13 at the end of this section.

The location of all of the proposed restoration sites can be found in the Candidate BMP Site Map in Appendix I.

ADDITIONAL MANAGEMENT MEASURES FOR BELCHER CREEK

In addition to the more specific measures mentioned for Belcher Creek, there are some measures that can be taken to reduce nutrient loading from the Creek to Greenwood Lake that would need more in depth evaluation before location and sizing can be decided.

Floating Wetland Islands (FWIs) are primarily used to control nutrient loading in lakes using biological nutrient uptake, a type of bioremediation. These systems provide a natural method to assist in nutrient removal relative to some of the other techniques, including chemical nutrient inactivants such as alum or ferric sulfate. Floating wetland islands are polymer mats that are anchored to the lake bed. The mats are planted with a variety of native wetland vegetation with the plants rooted in peat or other soil matrix and eventually growing down into the water column where they take up nutrients to support vegetative growth. In addition to the plants, the undersides of the islands are colonized by a variety of naturally-occurring beneficial microbes including bacteria and periphyton in biofilms that also remove nutrients from the water including both nitrogen and phosphorus. Literature indicates that the microbial community may have a larger effect in contributing to bioassimilation of nutrients. The removal of nutrients by plants and microbes in concert provide nutrient competition through uptake and sequestration that can limit local concentrations and reduce algal biomass. Typically, these units are not used in a stand-alone capacity and are meant to complement other nutrient control techniques. They are especially useful in treatment train applications. For instance, they are frequently deployed in near shore areas where stormwater BMPs have been installed to provide further pollution abatement, especially for dissolved substances. There are also a variety of secondary benefits including: habitat creation, refugia and nursery habitat for fish, reduction of suspended solids, and shoreline stabilization. They are aesthetically attractive, especially when some of the showy flowering plants are used including swamp rose mallow and blue flag iris. A 250 ft^2 FWI can remove ~10lbs of TP per year. FWIs can range in price based on size, with a series of islands totaling ~500t^2 costing approximately $20,000 to purchase, plant, install, and anchor.

Another measure that would provide management of nutrients into Greenwood Lake would include nutrient Inactivation injection systems to address TP in Belcher Creek before reaching the Lake, specifically ferric sulfate. Water from Belcher Creek would be collected in a basin that is injected with Ferric sulfate. These molecules then attach to the liquid phosphorus in the water and precipitate to the bottom of the basin and form a material that will be removed and re-used as fertilizer and other uses that are being developed.

The ferric sulfate dispenser unit and the basin becomes a part of the stream i.e. all water has to go through the treatment unit and should be installed as far upstream as possible so as to not impede boat traffic. Site evaluations need to be conducted on pollutant load, flow rates, and hydrology of the area to be installed in order to determine appropriate location and sizing for the system. Field assessment for installation site selection and implementation of the ferric sulfate system has an estimated cost of $135,000.

SITE 17: BELCHER CREEK (B-1: JUST UPSTREAM OF UNION VALLEY ROAD)

Just upstream of the Union Valley Road bridge crossing on Belcher Creek is a relatively wide section of the creek that has been altered by development. The major land use on both sides of the creek are residential properties that lack adequate riparian buffers. Some of the houses contain bulkheads along the shoreline and there was minimal aquatic plant growth or habitat for aquatic organisms. There is barely any canopy cover due to the lack of vegetation which increases the surface water temperatures. Habitat for aquatic organisms such as fish or invertebrates is limited here due to the lack of canopy cover or in-stream habitat.

Recommended Measures: A vegetative riparian buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion in areas without a bulkhead and increased filtration of nutrients from residential stormwater runoff. The right bank should be prioritized for a riparian buffer. Additionally, the placement of a floating wetland island in this section of the creek would sequester nutrients before the water empties into Greenwood Lake and would provide habitat and protection from the sun for fish and other aquatic organisms. There appear to be a few locations along either shoreline where a floating wetland island could be tucked in off the main channel, protecting the island during periods of heavy flow. The floating wetland island would have to be placed in a protective location and tied to the shoreline for protection.

Estimated Costs: The estimated costs for the riparian buffer and a floating wetland island is estimated to cost between $11,400 - $15,400.

SITE 18: (B-3: BELCHER CREEK ALONG BEAVER AVENUE)

The left Bank of Belcher Creek runs parallel to Beaver Avenue, and the creek 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 Beaver Avenue. This side of the creek also lacks adequate canopy cover which leads to increased surface water temperatures.

Recommended Measures: A vegetative riparian buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff that originates on Beaver Avenue.

Estimated Costs: The estimated costs for the riparian buffer is approximately $3,600 - $13,500.

SITE 19: (B-5: RESIDENTIAL SHORELINE NEAR LOUIS AVENUE)

The right bank of Belcher Creek runs parallel to a residential shoreline just downstream of Louis Avenue. The shoreline here lacks an adequate riparian buffer that would act as a nutrient filter from any residential stormwater runoff.

Recommended Measures: A vegetative riparian buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff that originates on the residential property.

Estimated Costs: The estimated costs for the riparian buffer is approximately $1,200 - $4,500.

SITE 20: (B-6: RIGHT BANK ALONG PARKING LOT DOWNSTREAM OF UNION VALLEY ROAD)

The right bank of Belcher Creek along the parking lot referenced in Site 4 is the site most in need of restoration measures, as determined during the field assessment on 16 July 2019. Extensive erosion, including undercutting and bank scour, was observed along the right bank. Sediment deposition was observed in Belcher Creek downstream from this site. In addition to the erosion, the right streambank lacks an adequate riparian buffer. The gravel parking lot referenced in site 4 likely washes into Belcher Creek during storm events due to the lack of vegetation.

Recommended Measures: The right bank of this stream is an ideal candidate for bank stabilization to help address the erosion and sedimentation that is occurring. The streambank should be regraded to a gentler slope to allow for floodplain connectivity; the streambank is currently very steep. Re-grading the streambank would also help prevent flooding that is reported to occur in the adjacent parking lot. 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. Additionally, a vegetative buffer would further enhance this site by acting as a nutrient filter for stormwater runoff and by stabilizing the streambank from further erosion.

Estimated Costs: The estimated cost for the streambank stabilization and riparian buffer enhancement is approximately $7,500 – $33,300.

SITE 21: (B-9: RESIDENTIAL SHORELINE NEAR WINDSOR ROAD)

The left bank of Belcher Creek runs parallel to a residential shoreline just downstream of Windsor Road. The shoreline here lacks an adequate riparian buffer that would act as a nutrient filter from any residential stormwater runoff.

Recommended Measures: A vegetative riparian buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff that originates on the residential property.

Estimated Costs: The estimated costs for the riparian buffer is approximately $1,200 - $4,500.

SITE 22: (B-10: BELCHER CREEK PARALLEL TO EDGECUMB ROAD)

There is a side channel of Belcher Creek that runs for approximately 375 feet from Glencross Road to the main channel of the creek. This it the same section of the creek that has a large sediment bar from erosion from Glencross Road that was referenced in site 9. The creek channel is surrounded by residential properties on both sides that lack adequate riparian buffers for the majority of the channel.

Recommended Measures: A vegetative riparian buffer in this location would provide multiple benefits, including the prevention of potential shoreline erosion and increased filtration of nutrients from stormwater runoff that originates on the residential property.

Estimated Costs: The estimated costs for the riparian buffer is approximately $1,800 - $6,750.

Table 12: Low and high pollutant removal estimates for proposed streambank projects.

Proposed Projects in Belcher Creek	Pollutant Removal	
Proposed Streambank Projects	**TP (kg)**	**TSS (kg)**
B-1: Upstream of Union Valley Road	6	10,000
B-3: Along Beaver Avenue	9	20,000
B-5: Residential shoreline near Louis Avenue	4	10,000
B-6: Downstream of Union Valley Road	4	33,000
B-9: Residential shoreline near Windsor Road	4	8,500
B-10: Channel parallel to Edgecumb Road	6	12,000

Table 13: Low and high cost estimates for proposed streambank projects.

Proposed Projects in Belcher Creek	Price Estimate	
Proposed Streambank Projects	**Low**	**High**
B-1: Upstream of Union Valley Road	$11,440	$15,400
B-3: Along Beaver Avenue	$3,600	$13,500
B-5: Residential shoreline near Louis Avenue	$1,200	$4,500
B-6: Downstream of Union Valley Road	$7,500	$33,300
B-9: Residential shoreline near Windsor Road	$1,200	$4,500
B-10: Channel parallel to Edgecumb Road	$1,800	$6,750

4. 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 9 and 12 in the previous section. The total cost of all proposed projects is estimated to cost in the range of $14 million.

FINANCIAL ASSISTANCE

From a practical perspective, one of the major limiters on successfully managing NPS pollution, meeting water quality standards and designated uses, and controlling stormwater is funding. The expense of these items is two-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.

Despite the costs of implementing individual implementation 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 options 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; 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. 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.

NJDEP FUNDED GRANTS IN 2020

The most recent round of 319 funding was released by NJDEP in December of 2019 with up to $3,500,000 in grants available for watershed restoration and enhancement measures with a request for proposals through February 2020. NJDEP currently uses a rotating basin approach for the five water regions of New Jersey, with this round focused on the Upper Delaware River Watershed; the next round will be focused on the Northeast in 2022. Even so, NJDEP is making up to $1,000,000 of the 2020 319 grant funding available to mitigate Harmful Algal Blooms (HABs) through in-lake and watershed planning and implementation projects. As a lake that experienced sustained HABs throughout the 2019 season, the Greenwood Lake Commission and the Township of West Milford should pursue these available grant funds for the implementation of watershed and/or in-lake measures that will help mitigate these algae blooms.

In addition to the release of the standard 319 funding to address nonpoint source pollution throughout the state of New Jersey, NJDEP announced grant funding that will be made available to prevent, mitigate, and/or control freshwater HABs. The request for proposals for these grants were also released in December of 2019 and will be due in January 2020. NJDEP has made up to $2,500,000 available for in-lake methods or projects to mitigate and/or control freshwater HABs throughout the state of New Jersey. NJDEP will award up to $500,000 per approved applicant and will require a 33% in-kind match by the applicant. As mentioned above, the Commission and the Township of West Milford should pursue these available grant funds for the implementation of in-lake measures that will help mitigate and/or control freshwater HABs in Greenwood Lake.

NEW JERSEY HIGHLANDS COUNCIL

The New Jersey Highlands Council is a regional planning agency that works exclusively with municipalities and counties in the Highlands Region of New Jersey. The Highlands Council works to encourage a comprehensive regional approach regarding the protection and enhancement of the natural resources within the Highlands Region. As such, the Highlands Council offers grant funding for projects that will protect and enhance water quality throughout the region. These grants include the planning, design, and engineering aspects of watershed-based projects, but do not include the implementation of these projects. As a township located entirely in the Highlands Region, funding through the Highlands Council grants is a great way to get the early stages of project development completed, allowing money obtained through other grants to be used exclusively on implementation.

OTHER 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 14). A brief summary of the highlights is discussed below.

The 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 has 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.

Table 14: 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 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.

5. 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 EPA nine elements.

The protection and preservation of water quality and the ability to address the TMDL in the Greenwood Lake 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 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.

EDUCATION AND OUTREACH IN THE GREENWOOD LAKE WATERSHED

For this WIP, the educational component includes a series of public presentations and verbal project status reports, hosted by the Commission, 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 lake, with an emphasis on phosphorus. One presentation will focus more on behavioral changes in general land use / homeowner practices that will aid in protecting the lake, such as septic management, use of non-phosphorus fertilizers, expansion of buffers and simple land / soil stabilization techniques. Another 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.

To minimize costs, Princeton Hydro utilized many of the existing information available on reducing NPS pollution (sources will include but not be limited to Rutgers University, NJDEP, US EPA, and the Center of Watershed Protection) to develop educational information for the WIP. However, the available information was slightly modified so it specifically addresses the needs and concerns of the Greenwood Lake watershed.

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

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

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

6. IMPLEMENTATION SCHEDULE

As required by the sixth EPA element, this document contains an implementation schedule. Step 6 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 Greenwood Lake 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.

YEARS 1 TO 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 essentially shovel ready Marshall Hill project, evaluating ferric sulfate injection feasibility, and installing FWIs**. These projects represent locations in the highest priority sub-watersheds that surround Belcher Creek. 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.

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 because they are located in sub-watersheds G, H, and I. 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 Belcher Creek and Greenwood Lake. The focus on implementing in these sub-watersheds 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.

Table 15: Implementation Schedule – Years 3 to 5		
Site ID	**Location**	**BMP**
1	West Milford Lake	Constructed Wetland
4	New Jersey Avenue – rear lot	Extended vegetative filter strip Rain garden
6	Bagel Town Café rear lot	Retrofit dry detention basin Retrofit wet pond
7	Union Valley and Edgecumb Road pond	Forebay reconstruction Deep drop inlet and road curbs
10	Athletic fields	Bioretention swale
14	Union Valley Road and Warwick Tpk	Bioengineered streambank stabilization Stabilized conveyance systems

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 Belcher Creek may be implemented in this phase.

Table 16: Implementation Schedule – Years 6 to 10		
Site ID	**Location**	**BMP**
2	Shop-Rite parking lot	NSBB Bioretention system
3	Adelaide Terrace stream	Riparian buffer enhancement Right bank grade control
5	New Jersey Avenue – front lot	NSBB Streambank stabilization
8	Gwyneth Road and Glencross Road	NSBB Extended Filter Strip
9	Belcher Creek at Glencross Road	Headwall installation
12	Almond Branch Church	Bioretention system(s)
15	Our Lady Queen of Peace Church	Rain garden
16	Elks Lodge stream	Enhanced riparian buffer Removal of downed tree

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 17: Implementation Schedule – Years 6 to 10		
Site ID	**Location**	**BMP**
13	Development west of Lincoln Avenue	Community wastewater system

7. 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 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

8. 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 EPA element.

As with the original SIP, the indicators 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 Greenwood Lake for TMDL compliance; a targeted mean, growing season TP concentration of 0.03 mg/L. This indicator will be based on the collection of empirical, in- lake water quality data.

The second indicator will be the amount of TP removed through each implemented stormwater BMP or watershed actions. 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 the lake's TMDL (obviously with an emphasis on the New Jersey end). Currently, the New Jersey end of the Greenwood Lake watershed TMDL is approximately 49% in compliance. 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 Greenwood Lake 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 measure and implemented projects is best expressed and consequently measured. This WIP is particularly focused on the management of TP in the Greenwood Lake watershed, with a secondary focus on associated NPS pollution, particularly additional nutrient pollutants and 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 Greenwood Lake, 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

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
- Macroinvertebrate metrics
- Submerged aquatic vegetation composition
- Chlorophyll-a, a proxy measure of algal biomass
- Phytoplankton and zooplankton metrics
- Cyanotoxin concentrations produced by cyanobacteria or blue-green algae
- Wetland plant composition
- Vegetative coverage

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 Greenwood Lake the following criteria are especially important:

- Dissolved oxygen
- Turbidity
- pH
- Nutrients
- Biological Condition

9. 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 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 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 WATER MONITORING

In-lake monitoring should also be conducted to gauge how Greenwood Lake is responding to the reductions in pollutant loads. In-lake and watershed-based monitoring should continue in the future, using a similar monitoring program as was established for the creation of the original SIP and this updated WIP. This will provide an ever-increasing inter-annual database to identify long-term trends in water quality. Five (5) in-lake monitoring stations are typically monitored in Greenwood Lake for a variety of physical, chemical, and biological parameters; *in-situ* (dissolved oxygen, temperature, pH, and conductivity) data and discrete samples are collected from 4 of the in-lake stations.

INTERNAL NUTRIENT LOADING MONITORING AND MODELING

In addition to the project site monitoring and standard surface water monitoring that should occur after the implementation of watershed-based projects, Princeton Hydro recommends implementing monitoring that will aid in the quantification of Greenwood Lake's internal phosphorus load. It was determined in the original SIP that internal phosphorus loading from the bottom sediment was the single largest contributor to the overall TP load, accounting for 1,739 kg (42%). While the work in the original SIP and this updated WIP are focused on the watershed-based TP load, an internal phosphorus load greater than 40% is very high and warrants in-lake measures, such as hypolimnetic aeration or the application of a nutrient inactivant, to reduce this load. With the recent increase in large scale and sustained harmful algal blooms in Greenwood Lake and other lakes throughout the region, it is imperative that the overall phosphorus load to Greenwood Lake be reduced in a timely manner to prevent future blooms.

It is first recommended that the internal load be updated soon, as this current estimate was calculated over 14 years ago. In order to better quantify the internal load on a monthly and seasonal basis, relatively frequent water quality monitoring is required in the lake. This type of monitoring would likely need to be conducted at least once per month during the growing season months and up to twice per month during the peak growing season months. It is essential that the depth of anoxia throughout the lake be characterized frequently throughout the growing season in order to accurately calculate the internal load.

An innovative method of obtaining frequent water column profiles, even on daily or hourly scales, is through the use of monitoring buoys. While expensive, these monitoring buoys provide invaluable data that go above and beyond the capabilities of the standard boat-based water column profiles that are obtained by a field scientist once or twice a month, depending on the monitoring schedule. Regardless of the method that is used to obtain this important data, it is imperative that the internal phosphorus load of Greenwood Lake be updated and addressed accordingly in order to combat harmful algal blooms in the most effective manner.

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