Palmer Lake Restoration Plan
Towns of Kent and Carmel
Putnam County, NY

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Introduction

Palmer Lake is a small impoundment of Michael Brook, which is a tributary within the Croton Reservoir system, which provides New York City with a portion of their potable water. Palmer Lake is located in Putnam County, New York where portions of both the lake and its watershed are located in the Towns of Kent and Carmel. The lake is 14 acres in surface water with a mean depth of 4 feet. The lake has a watershed area of 460 acres, which gives it a watershed:lake ratio of 33:1. Such large ratios are indicative of an artificial impoundment and higher pollutant loads (pollutants referring to suspended solids and the nutrients nitrogen and phosphorus). The lake flushes approximately 19 times per year, which means it flushes approximately 1.6 times per month. However, based on local and regional precipitation patterns, the summer or growing season flushing rates are substantially lower than the annual estimate. Such lower flushing rates over the growing season, coupled with higher water temperatures and the availability of nutrients, contribute toward the development of nuisance levels of algae and aquatic vegetation in Palmer Lake. Of these environmental components, being patterns of precipitation, seasonal water temperatures and nutrient availability, only nutrient availability is one that can be directly managed.

As a result of a decline in water quality over the last few decades, Palmer Lake was identified on the Lower Hudson River Basin Priority Waterbody List in 2011. The specific impacts include public bathing being identified as stressed and recreation in general being identified as impaired. The documented impairments include nuisance algal and weed growth, while the cause of these impacts is the nutrient phosphorus (NYS DEC, 2014).

As a result of this recognized decline in water quality in Palmer Lake a Total Maximum Daily Load (TMDL) analysis was conducted by NYS DEC. Based on the State draft TMDL the annual TP load for Palmer Lake needs to be reduced by 64.4 lbs (29.3 kg) in order to be in compliance. This excludes the waste load allocation of 10.7 lbs or lower that needs to be maintained by the Kent Manor WWTP. The TMDL identifies suggested targeted reductions for Palmer Lake (e.g. septic reduction of 100%, development (MS4) by 10%), however a fairly pragmatic approach was taken in the development of the

Restoration Plan. Specifically, recommended measures were suggested that could be implemented within a reasonable amount of time, with minimal or reasonable permit requirements. Other, more long-term recommendations are provided that improve water quality and can directly contribute toward reducing the amount of aquatic plant and algal biomass. However, this Restoration Plan focuses primarily on those measures that could be implemented within the next 1-2 years and would have a direct impact on the lake's existing phosphorus load.

Water Quality Data

As part of the development of this Restoration Plan, Princeton Hydro conducted a water quality monitoring event of Palmer Lake on 9 September 2014. A member of the local community allowed the use of their boat and oars to conduct the sampling event. During the monitoring event Princeton Hydro collected in-situ data just off the dam, in the deepest portion of the lake, for temperature, dissolved oxygen (DO), pH and conductivity. In spite of it being late summer, the lake was well mixed and well oxygenated from surface to bottom (Table 1). Thus, while the TMDL did not take into consideration the potential for internal phosphorus loading from the sediments, the source of phosphorus is more than likely minimal since the bottom waters of Palmer Lake were oxygenated at this time. However, since this is only based on one sampling event, additional sampling throughout the growing season should be conducted to confirm this. While total phosphorus (TP) were not excessive (> 0.06 mg/L) they did exceed NYS DEC's established TP value for mean summer concentrations of 0.02 mg/L. The surface TP concentration was 0.03 mg/L, while the inlet concentration was 0.04 mg/L (Table 2), which again supports the need for the TMDL and associated Restoration Plan.

The lake was experiencing a moderate bloom of the filamentous diatom *Melosira*, although some potentially nuisance, blue-green algae were present (*Anabaena*, *Microcystis*, and *Oscillatoria*). It is the *Melosira* bloom that gave the water a brownish tinge during the sampling event. In spite of this moderate bloom, water clarity as measured with a Secchi disk, was acceptable for recreational use (greater than 1.0

meter). A number of other algae, green algae, dinoflagellates and other diatoms were also identified. Zooplankton numbers were moderate with two genera of herbivorous (algae eating) cladocerans (*Daphnia* and *Diaphanosoma*) identified.

TABLE 1 – *In-situ* Data Collected at Palmer Lake
Putnam County, New York on 9 September 2014

Sampling Depth meters and feet	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (mmhos/cm)
0.0 (0.0 ft)	22.43	8.61	7.26	0.368
0.5 (1.65 ft)	22.42	8.38	7.44	0.364
1.0 (3.3 ft)	22.29	8.54	7.39	0.366
1.5 (5.0 ft)	22.18	8.28	7.40	0.365

Total depth at mid-lake sampling site was 1.75 m (5.8 ft)
Secchi depth at mid-lake sampling site was 1.6 m (5.3 ft)

TABLE 2 - Discrete Data Collected at Palmer Lake
Putnam County, New York on 9 September 2014

Mid-Lake Parameter	Value
Total Phosphorus (mg / L)	0.03 mg/L
Soluble Reactive Phosphorus (mg / L)	<0.002 mg/L
Nitrate-N (mg / L)	0.05 mg/L
Ammonia-N (mg / L)	0.01 mg/L
Inlet Total Phosphorus (mg / L)	0.04 mg/L
Chlorophyll *a* (mg/m^3)	10.0 mg/m^3
Total Suspended Solids (mg / L)	< 3.0 mg/L

Identified macrophytes included the floating leaved plants white waterlily and watershield; the submerged species Eurasian watermilfoil and brittle naiad (both recognized as invasive species) as well as coontail and duckweed; and the mat alga

Lyngbya. The dominant species during the early September sampling event was the invasive species brittle naiad.

Recommended In-Lake Management Measures

The draft TMDL provides a set of proposed algae and weed control measures for Palmer Lake. While the majority of these measures do little to reduce the annual TP load, some measures such as the use of aquatic pesticides or the stocking of sterile grass carp can actually increase the availability of nutrients. Thus, for the sake of this Restoration Plan the focus was placed on those measures that can actually reduce the amount of phosphorus, such as the physical removal of vegetation and mat algae through hand pulling or mechanical means. In the draft TMDL three modes of physical removal were described and included hand / diver harvesting, cutting and mechanical harvesting. Of the three the one that is being proposed as part of the Restoration Plan is mechanical weed harvesting.

Typically, mechanical weed harvesting is limited to larger, deeper waterbodies with formal boat launches / ramps since most harvesting machines are large, paddle-boat designs that require water depths of at least 4 feet to operate. Thus, such larger machines are limited in their use in smaller, shallower systems such as Palmer Lake. In addition, larger harvesters could not even be launched in such lakes due to size limitations. However, for mechanical harvesting in such smaller, shallower systems, the Truxor DM 5000 (known hereafter as the Truxor) can be considered. The Truxor is a small-scale, highly maneuverable vehicle that can be used to remove aquatic vegetation and algae from lakes and ponds (Figures 1 and 2). Typically, permits are not required for the use of the Truxor as long as the harvesting focuses solely on aquatic plant and algal biomass.

Figure 1: The Truxor, an amphibious aquatic harvesting machine

Figure 2: The Truxor in operation, harvesting water lilies and submerged vegetation

The Truxor can reach shallow areas that a conventional weed harvester cannot, from both water and land. It can harvest aquatic plants and algae in water as shallow as less than a foot and even harvest shoreline vegetation. The Truxor can also remove nuisance / invasive wetland species, leaf litter and woody debris and conduct some small-scale dredging but such activities would require permits. With the extendable arm, the Truxor can harvest at depths up to 6 feet deep, however, it is generally used to harvest aquatic vegetation from depths less than 3 feet, areas that are not readily accessible by conventional harvesting equipment. In addition, the machine is relatively easy to launch and deploy. Thus, the Truxor may be a particularly effective, non-chemical means of removing nuisance vegetation, particularly along the near-shore areas along the southern end of Palmer Lake.

As previously mentioned, based on the water quality monitoring event conducted on 9 September 2014 the dominant, nuisance species in Palmer Lake at that time was the invasive species brittle naiad. In addition, other identified, potentially nuisance, submerged macrophytes included Eurasian watermilfoil and the mat alga *Lyngbya*. Any harvesting should focus on these nuisance species of concern.

The disadvantage to the Truxor is similar to that of conventional weed harvesting. A near-shore disposal site is required to deposit the harvested material. In addition, transportation of the harvested material to a final disposal site is required. One way of increasing rates of harvesting is to have a floating barge follow the Truxor that can be used to temporarily store and transport the cut material to the shoreline, where it can then be transported to the final disposal site.

While some fish and other aquatic organisms may be harvested along with the plant / algal biomass, the small-scale of a Truxor operation would substantially limit the impact this would have on the lake’s overall aquatic community. Also, depending on the nuisance species involved and the time of the year, more than one Truxor harvesting event may be required, at least from a recreational perspective.

The Truxor typically costs between $1,800.00 and $2,200.00 per full day of operation. Depending on the targeted nuisance species and their relative densities, as well as the round trip distance to the shoreline disposal site(s), between 1-3 acres of surface area can be covered with the Truxor. In addition, this estimated cost range does not include disposal of the harvested biomass once it is deposited on the shoreline. To maximize the cost efficiency of the Truxor, it is strongly recommended that local resources and equipment (e.g. one of the Towns) be used to transport the harvested material to its final disposal site.

Since the ultimate goal of the Restoration Plan is to reduce the annual TP load to comply with the TMDL, the phosphorus associated with the removal of aquatic plant and algal biomass through mechanical harvesting should be quantified. Based on several studies (one at Lake Hopatcong, NJ and another at Westtown Lake, PA), Princeton Hydro has estimated that harvested plant / mat algae biomass has a mean TP concentration of 2,293 mg of TP per kg of biomass. Also, based on our three years of experience with the operation of the Truxor, it is estimated that approximately 162.5 cubic yards (124 cubic meters) of wet biomass can be harvested per day. In turn, each cubic meter of harvested wet biomass is estimated to weigh approximately 71 kgs. Using these data and running some calculations is it estimated that approximately 3.6 lbs of TP can be removed from a lake from a full day of harvesting with the Truxor. **Thus, if the Truxor is used once a year, over a period of four days sometime in June or early July, this in-lake management measure would remove approximately 13 lbs of TP per year.**

Another in-lake management measure that should be considered for implementation in Palmer Lake is the installation of two Floating Wetland Islands (FWIs). FWIs are an aesthetically pleasing, ecologically friendly means of reducing in-lake nutrient concentrations. They essentially divert some of the nutrients that would be used to fuel the growth of nuisance algae and weeds 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. **Thus, in the case of Palmer Lake, two FWIs are recommended for installation, which would remove approximately 20 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 3). The Islands are anchored in waters approximately 3 to 10 feet in depth. We would recommend installing them toward the northern end of the lake 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 blue-green algae also known as cyanobacteria) and aquatic plant growth.

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 3). 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 will leave the Islands alone. Additionally, the vegetation should be periodically inspected to ensure growth is healthy. Occasionally, after a particularly heavy storm the Islands 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 4).

Figure 3: Floating Wetland Island built, deployed and anchored in a lake in Wayne County, PA in 2010

Figure 4: Established Floating Wetland Island in a lake in Wayne County, PA in 2014

Recommended Watershed-Based Management Measures

The existing soils within the Palmer Lake watershed have a limited capacity to properly treat (e.g. shoreline depth to bedrock) the existing on-site wastewater loads. In addition, the existing septic leachate fields are located in close proximity to the lake or associated inlets, indicating that the local septic systems account for a substantial portion of the lake's annual TP load. In fact, the TMDL analysis reveals that septic leachate accounts for slightly over 65% (83.6 lbs) of the annual TP load entering Palmer Lake. Given these conditions, the TMDL proposes to take these septic systems off-line through the sewering of the Palmer Lake community sometime in the future. By sewering the community the septic-related TP load would be eliminated (83.6 lbs per year to 0 lbs per year).

The Kent Manor Waste Water Treatment Plan (WWTP) will contribute 10.7 lbs of TP per year to Palmer Lake; as per the TMDL the WWTP cannot exceed this contributing annual amount of TP, while at the same time having an allowable wastewater discharge of 103,200 gpd. As part of this established discharge rate, 13 parcels within the Palmer Lake watershed will be sewered, with their septic systems to be decommissioned. It is hoped that eventually all of the existing homes with septic systems will be sewered, which would eliminate this source of non-point source (NPS) pollution, which includes pathogenic organisms and nitrogen, as well as phosphorus. However, the sewering of the Palmer Lake watershed is not anticipated to be conducted within the immediate future (i.e. sometime over the next 5 to 10 years). Thus, as part of the Palmer Lake Restoration Plan it is recommended that all existing septic systems be pumped out on a routine basis; at least once every three years for full-year residents and once every five years for seasonal residents.

Princeton Hydro has developed two on-site wastewater treatment system (septic systems) Management Plans for two lake communities in northern New Jersey; the portion of the Township of Jefferson in the Lake Hopatcong Watershed (Morris County) and the portion of the Township of West Milford in the Greenwood Lake Watershed (Passaic County). Similar to Palmer Lake, both lakes have phosphorus TMDLs. Additionally, through a combination of direct monitoring and modeling the annual, septic-related TP load was quantified and targeted TP loads were established for the septic systems within these TMDLs. Thus, these septic Management Plans developed a strategy to reduce this source of phosphorus for the lakes and comply with their respective TMDLs. For both lakes the development of ordinances to require mandatory pump-outs of septic systems once every three years was an important component of these Plans.

Since the focus of this report is to develop a TMDL-based Restoration Plan for Palmer Lake, to comply with the targeted phosphorus load, the specifics of NYS DEC's modeling of watershed-based septic-system loading will not be compared to Princeton Hydro's modeling efforts. However, some of the results and research conducted as part of Princeton Hydro's efforts will be used to justify the recommendations associated with managing Palmer Lake's phosphorus load that originates from septic systems.

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 has been shown that in general a septic system leach field within 330 feet of a waterway will eventually (50+ years) be a net source of phosphorus (US EPA, 1980).

However, for the sake of consistency and to minimize potential complications associated with the management of the lake community, it is recommended the routine pump-outs be identified for all community members / watershed stakeholders regardless of where their septic systems are located. Even if their leach fields are not within the 330 feet septic Zone of Influence (ZOI) routine pump-outs will extend the life of existing septic systems as well as contribute toward avoiding / minimizing potential microbial contamination of potable wells or the local beach that may be immediately downgradient of these septic leach fields.

Routine pump-outs of local septic systems will contribute toward reducing the TP load entering the waterways within the Palmer Lake watershed. In order to quantify this associated reduction for the TMDL, a number of studies were reviewed, including the two northern New Jersey septic systems Management Plans developed by Princeton Hydro. 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 in the raw wastewater is separated out as sludge, which accumulates in the bottom of the septic tank (Day, 2011). Thus, for the Palmer Lake Restoration Plan, a conservative removal rate of 20% was used to calculate how much TP would be removed from the annual septic load once all tanks are pumped-out on a routine schedule of at least once every 3 years for year-round residents and once every 5 years for seasonal residents. The lower removal rate of 20% was selected for two reasons. First, no information is readily available on the existing septic systems and many of them are presumed to be at least 35 to 50 years old. Thus, in the absence of more detailed, on-site information, it is prudent to assume that many of these systems are operating on a sub-optimal capacity and using the lower removal rate of 20% will account for some of this in the model. Second, the lower removal rate of 20% also contributes toward accounting for an implicit margin of safety for the TMDL analysis.

While there may be some discrepancy between the State's TMDL model and Princeton Hydro's work in the details associated with the modeling of the septic system's annual TP load (e.g. State's septic ZOI of 250 ft vs. Princeton Hydro's septic ZOI of 330 ft), the anticipated annual reduction associated with watershed-based routine pump-outs was calculated by reducing the total annual septic TP load by 20%. **The resulting annual removal rate is 16.7 lbs of TP per year** (Table 3).

At this point in time the recommendation for routine pump outs is not mandatory. The first step should be a very aggressive and continuous educational campaign targeting all watershed stakeholders who have on-site wastewater treatment systems. 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 Towns to develop a mandatory pump-out ordinance, as was conducted for the northern New Jersey lake communities, 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 why it should be done once every 3-5 years.
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 pump-out, such as a small tax break, reduction on community use fee or other local benefit.

Additional actions will also contribute toward reducing the septic-based TP load, such as water conservation, 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.

Eventually, mandatory pump-outs through the use of local or community ordinances, the use of alternative septic system technology (e.g. sand filters) and, in particular, the eventual sewering of the Palmer Lake community would result in substantially large reductions in the septic system contribution to the lake's annual TP load. However, at this point in time, Princeton Hydro recommends focusing on educating the local community to pump-out their septic tanks on a routine basis.

In addition to septic leachate, stormwater runoff also contributes to the annual TP load that drives the production of algal and aquatic plant growth in Palmer Lake. 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 addition to the lack of space for such large BMPs, existing environmental constraints such as steep slopes and shallow depth to bedrock also limit 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 small amounts of space relative to more conventional BMPs and, depending on the type and model, can be relatively easy to maintain.

For the sake of the Palmer Lake Restoration Plan the recommended MTD is the Multi-Chambered Nutrient Separating Baffle Box (NSBB), possibly with the inclusion of a polishing unit to enhance the removal of dissolved phosphorus. 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.

As previously mentioned, 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 5). No special permits or certifications are required. However, it is always recommended that any stormwater structure be inspected after a particularly heavy / large storm event.

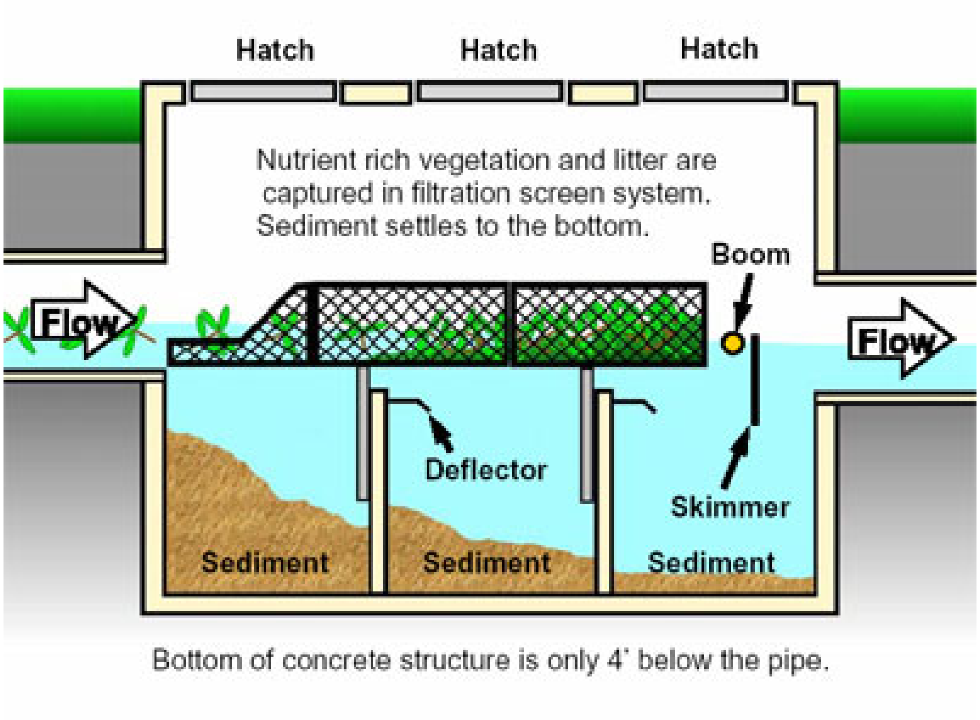

Figure 5: Schematic design of a Nutrient Separating Baffle Box (from Suntree Technologies, Inc.)

As shown in Figure 5 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 spot or location for the installation of a NSBB, tentatively areas that may be initially considered for such MTDs include at or adjacent to the tennis court and the community facility just off Bryant Trail in the northeast corner of the lake. However, in addition to environmental constraints other factors need to be considered for the feasibility of such MTDs such as property boundaries, easements and right-of-ways, existing stormwater infrastructure and the location / positions 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 the two proposed NSBBs.

Based on similar projects where Princeton Hydro has installed NSBBs in lake communities within the Mid-Atlantic region of the United States, such MTDs have been designed and installed to treat the small to medium-sized storm events, from a water quality perspective. The treated drainage areas have ranged from 5 to over 100 acres but with most being less than 30 acres. For example, of 11 NSBB stormwater structures Princeton Hydro has designed and installed in northern New Jersey and northeastern Pennsylvania, the treated drainage areas ranged from 5 to 125 acres with a median drainage area of 12 acres.

Again, based on Princeton Hydro's in-house database a NSBB treating approximately 12 acres of drainage area of land tends to remove between 5 to 12 lbs of TP per year. This range is based on whether or not the NSBB is part of a "treatment train" for stormwater, such as including a nutrient polishing unit or having the treated runoff flow through a vegetated filter or other small-scale, conventional BMP. On its own, the NSBB tends to remove approximately 5 lbs of TP per year while treating a 12 acre drainage area; however, some additional treatment increases this to approximately 12 lbs per year. For the sake of initiating the Palmer Lake Restoration Plan, two NSBB projects are being proposed for design / implementation.

As has been previously stated, some more detailed site-specific assessments and property surveys are required in order to identify appropriate locations where these NSBB structures could be installed. However, on a tentative basis, one NSBB could be installed at or adjacent to the tennis court and community facility just off Bryant Trail in the northeast corner of the lake. A second one could be on or around the community beach, located just south of the first site. These locations are being recommended for this initial assessment since they may contain community-owned property for the installation of the NSBBs. In addition, there may also be room at these locations for the installation of smaller post-treatment BMPs, like a vegetative filter to enhance phosphorus removal, as well as the NSBB. Another important factor is the location of Bryant Trail Road; there may be some existing stormwater infrastructure or pipes that can be retrofitted for the installation of the NSBBs. However, again it must be emphasized that some more site-specific, engineering assessments and property surveys are absolutely necessary to determine the feasibility of these proposed projects as well as provide a reasonable estimate of cost for their design and installation.

Based on previous projects, the estimated cost for the design (survey, engineering designs and calculations as well as possible permits) and installation of a NSBB and associated infrastructure / secondary BMP tends to range between $70,000.00 and $110,000.00. The actual cost depends on a variety of factors including but not limited to status of existing stormwater infrastructure and other utilities, property boundaries, availability of space, depth to bedrock and if additional post-treatment measures are included. For the sake of this Restoration Plan, an individual NSBB is proposed for the beach site and a NSBB coupled with some additional treatment (polishing unit or vegetative filter) is proposed for the tennis court site. **Assuming that the watershed treatment areas for each site would be approximately 12 acres, the amount of TP removed by the beach and tennis court stormwater project sites is 5 and 12 lbs per year, respectively.**

Summary of the Recommendations and Conclusions

Table 3 is a summary of the recommended management / restoration measures for Palmer Lake. It also compiles the amount of TP removed through each recommended measure. Essentially, the Palmer Lake TMDL states that the annual TP load needs to be reduced by 64.4 lbs in order to be in compliance. If all of the recommended measures are implemented, the annual TP load is estimated to be reduced by approximately 67 lbs per year, 2.6 lbs more than what is targeted under the TMDL. While these are estimated values based on other studies, models and project experience, this does provide a reasonable strategy in moving toward compliance with the TMDL and improving / protecting the water quality of Palmer Lake.

Table 3 – Summary of the Recommended Restoration Measures and their Associated Annual Removal Rates for Total Phosphorus (TP)

Recommended Restoration Measure	Amount of TP Removed (lbs)	Notes on Recommended Measure
Mechanical Weed Harvesting	13	Amount of TP removed based on the operation of the Truxor over the course of four (4) full days
Floating Wetland Islands	20	Amount of TP removed based on installation of two (2) Islands, each one 250 square feet in size
Mandatory pump-outs of existing septic systems	17	Amount of TP removed based on pump-outs of once every 3 yrs for year-round residents and 5 yrs for seasonal residents
Nutrient Separating Baffle Box stormwater device	5	Amount of TP removed based on 12 acre treatment drainage area at the community beach
Nutrient Separating Baffle Box stormwater device	12	Amount of TP removed based on 12 acre treatment drainage area at tennis court community area; includes additional treatment
Total TP Removed	**67**	**If all measures are implemented**

Table 4 provides a summary of estimated costs to design and implement all of the recommended restoration measures. Some of the costs are reasonable estimates, such as those associated with the harvesting with the Truxor and the installation of the Floating Wetland Islands. However, others such as the installation of the stormwater MTDs, are more generalized approximations of cost and require additional, site-specific data to provide a reasonable accurate estimate in cost. It may be possible to obtain local, regional or State grant funding to implement the stormwater projects.

It should also be recognized that the estimated costs do not include any additional water quality monitoring and watershed-based, engineering assessments to identify feasible locations for the installation of stormwater infrastructure. However, such additional work is absolutely necessary to move the Plan forward. Other measures that could be considered relative to the future management of the lake include the implementation of other algal / aquatic plant control measures such as the use of aquatic pesticides, nutrient inactivators or stocking sterile grass carp (specifically for submerged aquatic plant control). While these measures could provide valuable short-term relief from nuisance conditions, they do not directly reduce the watershed sources of phosphorus and were therefore not included in this analysis. Finally, it should also be mentioned that if the Palmer Lake watershed was sewered, and the treated effluent was discharged below the lake, it would be in complete compliance with its TMDL. However, since the sewering of the entire Palmer Lake community is not scheduled for the foreseeable future, this recommended restoration strategy will provide a means of complying with the lake's TMDL and, more importantly, improve the overall water quality conditions of Palmer Lake.

Table 4 – Summary of the Estimated Costs Associated with the Recommended Restoration Measures for Palmer Lake

Recommended Restoration Measure	Estimated Cost to Design + Implement	Notes on Recommended Measure
Mechanical Weed Harvesting	$8,200.00	Includes mob / demob of equipment and four (4) days of harvesting. Does not include disposal of harvested material; an annual restoration measure
Floating Wetland Islands	$22,000.00	Includes Islands, goose netting, plants and associated anchoring materials. Also includes shipping of material, construction, planting, deployment and anchoring
Mandatory pump-outs of existing septic systems	-----	Negligible cost over entire community. Approximately $150.00 per pump-out
Nutrient Separating Baffle Box stormwater device	$75,000.00	Design and installation of a NSBB (includes survey work, permitting, engineering design, oversight, materials and installation)
Nutrient Separating Baffle Box stormwater device	$115,500.00	Design and installation of a NSBB (includes survey work, permitting, engineering design, oversight, materials and installation)
Total Cost	**$220,200.00**	**If all measures are implemented**