Lake Peekskill Restoration Plan
Town of Putnam Valley
Putnam County, NY

Prepared for:

Town of Putnam Valley
Judy Travis, Administrator
P.O. Box 411
Carmel, NY 10512

Prepared by:

Princeton Hydro, LLC

203 Exton Commons
Exton, Pennsylvania 19341
(P) 610.524.4220
(F) 610.524.9434
(C) 610.310.5487
flubnow@princetonhydro.com
www.princetonhydro.com

June 2015 - DRAFT

Introduction

Lake Peekskill is small impoundment of Peekskill Hollow Creek and is located in the Town of Putnam Valley, Putnam County, New York (Figure 1 in Appendix A). The lake is a critical recreational focal point for the local community and includes three beaches: Carrara's Beach, Singer's Beach and North Beach (Figures 2, 3 and 4, respectively, in Appendix A). In the early 1990's it suffered from high densities of rooted, submerged aquatic vegetation and in response to this the lake was stocked with sterile grass carp, which effectively controlled nuisance vegetation. Since then the distribution of aquatic vegetation has been minimum or at non-nuisance levels in the lake. Periodic aquatic plant surveys revealed negligible to small amounts of rooted plants. However, benthic algae, such as filamentous green algae and the blue-green alga *Spirulina* would periodically produce nuisance conditions in the lake but such conditions were short-lived and were concentrated in near-shore areas.

In 2014 a large blue-green algal bloom occurred in Lake Peekskill and persisted through the majority of the bathing season (from early July to the Labor Day weekend and beyond). Additionally, measurable and problematic concentrations of the cyanotoxin microcystin-LR were found in the lake, particularly in near-shore areas, which resulted in the closing of the three beaches

Thus, in an effort to address this increasing water quality problem the Town of Putnam Valley hired Princeton Hydro to revise and update the lake and watershed Management Plan. The Plan and associated study was divided into three distinct but inter-related tasks. The first task is a review of the existing long-term water quality database on Lake Peekskill. The second task is to revise / update the pollutant budget for Lake Peekskill. The third task is to develop a short- and long-term strategy to improve overall water quality conditions in Lake

Peekskill. This third task is essentially the updated Management Plan and will focus heavily on the short-term management of the three beach areas.

Task 1 – Analysis of Long-Term Water Quality Database

The Lake Peekskill's water quality database is over 24 years long. Since the early 1990's and a large portion of these data were collected under the NYS DEC's Citizens Statewide Lake Assessment Program (CSLAP). However, over the years, the staff of Princeton Hydro has periodically conducted water quality monitoring at Lake Peekskill to assess conditions. This additional source of data was used to supplement the CSLAP database. Princeton Hydro used all of the existing water quality data to conduct an inter-annual analysis of in-lake water quality conditions. The analysis was conducted to identify trends or changes in water quality, similar to what DEC does with the CSLAP data, in order better develop a more lake-specific Restoration Plan. Additionally, the trend data was used to develop the recommendations in the Plan.

Specific conductivity measures the capacity of water to carry an electrical current. It can also serve as an indirect way of measuring the amount of dissolved substances in the water; the more dissolved substances, the higher the conductivity. Highly productive (eutrophic) waterbodies tend to have conductivity values greater than 500 uS/cm, while waterbodies with low levels of productivity (oligotrophic) tend to have conductivity values less than 100 mmhos/cm.

The specific conductivity of the surface waters of Lake Peekskill were graphed from mid-summer 1990 to late summer 2014 (Graph 1 in Appendix B). Since the early 1990's there has been a steady and progressive increase in conductivity from being less than 200 uS/cm in 1990 and 1991 to being slightly above 500 uS/cm in 2014. This increase in conductivity indicates an increase in the amount of dissolved substances, including nutrients such as phosphorus and nitrogen, in the lake. Other dissolved substances, such as dicing products, can also contribute to these increases in conductivity; however, as will be shown below, the increase in conductivity correlates well with phosphorus concentrations. These data agree with DEC's assessment of the long-term trend in conductivity for Lake Peekskill.

Princeton Hydro also graphed the long-term, surface water total phosphorus (TP) concentration data for Lake Peekskill (Graph 2 in Appendix B). While there was a considerable amount of variability in surface water TP concentrations over the years, the overall trend was one of increasing concentrations. Through the 1990's, surface water TP concentrations were typically between 0.01 and 0.03 mg/L. TP concentrations were more variable from the late 1990s to the mid 2000's, but most concentrations were between 0.01 and 0.04 mg/L. However, from late 2005 to 2014 TP concentrations were typically equal to or greater than 0.03 mg/L, with concentrations frequently being greater than 0.04 mg/L (Graph 2 in Appendix B). Additionally, TP concentrations equal to or greater than 0.05 mg/L were measured once from 1990 to 2000; in contrast, TP concentrations equal to or greater than 0.05 mg/L were measured six times from 2008 to 2014. The highest surface water TP concentration of 0.19 mg/L was measured on 13 July 2012.

TP concentrations have been on the rise in Lake Peekskill; this has been identified by both DEC and Princeton Hydro. Additionally, DEC identified that Lake Peekskill is a phosphorus limited system, which means that additional phosphorus stimulates additional algal growth and to reduce existing algae biomass and improve overall lake conditions the phosphorus load must be reduced. It takes very little phosphorus to generate a large amount of algal biomass. For example, one pound of phosphorus has the potential to generate up to 1,100 lbs of wet algae biomass. In any event, overall TP concentrations have been on the rise, particularly over the last six years.

Since all algae possess chlorophyll *a*, measuring this pigment in the surface waters of a lake is an excellent means of quantifying algal biomass. Similar to conductivity and TP, chlorophyll *a* concentrations have been measured in the surface waters of Lake Peekskill since 1990 and are shown in Graph 3 in Appendix B. It is interesting to note that a pattern is frequently observed each year; that is, chlorophyll *a* concentrations are relatively low in the beginning of the growth season and then increase, typically reaching their seasonal highs in late summer / early fall (Graph 3 in Appendix B).

Unlike conductivity and TP, an apparent, long-term trend in chlorophyll *a* was not readily apparent. In fact, between 2008 and 2012 chlorophyll *a* concentrations were lower than what has been observed in past years. However, 2014 was a particularly problematic year, with chlorophyll *a* concentrations being consistently greater than 15 mg/m^3. The highest chlorophyll *a* concentration in 2014 was 39.6 mg/m^3 measured on 2 August 2014; this was the second highest concentration out of the entire 1990 – 2014 dataset. In general, chlorophyll a concentrations in 2014 were consistently elevated, generating nuisance conditions in Lake Peekskill.

Coupled with these high chlorophyll *a* concentrations was the fact that the majority of the algae during these nuisance summer blooms were blue-green algae, many of which generate cyanotoxins. Indeed, near-shore concentrations of the cyanotoxin microcystin-LR actually exceeded the World Health Organization's (WHO) threshold for unsafe swimming of 20 ug/L twice between August and October 2014. This resulted in the lake being closed to swimming for a large part of the summer season. Since blue-green algae tend to dominant the plankton community as TP concentrations increase, the ultimate goal should be to reduce the annual TP load entering Lake Peekskill.

The elevated chlorophyll *a* concentrations in 2014 resulted in lower Secchi depths during that same year. In general, a lake is generally acceptable to the layperson for contact recreation when the Secchi depth is 1 meter (3.3 ft) or greater and from 1990 to 1996 Secchi depths were consistently at or greater than 1.5 meters. From 1998 to 2014 Secchi depths would reach 1.0 meters on a rare occasion but for the most part remained above the 1.0 meter threshold. However, at the height of the early August blue-green algal blooms in 2014, the Secchi depth fell below the 1.0 meter threshold, with 2014 Secchi depths varying 0.85 and 1.65 meters, along with a mean value of 1.2 meters. These lower Secchi depth values in 2014 are indicative of what water clarity conditions will be in the future unless the annual phosphorus load is addressed in some manner.

Task 2 – Updated Pollutant Budget

Princeton Hydro conducted a simplified pollutant loading analysis for Lake Peekskill to quantify the annual total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) loads entering the lake. The Unit Aerial Loading (UAL) method was used to quantify the stormwater / surface runoff loads. The Lake Peekskill watershed was delineated and the most up-to-date land use / land cover data was layered onto that database through GIS (Figure 5 in Appendix A).

Loading coefficients for TN, TP and TSS were selected for each identified land type and the area of each land type was multiplied with the appropriate loading coefficient. The resulting loads were then compiled for each pollutant.

As part of some detailed studies conducted by Princeton Hydro in northern New Jersey, a phosphorus loading coefficient was developed for septic systems in this part of the United States. This coefficient was based on the amount of phosphorus generated immediately down gradient of an old (> 25 to 30 years old). This empirically based septic P-loading coefficient (0.165 kg of TP / capita / yr) was used, along with the number of existing homes within 330 feet of the lake shoreline or associated tributaries and the mean number of people within each home, to calculate the annual TP load originating from the community's septic systems.

A combination of limited deep water TP concentrations and the relative strength of thermal stratification and the extent and duration of anoxia (where dissolved oxygen concentrations fall below 1 mg/L; below this concentration a substantial amount of phosphorus is released from the sediment and available for algal growth).

Standard nutrient loading coefficient from rainfall and dryfall were used to quantify the loads originating from the atmosphere. All of these sources of phosphorus were compiled and used to develop an annual TP budget for Lake Peekskill (Table 1).

Table 1 – Updated Total Phosphorus Budget for Lake Peekskill

Phosphorus Budget	lbs	Percent
Stormwater / Surface Runoff	66.6	22.4
Septic Systems	163.8	55.1
Internal Regeneration from Sediments	53.9	18.1
Atmospheric	13.2	4.4
Total	**297.4**	**100.0**

As shown in Table 1, TP loading from septic system leachate accounts for slightly more than half of the total amount of phosphorus entering Lake Peekskill. The second largest source of phosphorus originates from stormwater and surface runoff, which accounts for approximately 22% of the annual TP load. Combined, septic systems and surface runoff accounts for 77.5% of the total annual TP loading entering Lake Peekskill. Thus, in order to reduce the amount of phosphorus entering the lake, the Town of Putnam Valley needs to reduce the septic-related TP loads and to a lesser extent the stormwater / surface runoff loads.

Princeton Hydro

Task 3, Part 1 – Recommended In-Lake Management Techniques

The long-term goal is to reduce the phosphorus loads to Lake Peekskill. However, the implementation of measures to reduce these loads will take some time to implement and in turn manifest into observable improvements. Thus, some in-lake management techniques should be implemented to provide some immediate relief from the nuisance conditions experience at Lake Peekskill over the course of the summer season, when recreational activities on and around the lake at their maximum. Thus, the focus on the in-lake management measures will be the three beaches at Lake Peekskill.

Carrara's Beach is located in the northwestern corner of Lake Peekskill (Figure 2 in Appendix A). One of the issues along this section of the lake is the accumulation of floating debris, particularly blue-green algal cells. Thus, Princeton Hydro recommends the installation of an electric shoreline water pump system with an intake just off the shoreline and a discharge further into the lake to increase circulation along the beach. Princeton Hydro installed a similar system in Lake Mohawk (Sussex County, NJ) with positive results.

The first issue that would need to be addressed is relative access to electricity along the shoreline. Additionally, the pump would need to be housed in some sort of enclosure. The intake hose would come equipped with multiple debris screens and a buoy/anchor system so the screens can be inspected and unclogged when needed. The discharge would need to be strategically positioned somewhere off the shoreline to influence flow but cannot be more than 200 feet away to ensure acceptable flow rates. The discharge would most likely need to be re-positioned a couple times access and determine the maximize degree of positive influence.

Tentatively, the recommendations would be to install one (1) or two (2) Pacer 260 GPM (2") 5-HP Electric Water Pumps (230V); an additional on-site assessment is required to determine if one or two pumps is required. The pump(s) would be placed inside a small enclosure. The estimated cost to purchase and for Princeton Hydro to install two pumps is estimated to cost between $18,000.00 and $20,000.00. Please note this price does not include the cost associated with a New York State certified electrician.

A few years ago, Princeton Hydro suggested an alternative to a pump / flow system for Carrara's Beach, which was installing an air curtain along the swim area, using a number of Vertex air diffusers, coupled with a shoreline compressor system. Approximately 7 – 10 diffuser heads along a line would need to be installed. This air curtain would contribute toward preventing debris and algal scums from accumulating along the beach. Please note the air curtain will not eliminate the buildup of any material within the beach area but will prevent material from outside of the beach area to enter and accumulate along the shoreline. The estimated cost for the purchase and installation of a Vertex air curtain system at Carrara's Beach is between $8,000.00 and $10,000.00 but does not include the cost of a New York State certified electrician.

Singer's Beach is located in the eastern side of Lake Peekskill just north of the dam (Figure 3 in Appendix A). Over the years, Princeton Hydro has observed large amounts of filamentous mat algae, including the blue-green alga *Spirulina*, and other organic material along and around Singer's Beach. In an effort to utilize non-chemical means of addressing these nuisance conditions, Princeton Hydro is recommending the design and installation of an ozone / aeration system just off Singer's Beach to break down this accumulating organic material. The system would also contribute toward reducing, but not eliminating, a portion of planktonic algae that accumulates along the shoreline. Princeton Hydro has installed similar systems, particularly at golf course ponds, with positive results.

Some design and sizing of such a system would obviously be required, however, the design, purchase and installation of such a system is preliminary estimated to cost between $14,000.00 and $16,000.00. This price does not include the cost of a State certified electrician.

North Beach is located in the northern end of Lake Peekskill, adjacent to the lake's main inlet (Figure 4 in Appendix A). Similar to Singer's Beach, North Beach is frequently plagued with nuisance benthic algae and organic material, as well as planktonic blooms of blue-green algae. Thus, an ozone / aeration system just off North Beach is recommended as a non-chemical means of controlling the accumulating organic material over the growing season.

The design, purchase of material and installation of a system at North Beach is estimated to cost between $14,000.00 and $16,000.00, similar to that proposed for Singer's Beach. This price does not include the cost of a State certified electrician.

Solar Based Systems – Many of these aeration / circulation systems can be modified to be either solar-powered or hybrid systems. Obviously such systems are higher in cost but in the long-term can be more cost effective relative to energy savings and more feasible depending on the availability and access to conventional power along the shoreline. However, factors to be considered include the amount of available sunlight at each of the beach locations, how long each system will be run on a daily basis, and the availability of space for batteries and associated infrastructure. If the Town is interested in solar-based systems additional assessments are required by Princeton Hydro.

Permitting – Based on some conversations with NYS DEC, we would need to talk to the regional, environmental permitting staff prior to installing any such systems. However, more than likely a permit would not be required for any aeration / circulation system as long as the diffuser units are not within ¼ of regulated wetlands, the units that are installed in the lake are not considered "fill" and oxygenation is not considered to be an indirect pesticide. More than likely, the circulation / standard aeration systems would not require any sort of permit, however, the ozone systems proposed for Singer's Beach and North Beach may trigger the need for a permit if the regional office considers it an indirect pesticide. Thus, if the Town of Putnam Valley is seriously interested in pursuing, any or all of the recommended beach systems, the regional DEC office should be contacted to determine if any permits will be required for the specific systems.

Copper-Based Algicides

One of the most obvious and frequently applied means of controlling excessive algal growth is through the use of the algicide copper sulfate ($CuSO_4$). Copper sulfate is an extremely effective means of killing a large portion of the resident algal community; however, this response is brief and only controls the symptom of the problem and not the cause.

Several undesirable environmental impacts are known to be associated with copper sulfate treatments; negative impacts include potential fish and zooplankton toxicity, depletion of dissolved oxygen (DO), copper accumulation in sediments, increased internal nutrient recycling and increased tolerance to copper by some nuisance blue-green algae. In addition, conducting such treatments later in a bloom can exacerbate water quality problems by releasing taste and odor compounds (geosmin and MIB) or cyanotoxins normally sequestered in the blue-green algal cells into the water.

Large-scale dissolved oxygen (DO) depletion events can easily occur, especially when copper treatments are extensive and conducted frequently within a short period of time. Once the copper kills the algal biomass, bacterial decomposition can result in a reduction, and sometimes depletion, of DO, which can result in fish kills and/or contribute to unpleasant tastes and odors. Also, one of the most convincing reasons for minimizing the frequency and magnitude of large-scale copper sulfate treatments is the fact that several studies have demonstrated that many of the nuisance blue-green algae, such as *Anabaena* and *Coelosphaerium*, have increased in tolerance to long-term applications of copper sulfate (Hanson and Stefan, 1984). Indeed, studies have shown that blue-green algae tolerance to the liberal application of copper sulfate can increase to the point where it is no longer economically feasible to use copper sulfate as a means of algal control (Alhgren, 1970).

If the Town of Putnam Valley is interested in developing a copper sulfate treatment program for Lake Peekskill, it is strongly recommended that a chelated product be used; such products maximum the efficiency of the product, while at the same time minimizing the amount of copper added to the water. Obviously, a permit would need to be obtained from NYS DEC by a certified applicator. Princeton Hydro is a certified applicator in New York, and such treatments are estimated to cost approximately $300.00 to $500.00 per acre per treatment plus the cost associated with filing for the permit. However, Princeton Hydro does not recommend the use of copper-based algicides at Lake Peekskill due to the potential undesirable environmental side-effects.

Alternative Treatment Products

An alternative to copper-based products that could be used to control nuisance algal blooms in Lake Peekskill is GreenClean, which is a strong oxidizer that can be effective at controlling nuisance algae. Unlike copper-based algicides GreenClean completely breaks down and does not accumulate in the sediments or food web. The granular product is typically used to treat filamentous mat algae, either along the bottom early in the season or directly on floating mats that reach the surface. There is a relatively new, liquid formula of GreenClean that is supposed to be effective at controlling nuisance plankton / surface scum algal blooms. Additionally, these oxidizers are also said to breakdown cyanotoxins, depending on the dosage rate applied. Copper sulfate does not breakdown cyanotoxins. However, GreenClean is substantially more expensive in terms of product cost relative to copper products.

GreenClean has been approved for use in New York State by NYS DEC in 2015. Thus, this product could be used to control nuisance algal in Lake Peekskill. It does not have the potential environmental impacts of copper-based products and does not accumulate in the sediments. However, it is substantially more expensive than copper so large (third or half lake) treatments are not recommended. Nearshore, beach area treatments would be recommended, possibly prior to a summer holiday weekend or, more importantly, at the onset of a bloom to try to knock down some of the biomass.

As with any pesticide, a State permit needs to be obtained from NYS DEC by a licensed applicator. Princeton Hydro is a licensed applicator in New York State and can conduct GreenClean treatments in Lake Peekskill for $750.00 to $1,000.00 per acre per treatment plus the cost of filing the permit.

Floating Wetland Islands

Another in-lake management measure that should be considered for implementation in Lake Peekskill is the installation of Floating Wetland Islands (FWIs). FWIs are an aesthetically pleasing, ecologically friendly means of reducing in-lake nutrient concentrations. Thus, in contrast to the aeration / circulation systems and the proposed pesticide treatment measures, the FWIs will contribute toward reducing the cause of the problems (elevated phosphorus loads). The FWIs essentially divert some of the nutrients that would be used to fuel the growth of nuisance algae into the more desirable, aesthetically attractive native vegetation growing on the islands. The plants and associated microbial community (called a biofilm) that develops on their roots and within the island matrix, contribute toward nutrient uptake. It should be noted that it is this biofilm of microbes associated with the high surface area of the island matrix that greatly increases the levels of nutrient uptake associated with the FWIs.

The matrix material of the FWIs has a tremendous amount of surface area and it is estimated that one (1), 250 square foot floating island is roughly equivalent to one (1) acre of wetland in terms of surface area and nutrient uptake. Additionally, third party field studies have quantified the TP removal rate of these islands as being 106 mg of TP removed per day per sq ft; this estimate focused on microbial uptake only and did not take into account the additional sequestering of nutrients into plant biomass. For a FWI in the Mid-Atlantic region of the United States this translates to a 250 sq. ft. FWI removing approximately 10 lbs of TP per year.

The FWIs are constructed and planted along the shoreline and then deployed to their targeted located with the aid of a boat (Figure 1). The Islands are anchored in waters approximately 3 to 10 feet in depth. For Lake Peekskill it is recommended to install a FWI in the northern end just off of North Beach, where the main inlet enters the lake. This would provide a means of treating the incoming inflow and removing some of the available nutrients before entering the main body of the lake where it can stimulate nuisance algae (particularly the blue-green algae also known as cyanobacteria).

Maintenance is relatively minimal for the FWIs. Goose netting needs to be installed and routinely inspected to ensure it is intact at least for the first year (Figure 1). Princeton Hydro has installed and monitored FWIs throughout Pennsylvania and New Jersey since 2010 and after the first year once the vegetation is well established water fowl such as Canada geese tend to leave the Islands alone. Additionally, the vegetation should be periodically inspected to ensure growth is healthy. Occasionally, after a particularly heavy storm the Island may need to be re-positioned. However, in general the maintenance associated with the FWIs is fairly low and they have an expected life of approximately 15 years (Figure 2).

Again, if the Town of Putnam Valley is serious about the installation of a FWI in Lake Peekskill, it is strongly recommended that the regional DEC office be contacted to provide input as to whether a permit is required.

Figure 1: Floating Wetland Island built, deployed and anchored in a lake in Wayne County, PA in 2010

Figure 2: Established Floating Wetland Island in a lake in Wayne County, PA in 2014

Task 3, Part 2 – Recommended Watershed-Based Management Techniques

As the pollutant budget analysis revealed, near-shore on-site wastewater treatment systems (i.e. septic systems) are the largest source of phosphorus for Lake Peekskill. Septic systems account for over half of the lake's annual TP load (Table 1). Thus, the long-term focus from a watershed perspective is for the Town of Putnam Valley to control / reduce this source of phosphorus to the lake.

While it is unlikely that the Town of Putnam Valley will be sewered anytime in the near future, there are community-based measures that can be implemented to reduce the magnitude of the septic-based phosphorus load entering Lake Peekskill. These recommended measures are described below.

Mandatory Pump-Outs for all Septic Systems

If the Town of Putnam Valley already has a local ordinance for the mandatory pump-outs for all septic systems in order to ensure the proper operation and maintenance of such systems, some educational and outreach efforts should be made to remind people of this action and how it benefits the lake. If the Town does not have such an ordinance, it should seriously consider the establishment of one.

All septic systems in the community should be pumped out at least once every three (3) years for year-round residents and once every five (5) years for seasonal residents, in order to minimize future malfunctions and reduce the TP load entering Lake Peekskill. Removing the accumulated sludge from a septic tank on a regular basis will minimize the amount of particulate material that flows into the drainfield. In addition, a substantial portion of the phosphorus in the wastewater entering a septic system is adsorbed onto or integrated within particulate material. For example, almost half of the phosphorus entering a septic system settles and is retained within the tank (Gold, 2006). Thus, removing particulate material from the tank on a routine basis prevents the associated phosphorus from entering the drainfield and flowing into adjacent waterways.

Particulate material in the drainfield severely reduces its capacity to properly treat wastewater and remove pollutants such as phosphorus. Also, as mentioned above, particulate material entering the drainfield will carry with it phosphorus that can then in turn impact associated waterways. Thus, regular pump-outs of a septic tank are a very cost effective means of maximizing an existing system's ability to remove pollutants, including phosphorus.

It should be noted that an additional means of increasing the efficiency of mandatory pump-outs is to install an effluent filter in the existing system. Studies in New Jersey have shown that the application of an effluent filter, in conjunction with mandatory septic tank pump-outs will result in a 40% reduction in the amount of particulate material that flows into the drainfield. Thus, the individual property owner can increase the removal efficiency of particulate material, and associated phosphorus, by including such an effluent filter.

Water Conservation

Another way of maximizing the effectiveness of a septic system to remove pollutants is to minimize the amount of water flowing through the system. A large hydrologic load flowing through the drainfield keeps the soils saturated and can result in a depletion of oxygen within those soils, resulting in the release and subsequent movement of phosphorus to a receiving waterway as a "plume". Thus, minimizing the amount of water that flows through a septic system's drainfield allows for the soils to aerate and more effectively retain / remove phosphorus.

In addition to fixing / repairing leaks, toilets, showerheads and faucets can be replaced by low-flow devices where feasible. If these three water uses are upgraded to low-flow devices, the daily water use per person per day is expected to be reduced by 32%.

It should be noted that mechanisms behind the expected reduction in phosphorus associated with reducing the hydrologic load flowing through the septic systems is twofold. First, a larger flow will result in less settling of the particulate material (and associated phosphorus) in the septic tank and can also increase the re-suspension of already settled material in the tank. The net result is a higher concentration, and thus loads, of phosphorus leaving the tank and entering the drainfield.

Second, as previously mentioned, a lower flow through the drainfield will increase the soil's capacity to retain / remove phosphorus. A drainfield that is constantly saturated will result in a depletion of dissolved oxygen within the soil matrix and the subsequent mobilization of dissolved phosphorus to adjacent waterways. For example, in studies conducted by Ptacek, it was demonstrated that phosphate (dissolved phosphorus) concentrations were above the background concentrations in soils with low dissolved oxygen concentrations as far as 60 meters (almost 200 ft) from the septic tank (Ptacek, 1998). Thus, water conservations efforts to reduce the magnitude of the hydrologic load through a septic system will contribute toward reducing the pollutant load, particularly phosphorus, leaving the septic tank and entering the drainfield.

Alternative Septic System Structures

While lot sizes and available space severely limits the potential rehabilitation or retrofit of existing septic systems, upgrades should be considered where feasible (e.g. community buildings or structures) and for new development. Depending on site-specific conditions (i.e. available space, number of people who will use the system, type of land use, existing environmental constraints) a number of alterative systems could be considered such as:

- Peat Biofilter Systems
- Intermittent Sand Filters
- Incinerating or Composting Toilets (typically only for cabins or camps)

Other systems may be feasible as well; however the Town should consult with the NYS Department of Health and the County for additional input.

In conclusion, to effectively manage the septic load of phosphorus to Lake Peekskill, the first step should be a very aggressive and continuous educational campaign targeting all watershed stakeholders who have septic systems in the community. Some informational literature should be either developed or obtained from Federal, State, County and/or local sources, that explains the benefits and value to routine pump-outs to the individual, the lake and the community as a whole. While the community may eventually want to work with the Town to develop a mandatory pump-out ordinance, at this point in time efforts should focus on an educational campaign that would include the following:

1. Provide information in the form of a newsletter or pamphlet to all homeowners on the need and value of pumping out your septic system and why it should be done once every 3 years (once each 5 years for seasonal residents).

2. Post this information on-line either on the Town's website or a community-based website.

3. Conduct presentations on general septic management and how it contributes toward improving / protecting the water quality of the lake.

4. Possibly develop local incentives for individuals who have documented that their systems have been pumped-out, such as a small tax break, reduction on community use fees or other local benefits.

As cited above, additional actions will also contribute toward reducing the septic-based TP load, such as water conservation. However, others to consider include the use of non-phosphorus products (particularly dishwasher detergents), and other general maintenance activities associated with septic systems (e.g. the installation of an effluent filter on all septic tanks). Such recommendations can be provided in future newsletters or presentations; however, for now the emphasis should be on routine pump-outs.

Stormwater Management

Stormwater / surface runoff was the second largest source of phosphorus entering Lake Peekskill (Table 1). As with many small lake communities there is very little room for the design and installation of large, conventional stormwater Best Management Practices (BMPs) such as wet ponds, wetland treatment systems and extended detention basins in the Lake Peekskill watershed. In addition to the lack of space for such large BMPs, existing environmental constraints such as steep slopes and shallow depth to bedrock also limits the size and type of BMPs that can be installed to treat stormwater runoff. Thus, for many lake communities, Manufactured Treatment Devices (MTDs) are used to treat stormwater runoff. Most MTDs tend to require smaller amounts of space relative to more conventional BMPs and, depending on the type and model, can be relatively easy to maintain.

In the past, several, small stormwater retrofits, such as SNOUTs and hydrocartridges, were installed into the existing stormwater systems surrounding Lake Peekskill to contribute toward reducing the pollutant loads entering the lake. These structures should be inspected and are probably in need of maintenance. More importantly, the Town should consider the installation of larger, multi-chambered systems that can be installed under existing roads or road-side easements. Obviously the actual installation of such structures is largely dependent on the size of the existing drainage areas and environmental constraints such as slope, depth to bedrock, etc. One such MTD frequently installed in lake communities where space is limited and severe environmental conditions exist is the Multi-Chambered Nutrient Separating Baffle Box (NSBB).

The NSBB has been widely used in Pennsylvania and New Jersey as a cost effective means of reducing the TP and total suspended solids (TSS) loads of stormwater. Based on a review of several studies US EPA has documented that NSBBs have percent TP and TSS removal rates of 39% and 71%, respectively (US EPA, 2001). These estimates agree with Princeton Hydro's experience with the installation and monitoring of these MTDs. In general, based on our collection of stormwater samples entering and leaving NSBBs, we have measured percent removal rates of 30 – 40% for TP and 70 – 80% for TSS.

General maintenance of the NSBB is relatively low for a MTD. The trash racks, which are elevated above the sump within each basin, need to be simply cleaned out by hand 1-2 times per year, while the sumped basins need to be cleaned out at least once a year with a Vac-all (Figure 3). No special permits or certifications are typically required. However, it is always recommended that any stormwater structure be inspected after a particularly heavy / large storm event.

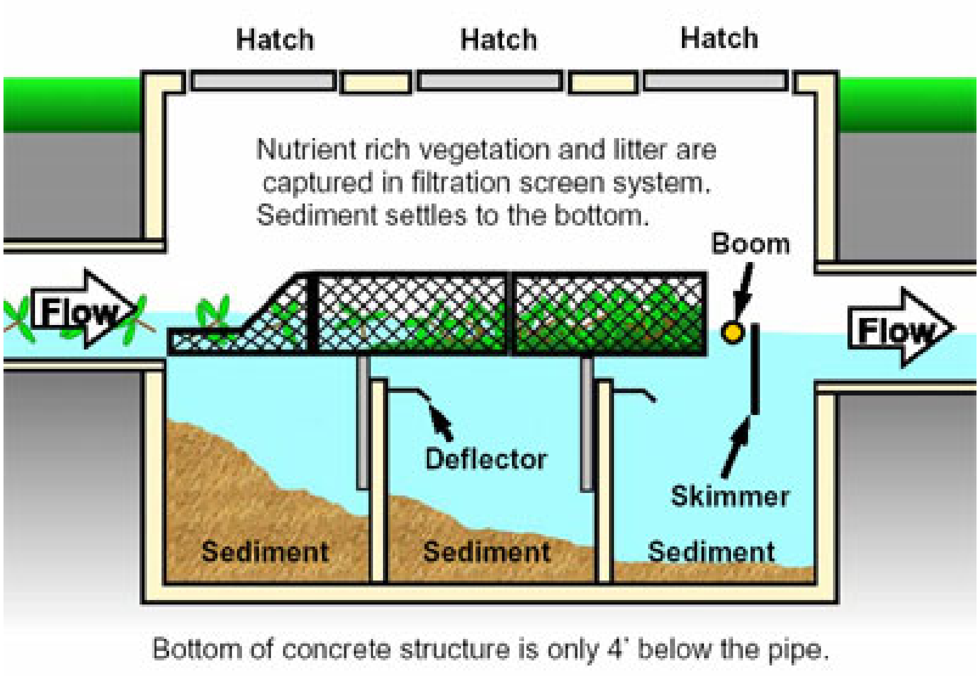

Figure 3: Schematic design of a Nutrient Separating Baffle Box (from Suntree Technologies, Inc.)

As shown in Figure 3 the NSBB is typically installed underground and is frequently retrofitted into existing stormwater infrastructure. While on-site engineering assessments and topographic surveys are required in order to formally select an appropriate location for the installation of a NSBB, tentative areas that may be initially considered for such MTDs include where Point Drive North and Point Drive South connect, along the section of Lake Drive that runs past Carrara's Beach and possibly along the northern stretches of Lake Drive along the western and eastern shoreline.

In addition to environmental constraints that need to be taken into account, other factors need to be considered for the feasibility of MTDs such as property boundaries, easements and right-of-ways, existing stormwater infrastructure and the location / position of various utilities (both above and below ground). Thus, it is strongly recommended that a preliminary engineering site assessment be conducted by a representative from the Town as well as a professional civil engineer (such as Princeton Hydro) to identify potential locations for the actual installation of any NSBBs.

Other non-structural, on-site measures that individual property owners can implement to minimize their contribution to the stormwater / surface runoff TP load include:

- The use of non-phosphorus fertilizers
- Maximizing vegetative cover and minimizing impervious cover
- Where possible, establish shoreline plantings of native vegetation
- Minimize surface runoff through the use of rain barrels
- Do not direct roof runoff or grey water pipes into existing stormwater infrastructure
- Where feasible, create a small rain garden and direct runoff to it

North Beach Wet Pond BMP

While there is very little room for large, conventional BMPs around Lake Peekskill, such as those identified in the State's Stormwater Manual, one was installed in the early 1990's. This is the large wet pond BMP located adjacent to the North Beach (hereafter known as the North Beach wet pond). This BMP was designed to treat and remove a large portion of the non-point source pollution that enters Lake Peekskill from the northern sub-watershed. Such large BMPs allow for both the settling of particulates and the assimilation of dissolved nutrients (including phosphorus). Thus, according to the New York State BMP Manual wet ponds are “good” at removing phosphorus. Typically, wet pond BMPs are known to remove approximately 60% of the phosphorus in stormwater when properly functioning.

Again, the North Beach wet pond was installed in the early 1990’s; thus this BMP is between 20 and 25 years old. Typically, wet pond BMPs need to be dredged approximately once every 15 to 25 years. Additionally, about ten years ago there were questions as to whether or not the BMP was leaking or had some structural problems associated with its clay bottom. Given the current conditions of the wet pond and its age, Princeton Hydro strongly recommends a formal assessment of the BMP to determine if it is indeed leaking, quantify the amount of accumulated sediment and inspect the existing condition of its associated infrastructure and vegetation.

As with all stormwater infrastructure, the North Beach wet pond requires some routine and non-routine (dredging) maintenance to ensure it is operating at maximum capacity. More than likely the wet pond has never been dredged since its construction; the removal of accumulated material will optimize the operation of this BMP and increase its capacity to remove phosphorus from the incoming stormwater. In fact, dredging and conducting additional maintenance activities associated with the wet pond should have a measurable contribution toward improving the overall water quality of Lake Peekskill.

Without conducting a formal assessment of existing state of the wet pond it is difficult to say how much the necessary maintenance activities will cost.

However, the removal of the accumulated material from the wet pond is very preliminarily estimated to cost between $10,000.00 and $50,000.00 depending on the amount of material in the pond, the round trip distance to the final disposal site and the composition of the material. Permitting should be relatively easy since the wet pond is clearly recognized as a stormwater structure.

Water Quality Monitoring and Cyanotoxins

Princeton Hydro strongly recommends that the Town of Putnam Valley continue to participate in the SCLAP program to collect detailed long-term water quality data on the lake. Such information will be particularly important in order to assess how the lake will respond to all future restoration measures. Additionally, sampling of cyanotoxins should be continued; however, other parameters can be used to determine if the beaches should be temporarily close for use, as is currently being done with fecal coliform counts. Visual assessments and Secchi depth measurements taken just off the beaches can also be used to determine if at least residents should be warned about existing conditions. For example:

- Secchi depths less than 1 meter (3.3 feet) or
- A noticeable amount of green or blue-green surface scum concentrated along the beach shoreline

Such conditions should be used to make decisions on possibly putting up warnings over potential cyanotoxin-producing algal blooms.

One thing the Town of Putnam Valley may want to do is conduct a simple water quality modeling study with the long-term database to develop a relatively simple model(s) that can be used to predict what the lake will look like under various phosphorus loading scenarios. This would provide a means of quantifying how much the annual phosphorus load should be reduced by in order to attain and specific improvement in water quality (e.g. lower amounts of chlorophyll *a*; higher Secchi depths).

Summary of the Recommendations and Conclusions

Table 2 is a summary of the proposed recommended management / restoration measures for Lake Peekskill.

Table 2 – Summary of the Recommended Restoration Measures for Lake Peekskill, Putnam County, New York

Recommended Restoration Measure	Notes on Recommended Measure
Beach, Shoreline Aeration / Ozone Systems	Should conduct a formal assessment at each beach to conduct formal designs and possibly install one system this year.
Floating Wetland Islands	Consider the design, construction and installation of one 250 sq.ft. Island in the northern end of the lake.
Mandatory pump-outs of existing septic systems	Pump-outs of once every 3 yrs for year-round residents and 5 yrs for seasonal residents. In addition, distribute information on the need and value to pump-outs.
Nutrient Separating Baffle Box stormwater MTDs	Conduct a survey and identify feasible locations for the installation of these MTDs.
Maintenance / dredging of North Beach Wet Pond	Conduct an assessment, including quantifying the sediments in the wet pond to develop a maintenance plan for the wet pond.
General Education	Provide the local community with information on what property owners can