Development of a Lake and Watershed Management Plan for Lake Oscawana, Putnam County, New York

Submitted to:

Lake Oscawana Civic Association
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Introduction

Lake Oscawana is a 368 acre waterbody located in Putnam County, NY (Figure 1 in Appendix A). The lake functions as a primary recreational waterbody and is used for fishing, boating, and swimming. The lake also provides a scenic backdrop and focal point for the community as a whole. In general, the water quality of Lake Oscawana directly impacts its recreational and ecological value. Thus, the long-term goal of the Lake Oscawana Management Plan is to protect the recreational and ecological value of the lake, as well as the property value of the local community.

Recent studies of Lake Oscawana have demonstrated that the lake is an eutrophic waterbody. Furthermore, the lake was listed as impaired for phosphorus by the New York State Department of Environmental Conservation (NYS DEC) in 2004 and a draft Total Maximum Daily Load (TMDL) was issued in 2008. This impaired listing indicates that existing nutrient loading is large enough to cause problems that impact recreational use and aesthetics. Some of the common problems that have arisen at Lake Oscawana include:

1. Nuisance growth of aquatic plants (especially Eurasian watermilfoil)
2. Planktonic algal growth
3. Nuisance amounts of mat algae

Although the Lake Oscawana Civic Association (LOCA) has initiated some actions aimed at reducing the severity of these symptoms of eutrophication, it has been recognized that a more well-defined plan is required. Thus, the objective of this Management Plan is to analyze data from previous monitoring reports, quantify nutrient loading, and to describe and recommend management activities that can reduce the nutrient load entering Lake Oscawana. A balance must be struck between in-lake activities, which are designed to ameliorate such problems as algal blooms/ nuisance aquatic plants and watershed-based initiatives designed to decrease the magnitude of nutrient input. In general, Lake Oscawana is not extremely eutrophic, meaning that it has not been subjected to extremely severe water quality impacts. However, a large part of the Management Plan was designed to implement protective measures that will prevent additional declines in water quality. As such, improvements to the condition of the lake, especially with respect to recreational use, can be achieved with a reasonable amount of effort and funds.

Acknowledgements

The development of this holistic Management Plan for Lake Oscawana and its watershed could not have been possible without the data and information accumulated through past studies. Thus, these efforts are being acknowledged here. First, LOCA would like to recognize both the Lake District and the Aquatic Plant Growth Control District for all of their long-term efforts in the general management and upkeep of the lake.

Dr. Robert Kortmann of Ecosystem Consulting Services, Inc. conducted the original Diagnostic Study and assessment of management alternatives for Lake Oscawana in 1987. Dr. George

Knoecklein of Northeast Aquatic Research has been responsible for the long-term monitoring of Lake Oscawana since the early 1990's and the 2002-2007 database that was used for in the analysis section of this Management Plan. Also, an assessment of lake and its associated long-term database was conducted in 2003 by Dr. Kenneth Wagner of ENSR. Finally, the Town of Putnam Valley recently adopted a Comprehensive Plan and Generic Environmental Impact Statement; some of the information in this EIS was useful in the development of the watershed-based component of the lake's pollutant budget.

1.0 Lake Oscawana Pollutant Load

Pollutants can enter a lake either as discrete discharges from known sources or through runoff from a variety of sources within the watershed. Discrete discharges are referred to as point sources, and all other sources of pollutants are referred to as non-point sources (NPS). NPS contribute pollutants through stormwater runoff, on-site wastewater treatment systems (i.e. septic systems), precipitation on the lake's surface, and internal sources such as release from lake sediments. By quantifying all of the pollutant sources for a lake, a pollutant budget can be developed. This pollutant budget is absolutely necessary in assessing the ecological and recreational health of a waterbody. In addition, pollutant budgets are also used to develop and/or evaluate various in-lake and watershed management strategies. For the purposes of this study, the term "pollutant" refers to the nutrients nitrogen, phosphorus, and suspended sediments.

Typically, the largest source of pollution originates from a lake's watershed. Therefore, land use practices impact a lake through extensive sedimentation and/or heavy nutrient loading. Most of this loading occurs during storm events; eroded soils, fertilizers, heavy metals and petroleum hydrocarbons are all constituents of storm runoff. A large majority of these storm runoff pollutants are either absorbed or adsorbed onto the surface of sediment particles (Wanielista, et al., 1982). However, recent data suggests that under post-development conditions for residential and commercial lands, approximately half of the phosphorus in stormwater is in a particulate form while the remaining half is dissolved.

As a watershed becomes more developed, there is an increase in impervious surfaces. Such conditions substantially reduce the opportunity for stormwater to percolate through the soil. Thus, more watershed-generated pollutants will be discharged into receiving water bodies. As such, residential areas will contribute, on a unit areal basis, more nutrients and suspended sediments than forested areas.

There are also internal processes that are responsible for a given amount of a lake's annual pollutant load. Die back of weeds and algae can generate nitrogen and phosphorus as a result of the bacterial decomposition of plant tissue and algal cells. This process can also lead to the accumulation of organic sediments. It is also possible, under anoxic (no measurable amount of dissolved oxygen) conditions, to liberate substantial amounts of phosphorus from the sediments into the overlying water column. Depending on certain physical factors, this internally regenerated phosphorus can be a significant component of a lake's total annual phosphorus load.

Intuitively, pollutants are generally thought of as having a direct and harmful impact on organisms and the environment. In contrast, nitrogen and phosphorus stimulate algal and aquatic plant growth, which typically results in an increase in the biomass and growth of other organisms (i.e. fish). However, excessive amounts of nitrogen and phosphorus can also generate nuisance densities of algae and/or aquatic plants which, in turn, create a decline in water quality and ecological value.

In contrast to nitrogen and phosphorus, total suspended solids (TSS) do not stimulate excessive algal or aquatic plant growth. However, elevated TSS concentrations limit algal/ aquatic plant growth by limiting the amount of light available for photosynthesis. Elevated TSS concentrations can destroy fish habitat (i.e. spawning beds), directly impact the health of fish (covering the surface of the gills), and accelerate the rate of in-filling of aquatic ecosystems. Similar to nitrogen and phosphorus, the impacts of TSS concentrations are cumulative in nature. As the TSS load increases, its impact on the environment increases. As such, the impact of the NPS pollutants total phosphorus (TP), total nitrogen (TN), and TSS on aquatic ecosystems needs to be evaluated with a cumulative perspective in mind.

Thus, when preparing a lake's nutrient budget it is important to properly account for all the site specific factors that can contribute towards these pollutant loads. This includes an assessment of the relative contributory effects of such factors as lake morphometry, land use, slope, soil, and existing stormwater infrastructure. In this management plan, four main components of the Lake Oscawana nutrient budget were analyzed:

1. Overland (surface runoff)
2. Internally recycled
3. Septic Leachate
4. Atmospheric (precipitation and dryfall)

1.1 Surface Runoff Pollutant Load

The first step in quantifying the surface runoff pollutant load entering Lake Oscawana was to delineate its watershed (Figure 1 in Appendix A) using Geographic Information Systems (GIS). The watershed was delineated by Princeton Hydro, LLC using a USGS topographic map (Figure 1 in Appendix A); this watershed map was them compared to a pre-existing watershed map from the Lake Oscawana Civic Association (LOCA). It should be noted that the watersheds were very similar, with the exception of the north western boundary. In the Princeton Hydro delineated watershed map Clear Lake was excluded because, upon examination of the USGS topographic map, this lake appears to drain into a wetland near the Wiccopee Reservoir. The watershed was then divided into a set of sub-watersheds in order to conduct a more site specific assessment of the surface runoff pollutant loading. A total of five sub-watersheds (Table 1) were delineated within the Lake Oscawana watershed (Figure 2 in Appendix A).

The annual pollutant loads for total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) generated within each sub-watershed within the Lake Oscawana watershed were calculated.

Table 1: Area of Sub-watersheds

Sub-watershed	Approximate Area (Acres)
1	**142**
2	**278**
3	**562**
4	**866**
5	**614**
Total area:	**2,462**

After the sub-watersheds were delineated, land use/ land cover (LULC) classes within each sub-watershed were quantified. LULC data from 2001 and a document of land cover class definitions were downloaded from the Multi-Resolution Land Characteristics (MRLC) Consortium. Within each sub-watershed's attribute table, LULC classes were identified by a LULC ID and name. For example, LULC ID 21 corresponds with the 2001 Land Cover Class Definition "developed open space". Thus, within each sub-watershed LULC IDs were identified and grouped into order to quantify the total area for each land cover class (Table 2).

Next, the areas of each land class (Table 3) were input into Excel and converted into hectares in order to calculate the pollutant loads. The Excel data were used to calculate the pollutant loads using the Unit Aerial Loading (UAL) model. This is a relatively simple but widely used model to calculate surface runoff pollutant loading. Essentially, the UAL models used pollutant loading coefficients based on land use / land cover (Table 2) and area of each land use / land cover to calculate the annual pollutant load for each pollutant of concern. The selected pollutant loading coefficients were obtained from the scientific literature and have been widely used in other lakes and by other States. Negative pollutant loading coefficients reflect land cover classes that reduce pollutants (sink); whereas, positive pollutant loading coefficients denoted land cover classes that are sources of pollutants.

Total annual pollutant loads, developed annual pollutant loads, and annual residential/ commercial pollutant loads were calculated for each sub-watershed (Appendix B). As per the UAL model, calculations for total pollutant loads were conducted by multiplying the total area for each land cover class by the pollutant loading coefficient. The developed load was done using the same methodology, except only developed land classes (i.e. developed open space, developed low intensity, developed medium intensity, and pasture/hay) were used in the calculations. Lastly, residential/ commercial pollutant loads were calculated the same as the previous two pollutant loads, expect for this calculation only developed open space, developed low intensity, and developed medium intensity were used.

Table 2- Land Class Definitions and Pollutant Loading Coefficients (kg/ha/yr)

LULC ID	Land Cover Class	Definition*	Pollutant Loading Coefficient**		
			TN	TP	TSS
21	Developed, Open Space	Includes both constructed materials, but mostly vegetation in the form of lawns. Less than 20% impervious cover.	5.7	0.25	750
22	Developed, Low Intensity	Includes constructed materials and vegetation. 20-49% impervious cover. Mostly single-family housing units.	6.1	0.62	875
23	Developed, High Intensity	Includes constructed materials and vegetation. 50-79% impervious cover. Mostly sing-family housing units.	6.4	0.67	1000
41	Deciduous Forest	Areas dominated by trees generally over 5 meters tall, greater than 20% total vegetation cover, and 75% or more of the trees are deciduous (shed their leaves).	2.6	0.2	250
42	Evergreen Forest	Areas dominated by trees generally over 5 meters tall, greater than 20% total vegetation cover, and 75% or more of the trees maintain their leaves all year. Canopy is never without green foliage.	2.6	0.2	250
43	Mixed Forest	Areas dominated by trees taller than 5 meters and greater than 20% total vegetation cover. Neither deciduous nor evergreen species are greater than 75% total tree cover.	2.5	0.2	250
90	Woody Wetlands	Areas where forest or shrubland vegetation accounts for more than 20% of vegetation cover and the soil or substrate in periodically saturated or covered with water.	0.0	-0.25	-200
95	Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for more than 80% of the vegetative cover and the soil or substrate is periodically saturated with or covered with water.	0.0	-0.25	-200

* As per NLCD 2001 Land Cover Class Definitions
** As per coefficients selected from the scientific literature

Table 3: Area (Acres) Per Land Cover Class for Each Sub-Watershed

Land Cover Class	Sub-watershed				
	1	2	3	4	5
Developed Open Space	88	14	55	63	153
Developed Low Intensity	8	0	0	3	13
Developed Medium Intensity	1	0	0	0	0
Deciduous Forest	34	257	444	759	314
Evergreen Forest	4	3	12	22	63
Mixed Forest	1	0	1	0	3
Pasture/Hay	3	0	5	0	5
Woody Wetlands	0	0	32	19	59
Open Water	3	4	13	4	0
Total Area:	**142**	**278**	**562**	**866**	**614**

Ranking the sub-watershed simply based on the magnitude of their TP loads can be misleading relative to the development of a Lake Management 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 (Appendix B).

Based on these calculations, sub-watersheds 1 and 5 had the highest developed and commercial TN, TP, and TSS loads. Whereas, sub-watershed 2 had the lowest developed and commercial pollutant loads. Thus, sub-watersheds 1 and 5 should be targeted for watershed-based best management practices to help reduce pollutant loads entering Lake Oscawana. Furthermore, it should be noted that approximately 70% of the land associated with sub-watershed 1 is developed (LULC IDs 21, 22, and 23), whereas, approximately 5% of sub-watershed 2 is comprised of developed land. The larger pollutant loads of sub-watershed 5 are due to its larger size (614 acres), which is approximately 4 times larger than sub-watershed 1. Furthermore, sub-watershed 5 has a pollutant load 1.6 times greater than the pollutant load originating from sub-watershed 1.

Table 4
Total Phosphorus, Total Nitrogen, and Total Suspended Solids by Land Cover Class and Sub-Watershed for Lake Oscawana (kg/yr)

Sub-Watershed	Land Cover Class	TP	TN	TSS
1	**Developed**	11	225.3	29,703
1	**Forested**	3.15	40.9	3945.7
1	**Pasture/Hay**	2	17	485.6
2	**Developed**	1.0	32.3	3925.3
2	**Forested**	21	273.6	26304.5
2	**Pasture/Hay**	0	0	0
3	**Developed**	5.6	129.9	15641.1
3	**Forested**	38	480.8	46,235.1
3	**Pasture/Hay**	3.2	28.3	809.3
3	**Wetland**	-3.2	0	-2590
4	**Developed**	7	152.7	20,183.7
4	**Forested**	5.77	821.7	79014.9
4	**Wetland**	0	-1.9	-1537.8
5	**Developed**	18.7	385	51,040.7
5	**Forested**	30.7	399.7	38,445.1
5	**Pasture/Hay**	46.4	28.3	809.3
5	**Wetland**	-0.5	-6.0	-4775.5

1.2 Lake Oscawana Septic System Analysis

Soil data for Putnam Valley, New York were downloaded from Soil Survey Geographic database (SSURGO); this database is managed by the United Stated Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). In addition, a table of the New York soil types and their suitability for septic systems was downloaded from the USDA NRCS. It should be noted that land parcel data could be easily obtained so Google Earth was used to estimate the number of dwellings within the Lake Oscawana watershed.

Once the watershed, lake, stream, and wetland data were obtained, a 100 m (330 ft) buffer was created around lakes, streams, and wetlands using ArcGIS. This buffer (i.e. zone of influence) is the average distance in which septic systems can influence waterbodies. Soil types within the area were determined (Figure 3). The next step was to extract the data so only dwellings within the zone of influence were identified. Each soil identified within the zone of influence was ranked as "not limited", "somewhat limited", or "very limited" (Figure 4). For example, Carlisle muck was ranked "very limited", whereas Charlton loam with a 2% to 8% slope was ranked "not limited". In addition, there were also some soil types that were not rated. To err on the side of caution, soils that were identified as "not rated" were labeled as "very limited". A total of four ratings were mapped based on the USDA NRCS data: not limited, somewhat limited, very limited, and not rated (which was mapped in the same color as "very limited").

If parcel data were available, the land parcels within each suitability class would have been counted. However, as previously mentioned, this data was unavailable, and thus the number of houses for each soil rating was counted using Google Earth to estimate the number of dwellings within the zone of influence. It should be noted that land parcel data should be obtained to determine a more accurate estimate the number of dwellings. A total of 239 houses were counted within the zone of influence; of these dwellings 14 were "not limited", 137 were "somewhat limited", and 86 were "very limited" or "not rated". In addition, 2 houses were within 100 m of wetlands and were classified as "very limited".

Based on 2000 census data, the population within Putnam Valley was 10,686 people and the total number of dwellings was 4,253 (On average there are 2.51 people per dwelling). Therefore, there are approximately 600 people living within 100 m of a shoreline or wetland within the Lake Oscawana watershed. Using this data, the annual phosphorus load originated from septic systems was calculated.

The most commonly used and cost effective protocol to quantify the annual phosphorus contribution from septic systems incorporates information on the number of persons per residence (per capita), soil type and conditions, and distance of leachfield to surface waterway/shoreline (USEPA, 1980). The base formula used to quantify the septic load for each soil suitability class is provided in equation 1:

$$P_s = EC_s \text{ X } \# \text{ of capita X}(1 - SR)$$

P_s	=	Annual phosphorus load originating from septic systems (Kg/yr)
EC_s	=	Selected export coefficient to septic tank (kg / capita / yr)
# of capita	=	Average # of persons per dwelling X # of dwellings
SR	=	Soil retention coefficient (dimensionless)

A number of empirically-derived phosphorus loading coefficients for wastewater entering the septic tank were reviewed (Reckhow, 1980) for the municipal-based septic analyses and a conservative coefficient of 0.74 kg / capita /yr was selected for septic tanks within the Oscawana Lake watershed.

The soil retention coefficient (SR) is an estimate of how well the septic system leachfield traps or retains phosphorus, preventing it from entering the lake or tributary via groundwater. The coefficient is a dimensionless value that ranges from 0 to 1. If all of the generated phosphorus moving through a septic system enters the lake or tributary, the SR is 0. However, if all of the phosphorus is trapped and treated within the soils and none of it enters a receiving waterway, the SRP is 1 (Reckhow, 1980).

Other studies where near shore soils varied from moderate to poor in phosphorus adsorbing capacities had a coefficient of 0.25, while more moderate soils had a coefficient of 0.50 (Reckhow, 1980). Utilizing these ascribed soil retention coefficients as well as a certain degree of professional judgment, it was decided that the soils would be categorized as not limited (0.70), somewhat limited (0.50), or very limited (0.30) in terms of the degree of septic limitation. Finally, it was approximated that half of the dwellings within the 100 m septic zone of influence are seasonal or part-time residences, with the other half being full year round residence. This local demographic was incorporated into the model.

Using this equation and the available data, the annual total phosphorus load originating from septic systems was estimated to be 184.7 kg/yr.

1.3 Lake Oscawana Internal Regeneration of Phosphorus

Internal regeneration can be a significant source of TP in a lake ecosystem. Mostly as a result of bacterial decomposition of organic matter in the lake sediments, phosphorus is produced near the sediment interface. If sufficient dissolved oxygen is available, this phosphorous will adsorb to iron particles and remain in the sediment. However, when high microbial decomposition and other factors combine to reduce the dissolved oxygen (DO) levels to anoxic levels, the adsorbed phosphorus is released to the water column, thereby increasing phosphorus concentrations in the water column. Under certain conditions, the internal load can account for a large proportion of a lake's annual phosphorus load, especially during the dry summer months when surface runoff is minimal. In addition, phosphorus from internal loading can contribute significantly to nuisance algal blooms, especially during fall turnover or when the thermocline descends into the anoxic zone and releases phosphorus to the overlying waters.

Examination of Lake Oscawana's dissolved oxygen/temperature profiles and morphometry from 2002-2005 monitoring reports (Northeast Aquatic Research) indicates the lake was stratified and adequately oxygenated at the surface throughout the monitoring period (May to September). However, depleted dissolved oxygen (DO) concentrations (<1 mg/L) were present during the summer at the bottom of all 3 sampling stations throughout the 2002-2005 monitoring period. From these data it was determined that anaerobic sedimentary phosphorous release would occur in water equal to or greater than 7 meters (23 ft) during June and September and 6.5 meters (21.3 ft) during July and August. This area represents approximately 59% of the lake. These depth measurements were calculated using updated bathymetric data from the 2003 monitoring report (Northeast Aquatic Research) by extrapolating between the 20 and 25 ft. depths.

A number of TP release rates for aerobic and anaerobic sediments were reviewed (Nurnberg, 1984; Mawson, et al., 1983) and flux rates of 0.6 and 6.0 $mg/m^2/day$ were selected, respectively. Using the TP data from the monitoring reports and accounting for temperature effects on bacterial and chemical activity it was determined that TP release would most likely occur from mid-May through mid-September. However, DO data for May was only available for 2002 and indicated no anoxic conditions; therefore, only aerobic TP contributions were calculated for May. During the above mentioned time period, aerobic and anaerobic internal regeneration were estimated to annually contribute 102 kg (224 lbs.) and 352 kg (776 lbs.) of phosphorus to Lake Oscawana (Table 5), respectively. Therefore, internal loading contributes 565.67 kg/yr of phosphorus. These data indicate that internal loading was the major source of TP for Lake Oscawana and continues to be a considerable problem.

Table 5

Total Internal Phosphorus Loading by Month for Lake Oscawana

	May	June	July	August	September	Total
Aerobic Load (kg)	27.7	16.39	12.72	12.72	16.39	**85.92**
Anaerobic Load(kg)	0	104.2	149.79	149.79	104.2	**507.95**
Total (kg)	**27.7**	**120.59**	**162.51**	**162.51**	**120.59**	**565.67**
Aerobic Load (lbs)	61	36.13	28.04	28.04	36.13	**189.34**
Anaerobic Load (lbs)	0	229.72	330.23	330.23	229.72	**1,119.9**
Totals (lbs)	**61**	**265.85**	**358.27**	**358.27**	**265.85**	**1,309.24**

1.4 Atmospheric Loading of Phosphorus and Nitrogen

Another source of nutrients entering Lake Oscawana comes from atmospheric loading, otherwise known as atmospheric dryfall. United States Environmental Protection Agency (US EPA) loading coefficients were utilized to calculate TN and TP for atmospheric deposition. The coefficients are listed in Table 6. It was calculated that on an annual basis direct precipitation accounted for 1490 kg of TN and 37.3 kg TP, while atmospheric dryfall accounted for 465 kg TN and 2.3 kg TP. Therefore, on an annual basis atmospheric sources accounted for 1955 kg TN and 39.6 kg of TP.

Table 6 – U.S. EPA Loading Coefficients For Total Nitrogen and Phosphorus (kg/ha/yr)

	TN	TP
Precipitation on Lake	10	0.25
Dryfall on Watershed	0.4	0.002

1.5 Lake Oscawana Phosphorous Budget

Table 7 summarizes the annual phosphorus budget for Lake Oscawana in kilograms, pounds, and percent contribution. Internal phosphorus loading accounted for 54% of the TP budget due to the severe anoxia below 6-7 meters and the large amount of surface area at that depth. Septic system leachate contributed 23.5% of the TP load. Surface runoff accounted for 18.5% and atmospheric deposition contributed 3.8% of TP, respectively. Based on these assessments, phosphorus abatement efforts need to focus on internal loading and septic leachate. However, internal phosphorus abatement techniques such as hypolimnetic aeration and alum applications are frequently cost prohibitive. From a cost perspective, watershed techniques to reduce septic leachate will need to be considered.

Table 7

Annual Phosphorus Budget for Lake Oscawana

Sources of Pollutants	Kilograms	Pounds	Percent Contribution
Surface Runoff	194.1	428.0	19.7
Internal Loading	565.7	1,247.4	57.5
Septic Leachate	184.7	407.3	18.8
Atmospheric	40.0	88.2	4.0
Total	**984.5**	**2,170.8**	**100.0**

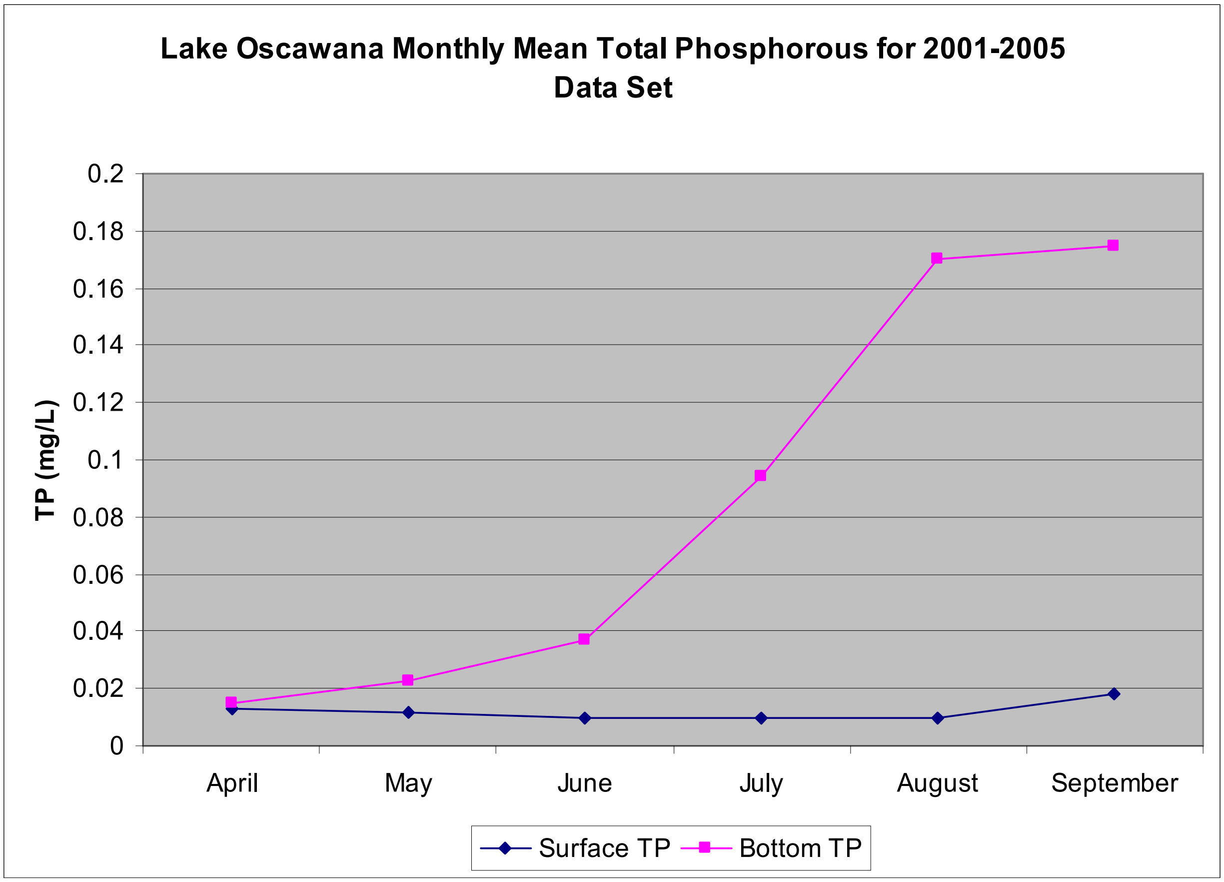
2.0 Analysis of Previous Monitoring Reports

2.1 Total Phosphorous for Lake Oscawana

Phosphorus has been identified as the primary limiting nutrient for algae and aquatic plants in most freshwater lakes. Total phosphorus (TP) is a measure of all fractions of phosphorus found within the lake water which includes organic, inorganic, dissolved, and particulate forms. TP is useful as a predictor of the general phosphorus load. Based on Princeton Hydro's in-house Mid-Atlantic database, TP concentrations >0.06 mg/L can cause nuisance algal blooms. In addition, due to high turnover rates of phosphorus within the algal community, TP can also serve as an excellent predictor of algal biomass and nuisance algal blooms.

Average TP concentrations for surface and bottom waters of Lake Oscawana were calculated for the monitoring period 2001-2005 using monitoring reports (Northeast Aquatic Research). Over the monitoring period, mean surface TP concentrations were moderate and ranged from 0.013 mg/L in April to 0.018 mg/L in September. However, average bottom TP concentrations increased markedly from April through September, which coincide with the onset of anoxia below 6-7 meters. The average bottom TP concentration for April was 0.015 mg/L and the average bottom TP concentration for August and September was 0.22 mg/L and 0.17 mg/L, respectively (Chart 1). This large difference is due to anoxic conditions at depth and resulting internal loading of phosphorus. In addition, the large difference between surface and bottom TP concentration may be caused by blue-green algae that migrate downward and assimilate phosphorus and then return to the surface to accumulate sugars through photosynthesis. Although blue-green algae possess buoyancy control, they can accumulate large amounts of carbohydrates during photosynthesis which allows them to sink into deeper water where they can assimilate phosphorus. A slight increase in surface TP concentration occurs in August into September, probably because the thermocline is being pushed into the anoxic zone.

Chart 1

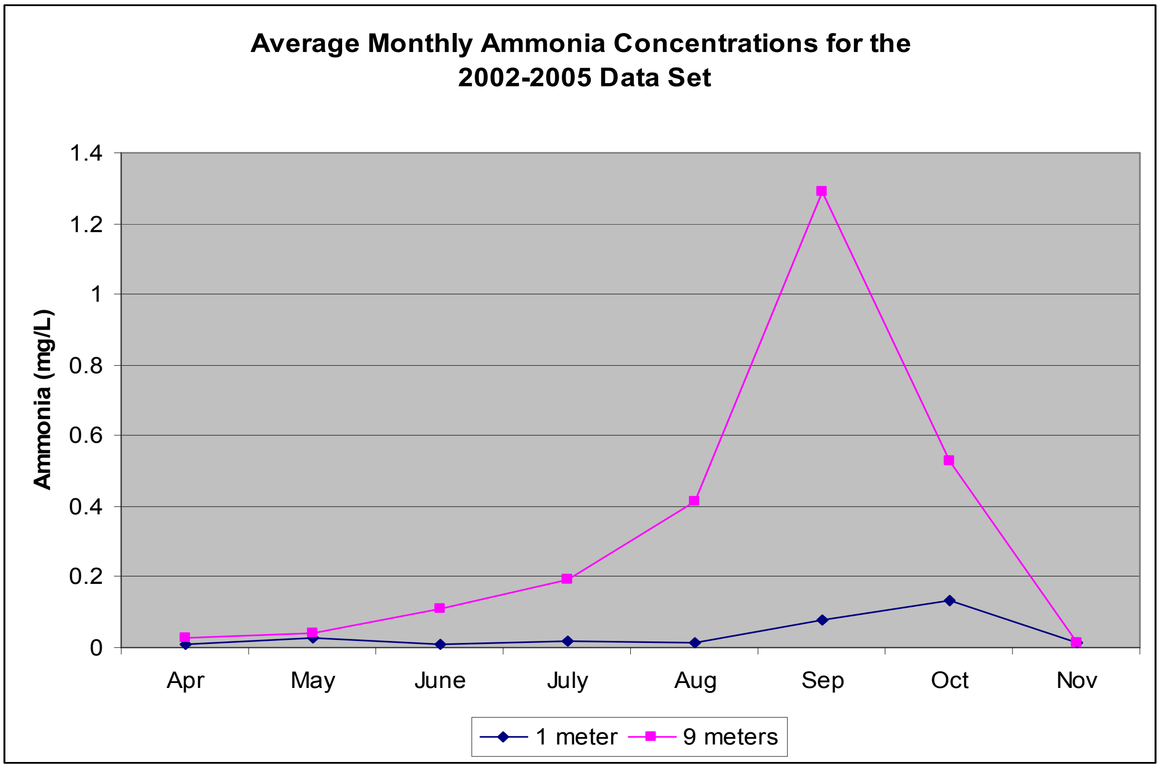


2.2 Ammonia-N

The nitrogen cycle in waterbodies is considerably more complicated than the phosphorus cycle primarily because nitrogen has a gaseous phase and can exist in oxidized forms (i.e. nitrate or nitrite) or reduced forms such as ammonia (NH_4-N) and organic nitrogen. Since nitrate is a more oxidized form of inorganic nitrogen relative to ammonia, it takes more energy for algae to utilize nitrate. Therefore, ammonia is the preferred form of nitrogen for most algae and excessive amounts of ammonia can contribute to nuisance algal blooms. Ammonia is formed when microorganisms such as bacteria decompose dead plant material and other forms of organic detritus. Concentrations of ammonia above 0.05 mg/L can cause algae blooms.

Lake Oscawana was sampled for ammonia during the 2002-2005 monitoring program. The data from those samples were used to obtain a monthly average surface concentration and average bottom concentration (Chart 2). Mean ammonia concentrations at the surface were mostly moderate and varied from non-detectable in April to 0.097 mg/L in October. A rise in concentration of surface ammonia occurred from September to October. Mean ammonia concentrations at 9 meters followed a pattern similar to TP. Concentrations were moderate in the spring and gradually increased until August when a sharp increase occurred until late September. The concentration of ammonia then declined sharply through November. The high concentrations of ammonia at 9 meters are caused by high microbial activity and severe anoxic conditions near the sediment interface. Where there is not sufficient dissolved oxygen, bacteria cannot convert ammonia to nitrate and thus will result in a low NO_3:NH_4 ratio and high accumulations of ammonia.

Chart 2

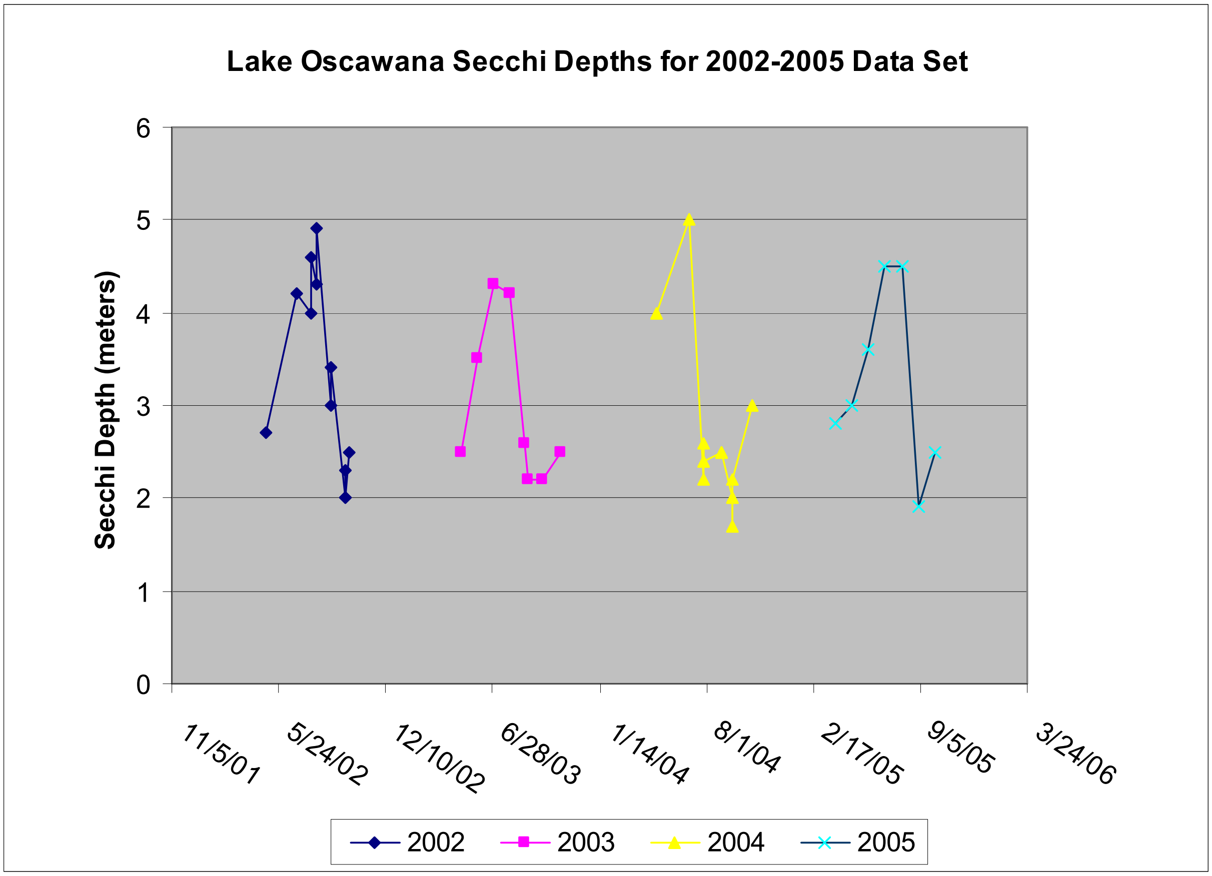


2.3 Trends in Water Clarity for Lake Oscawana

Water clarity is primarily a function of the amount of particulate matter in the water column; the more particulate matter the lower the clarity. Algal biomass and/or suspended sediments are primarily responsible for the water clarity observed in lakes. Water clarity, or transparency, is most often measured with a Secchi disk. According Princeton Hydro's database of Mid-Atlantic lakes, Secchi depths less than 1.0 meter are usually considered undesirable for recreational lake uses.

Water clarity was generally lower in spring and increased through the beginning of summer and into early August (Chart 3), where Secchi depths reached 4.6m. Then, water clarity declined from mid-August through October. The late summer decline in water clarity was probably caused by the production of blue-green algae, which typically bloom in late summer. The blue-green algae *Anabaena* was identified as the dominant late summer algae throughout the monitoring period. A chlorophyll *a* sample would need to be collected in order to identify the magnitude of the algal bloom. Overall, Lake Oscawana had above-average water clarity.

Chart 3



2.4 Tributary Stream Sampling

The seven major tributaries that drain to Lake Oscawana were sampled during the monitoring period for various chemical and physical parameters. For the purposes of this Management Plan, TP (Chart 4) and ammonia (Chart 5) were examined. The average TP concentrations for all streams except Stream #4 were moderate to low throughout the monitoring period. Stream #4 exhibited a high average TP concentration since it flows through the most densely populated area on the southern end of Lake Oscawana. It should be noted that Stream #4 was one of five streams that did not flow during the summer months (from July through September). These no-flow conditions reduce the contributions of TP from tributaries during dry periods. Streams #4, #3, and #7 also had elevated average levels of nitrate-nitrite. Compared to internal loading and septic system contributions of TP, tributary additions of TP were low. However, some springtime tributary phosphorus concentrations were high probably due to large rain events. These rain events wash phosphorus from the watershed and septic leachate into the tributaries, which in turn deposits phosphorus into the lake. This is especially true for stream #4, which is located in a densely populated area with septic systems very close to the lake. Furthermore, stormwater monitoring in 1987 found high levels of phosphorus, which indicates that stormwater discharge may be loading phosphorus into the lake.

Chart 4

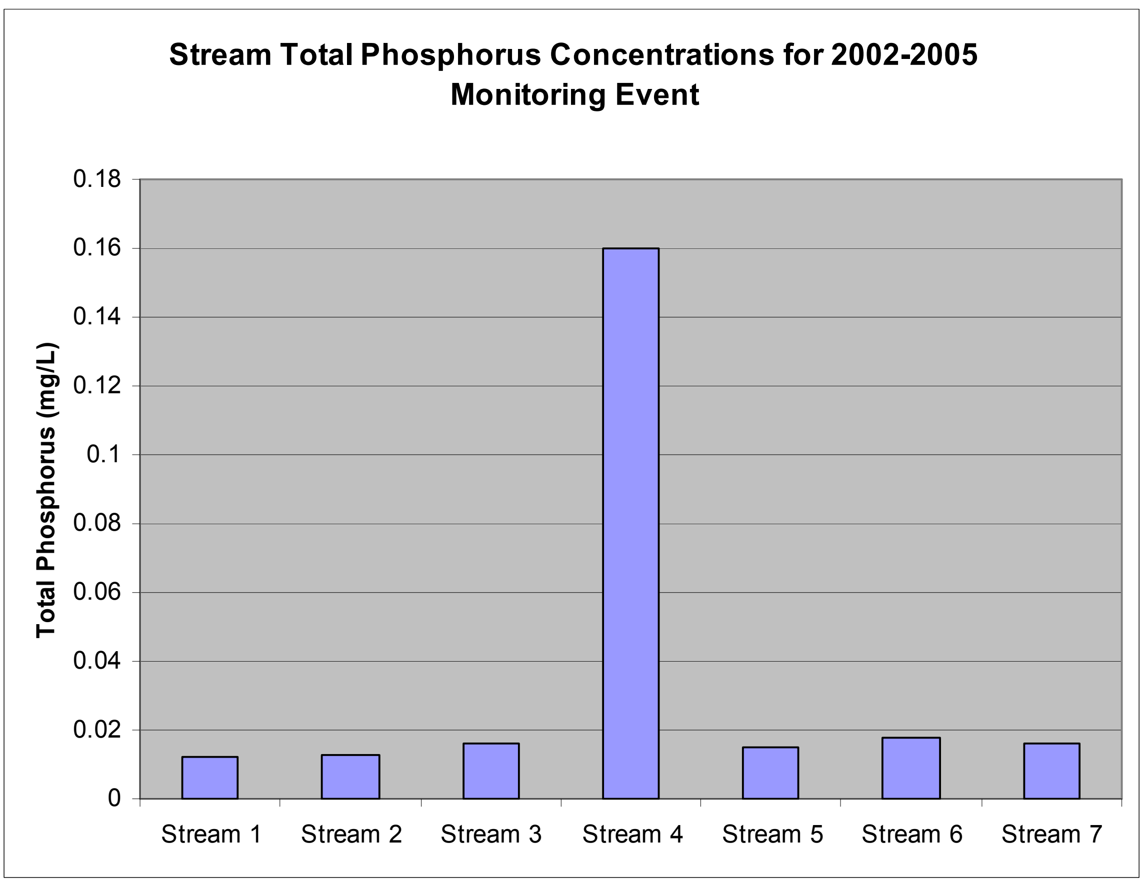
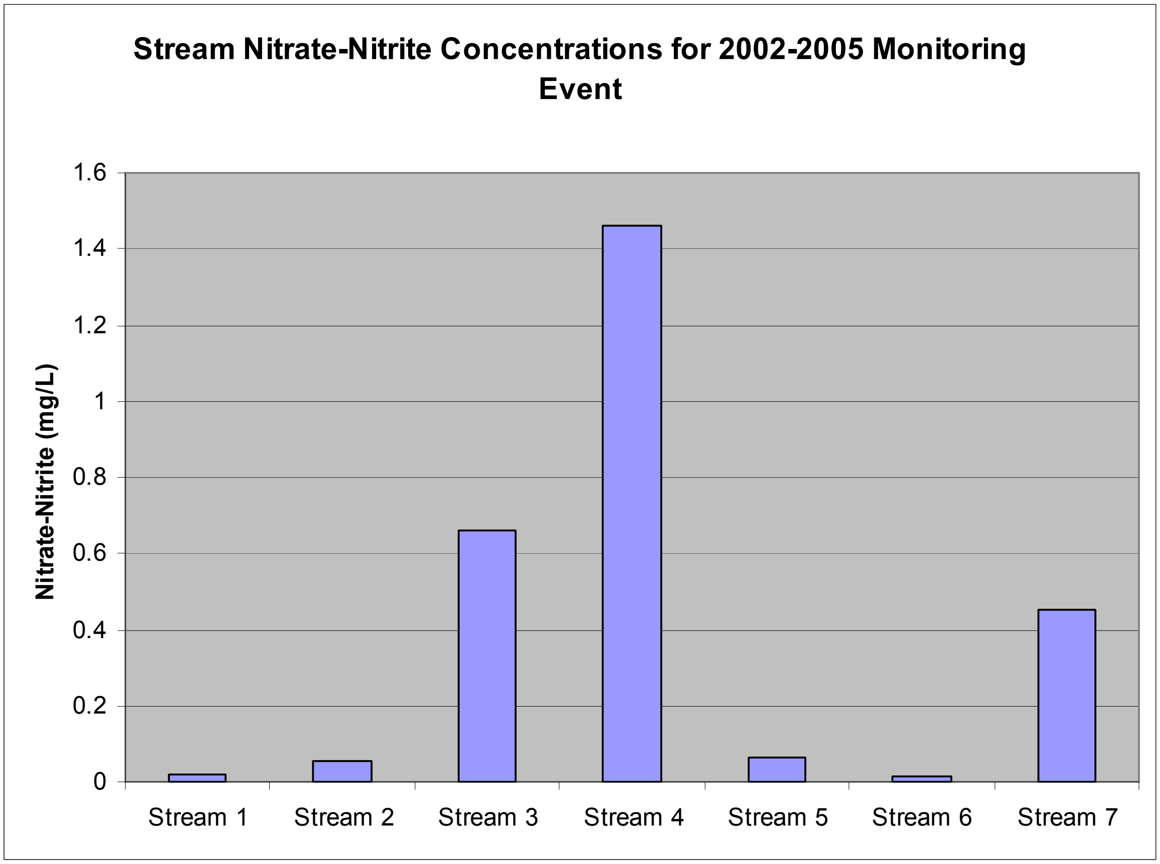


Chart 5



2.5 Lake Oscawana Phytoplankton

Phytoplankton are freely floating algae in the open waters of a lake or pond. These algae are vital to supporting a healthy ecosystem since they are the base of the aquatic food web. However, high densities of phytoplankton can produce nuisance conditions; the majority of nuisance algal blooms in freshwater ecosystems are the result of cyanobacteria (i.e. blue-green algae). Some of the more common water quality problems created by blue-green algae include bright green surface scums, taste and odor problems, and cyanotoxins.

Diatoms bloomed and dominated in the spring until July when blue-green algae became dominant through September. Blue-green algae can dominate the phytoplankton community since they can fix atmospheric nitrogen, assimilate nitrogen and phosphorus better than other phytoplankton, are not a preferred food source for most herbivores, and have excellent buoyancy control. Throughout the monitoring period the blue-green algae were dominated by the genus *Anabaena,* which has excellent buoyancy control. *Anabaena* has been known to migrate downward in the water column to take advantage of high phosphorus concentrations near the thermocline. Blue-green algae bloom concentrations varied from 7500 cells/ml in 2003 to 90,000 cells/ mL in 2002. Although green algae were present in summer, their concentrations were very low compared to blue-green algae. Due to the low numbers of large-bodied cladocerans, low numbers of green algae, and high numbers of blue-green algae Lake Oscawana had a below average grazing structure.

3.0 Trophic State Modeling

Waterbodies are typically categorized in terms of overall biological productivity. Trophic state modeling essentially consists of the quantification of a lake's relative potential productivity by regression analysis of nutrient, hydrologic, and morphometric data. The modeling not only quantifies the productivity of a waterbody, but may also be used to make predictions of changes in water quality (i.e. transparency, productivity, frequency and magnitude of blooms, etc.) arising from changes in land use, pollutant loading, climatic variability, and alternative lake management strategies. As such, these models serve as valuable planning and management tools.

Many shallow waterbodies can accept a higher TP load relative to larger, deep waterbodies due to their higher flushing rates. Given the morphometry and hydrologic / pollutant loads of Lake Oscawana; a model was needed to reasonably predict in-lake conditions for Lake Oscawana.

The first step in this water quality/ trophic model assessment involved calculating the phosphorus retention coefficient (i.e. the percentage of the annual phosphorus load that is retained in the lake). This value is important since it largely determines the amount of phosphorus available for algal, and eventually plant, uptake. Waterbodies with a substantial annual hydrologic load flush frequently, typically have lower phosphorus retention, and usually support less large and frequent algal blooms than do infrequently flushed waterbodies.

3.1 Phosphorous Retention

The importance of flushing on phosphorus availability and trophic state stems from its relationship with the areal water load (q_s). The areal water load is a function of the lake's surface area and its annual amount of water outflow. The areal water load was used to calculate the phosphorus retention coefficient using Equation 2 (Kirchner and Dillon 1975).

Equation 2: $$R = 0.426e^{(-0.271q_s)} + 0.574e^{(-0.00949q_s)}$$

Where:

R = Phosphorus Retention

q_s = Areal Waterload = $\dfrac{\text{Annual Outflow from Lake}}{\text{Surface Area of Lake}}$

e = 2.718 (natural log)

Using a flushing rate of 422 days, the amount of water outflow for Lake Oscawana was determined to be 7,000,974 m^3/year. The areal waterload was then calculated and used in the above equation. Based on normal, long-term, climatic conditions the phosphorus retention of Lake Oscawana was calculated to be 0.68; thus 68% of the phosphorus entering the lake was predicted to remain. In general, waterbodies with phosphorus retention coefficients greater than 0.6 (60%) are productive and prone to excessive algal blooms and/or nuisance densities of weed growth. Thus, according to the calculated phosphorus retention coefficient, Lake Oscawana is likely to experience excessive algal blooms under typical climatic conditions. The relatively long retention time of 422 days is probably responsible for the high phosphorus retention rate.

3.2 Prediction of Steady-State Phosphorous Concentration

The next step in this modeling procedure was the selection of a general model that could be used for Lake Oscawana to predict in-lake phosphorus concentrations. Princeton Hydro reviewed a variety of empirically based water quality models and selected the Reckhow model (1979) to relate annual phosphorus loading to steady-state, in-lake phosphorus concentrations. The Reckhow model was selected because it has the broadest range of hydrologic, morphological, and loading characteristics in its database of northern temperate lakes (Equation 3). Thus, the Reckhow model was used to model steady state, in-lake TP concentrations in Lake Oscawana.

Equation 3: $[TP] = L / (11.6 + 1.2 * qs)$

Where:

- [TP] = Predicted mean TP concentration (mg/L)
- L = Areal phosphorus loading ($g/m^2/yr$)
- qs = Areal water loading

Areal phosphorus loading was determined using the estimated inputs of phosphorus from septic leachate, internal loading, atmospheric deposition, and watershed runoff and then dividing this number by the lake surface area. Using the Reckhow model, the predicted mean TP concentration in Lake Oscawana as per 2007 watershed conditions was 0.04 mg/L. Using the 2001-2006 monitoring program data for Lake Oscawana (Northeast Aquatic Research), the mean growing season (April to September) TP concentrations were calculated for surface water (all years combined) and the TP concentration of the whole lake was calculated for each year.

The calculated mean surface water (1 meter) concentration from the monitoring data was 0.012 mg/L. This value was far below the predicted TP value of 0.04 mg/L and was probably due to the fact that the Reckhow model predicts TP concentrations for an entire year, not just the growing season. In addition, the Reckhow model accounts for the entire lake, not just the surface waters. This was more evidence that internal loading is dictating TP concentrations during the growing season by entraining large amounts of phosphorus released from the sediment in the anoxic zone below 6 m. Fall and spring turnover will release that phosphorus and mix it in the water column, thereby increasing epilimnetic TP concentration and coming closer to the predicted value.

A mean TP concentration for the entire lake from 2001-2006 was calculated by averaging the phosphorus samples for a given year. For the period from 2001-2004 the average measured concentrations were approximately 0.039 mg/L. This concentration was very close the predicted concentration of 0.04 mg/L, which accurately predicts in-lake TP concentrations for those years. However, the average TP concentrations for 2005 and 2006 were 0.051 mg/L and 0.084 mg/L, respectively. These results are probably due to high internal phosphorous loading. Several phosphorous concentrations in the anoxic zone exceeded the maximum limits of the Reckhow model. As stated before, internal phosphorus regeneration accounts for nearly 60% of the phosphorus budget of Lake Oscawana.

3.3 Gauging Water Quality Responses

In order to gauge the water quality response to existing and targeted conditions, mean TP concentrations were converted into chlorophyll *a* concentrations. Chlorophyll *a* is a pigment all algae and plants possess and use in the process of photosynthesis. Therefore, measuring chlorophyll *a* in lake water is an effective way of quantifying phytoplankton (free-floating algae) biomass. The relationship between TP and chlorophyll *a* provides a means of translating phosphorus loads into a distinct, measurable, and perceived "ecological" endpoint (i.e., algal blooms). Therefore, chlorophyll *a* was used to confirm the validity of the established targeted phosphorus loads.

Several water quality models were used to predict chlorophyll *a* concentrations based on the various phosphorus loading scenarios. These models include Carlson (1977) and Schindler (1978). Although each model had particular requirements and limitations, these were selected for consideration because each is based on a large empirical lake database. Such models are highly robust and can be used for a wide variety of temperate waterbodies. Thus, the predicted (Reckhow model) and measured TP concentrations were used to calculate chlorophyll *a* concentrations for Lake Oscawana. However, since there was no data on chlorophyll *a* concentrations, these modeled concentrations are estimates only.

According to the Carlson model, predicted and measured TP concentrations resulted in chlorophyll *a* concentrations of 18.2 mg/m^3 and 3.2 mg/m^3, respectively. For the Schindler model, predicted, and measured TP concentrations resulted in chlorophyll *a* concentrations of 12.5 mg/m^3 and 2.9 mg/m^3, respectively. Unlike the phosphorus retention coefficient, these concentrations are representative of a water body that doesn't experience nuisance algal blooms. This is probably a result of the models not taking into account the large amount of internal phosphorus regeneration.

The variation between predicted and measured chlorophyll *a* concentrations was probably due to the fact that predicted chlorophyll *a* was calculated using predicted TP, which were much higher than the measured growing season surface TP. As explained above, the predicted TP (Reckhow) was based on an entire year and the entire lake while the measured TP did not incorporate the high TP concentrations in the anoxic zone. This resulted in much lower TP concentrations near the surface. However, while the high TP concentrations measured in the deep waters were not measured in the surface, this deep water "pool" of TP was still available to use by blue-green algae. According to the monitoring reports, the lake has experienced nuisance blue-green algal blooms, including the filamentous genus *Anabaena*. The blue-green alga *Anabaena* is well known to migrate up and down the water column to take advantage of the phosphorus that is released from internal loading when the thermocline intersects with the anoxic zone in August and September.

4.0 In-Lake Restoration Measures

In-lake restoration measures are aimed at enhancing the viability of lakes by alleviating specific symptoms of eutrophication. Although these measures typically provide only short-term relief without controlling pollutant sources, they can substantially improve the aesthetic and recreational potential of the lake and help gain public support for the restoration program while long term management practices are being implemented.

For convenience, the in-lake restoration measures were divided into one of two groups. The first represent those that focus on the control / management of planktonic (open water) algal blooms, primarily blue-green algae. The second represent those that focus on the control / management of aquatic macrophytes, primarily the aquatic plant Eurasian watermilfoil (*Myriophyllum spicatum*) and benthic, filamentous mat algae. In case of blue-green algae that can migrate through the water column, the focus is placed on reducing the internal phosphorus load, which accounts for slightly less than 60% of the annual TP load. For Lake Oscawana the two primary in-lake restoration techniques being considered for reducing the internal phosphorus load include circulation / aeration and nutrient inactivation.

4.1 Artificial Circulation/Hypolimnetic Aeration

Lake Oscawana has a large area of anoxic water from June through September that should be of prime concern in considering lake restoration techniques. One of the first signs of lake eutrophication, or excessive productivity, is depletion of dissolved oxygen in the deeper waters (hypolimnion) of a stratified lake. Dissolved oxygen concentrations below 1 mg/L are generally considered to be anoxic. Anoxia can cause undesirable changes in lake water quality, including increased internal recycling of nutrients such as phosphorus and ammonia, and can limit fish habitat. In Lake Oscawana, anoxic conditions are producing large amounts of internally- derived phosphorus and ammonium-N.

Two methods of increasing concentrations of dissolved oxygen are artificial circulation and hypolimnetic aeration. The decision on which method to use is usually based on whether a layer of cold, oxygenated water beneath the thermocline is desirable. For instance, if a cold water fishery was desired for Lake Oscawana then a deeper layer of cold, oxygenated water would be essential. Cold water fish (i.e. trout) generally require water with a temperature below 20°C and dissolved oxygen concentration greater than 4 mg/L. Hypolimnetic aeration will sustain the cold water layer over the growing season. In contrast, artificial circulation eliminates the thermocline, mixing the water column and eliminating the possibility of a cold water fishery. Costs are also another consideration in choosing a method to alleviate anoxic conditions.

4.1.1 Hypolimnetic Aeration

Hypolimnetic aeration is a lake management technique that is designed to minimize deep-water (hypolimnetic) anoxia and its associated negative effects. The main objective of hypolimnetic aeration is to reduce or eliminate anoxia while preserving stratification and the thermocline and subsequently warming the hypolimnion. The result is a layer of deep, cold water that provides food and habitat for coldwater fish species such as trout. Another positive result of hypolimnetic aeration is a reduction in the sediment release of phosphorus and subsequent decrease of internal phosphorus loading. In addition, reducing anoxia can also lower the concentration of other nutrients such as ammonia.

The first method of hypolimnetic aeration is a full-lift approach, which moves hypolimnetic water to the surface, aerates it, and returns it back to the hypolimnion through a pipe that keeps the newly-aerated hypolimnetic water separated from shallow water. The drawback of this method is that the surface structure is visible at the lake surface and may affect lake use and aesthetics. Another method is the partial lift system which pumps air into a submerged chamber where oxygen is exchanged with the deeper waters, in effect oxygenating at the bottom. The drawback to this system is that the compressor must be located on the shore of the lake. Both of these systems utilize compressors to move the water.

Although hypolimnetic aeration can increase dissolved oxygen concentrations in the hypolimnion while retaining stratification of the lake, the phosphorus reduction capabilities of this method have not always met expectations. While phosphorus reductions are achieved within most lakes, the reductions typically vary between 30 and 50% (Cooke et al., 2005).

A major factor in considering hypolimnetic aeration is the cost of the installation and maintenance of the system. In order to determine the sizing of the aeration system, a detailed analysis would need to be performed to estimate the oxygen demand of the hypolimnion. Accurate sizing of the aeration system is absolutely essential because an undersized aeration system would be of little value to the lake and may exacerbate existing problems. As a preliminary estimate, Lake Oscawana would probably require, at a minimum, a 50 horsepower compressor to operate two hypolimnetic aerators. Two 25 horsepower compressors could also be used. The hypolimnetic aerators are likely to cost approximately $50,000.00 each.

In addition to the cost of the compressors and aerators, a shed to house the compressor(s) would need to be constructed. The size of the shed would need to be at least 10 ft x 20 ft and may need to be soundproofed if located near any residences. Land may also need to be purchased for this shed if suitable public property is not available. In addition, because of the hot air buildup from the compressors, exhaust fans will have to be installed on the shed. The compressor(s) require a three-phase electrical hook-up, so if one is not present it will need to be added to the project. Other incidentals include air lines to the aerators which need to be trenched to the lake, line filters, and oil filters to keep oil out of the airlines. Considering all of these requirements and other unforeseen costs, installation of hypolimnetic aerators at Lake Oscawana would cost well over $200,000.00. In addition to the installation, there will also be annual costs to operate and maintain the system.

4.1.2 Artificial Circulation

Artificial circulation, also known as aeration, is another management technique that can be used to reduce the impact of anoxic conditions on the water quality of a lake. Essentially, keeping the lake well mixed prevents the establishment of thermal stratification which, in turn, prevents the development of anoxic conditions in the bottom waters. By keeping the bottom waters oxygenated, phosphorus release from the sediments is reduced by remaining bound to iron. This reduces the magnitude of the internal phosphorus load and helps reduce algal productivity. Artificial circulation can also reduce the concentration of ammonia by converting it to nitrate. However, it should be noted that it is highly recommended that this technique be installed prior to thermal stratification to prevent the release of phosphorus accumulating beneath the thermocline. Furthermore, if the lake is already stratified it is also possible that mixing will only occur to the depth of the thermocline.

Aeration systems are designed to aerate a lake through the use of pumps, jets, and bubbled air. Specifically, most aeration systems are comprised of a series of perforated lines strategically placed along the bottom of a lake. The lines are connected to a compressor(s) which pumps compressed air into the lines. The resulting plumes or curtains of air bubbles prevent thermal stratification and allow the bottom waters to mix with the surface waters. Thus, the objective of a typical artificial circulation system is not to introduce or inject oxygen into the lake. Instead, the objective is to circulate bottom water to the surface where it remains oxygenated by being exposed to the atmosphere. Therefore, these systems are designed to prevent the establishment of stratification and thus prevent anoxic conditions from forming in the bottom waters. However, artificial circulation creates a uniform temperature profile throughout the water column, thereby eliminating the option of a cold water fishery.

An artificial circulation system would serve several roles at Lake Oscawana. First, the system would continuously circulate the water, thus preventing a depletion of dissolved oxygen. Internal release of phosphorus from the sediments is the major contributor to the phosphorus load of Lake Oscawana, and phosphorus release rates from sediments decrease under oxygenated conditions. Minimizing oxygen depletion would therefore minimize the amount the amount of phosphorus available for nuisance algal growth. Second, by minimizing the growth of undesirable algal species and enhancing the growth of zooplankton, artificial circulation can enhance the lake's fishery.

Some problems are associated with artificial circulation. For example, under some circumstances artificial circulation can increase in turbidity and nutrient availability if improperly positioned, sized or initiated during the growing season. In addition, artificial circulation tends to eliminate cold water habitat through the complete mixing of the water column. As is the case with hypolimnetic aeration, a shed would need to be built to house the compressor(s) and a 3-phase electric hook-up is also necessary. In addition, a large amount of power would be required due to the large volume of anoxic bottom water.

The cost of artificial circulation systems varies widely depending on the supplier, the type of system installed, the type and availability of power supplies and the number of pumps or compressors required. Two scenarios exist for the implementation of an artificial circulation system. In the first scenario, one large compressor is used to pump air into the air supply tubing. This scenario is probably the least expensive, however there are limitations. The main drawback to using one large compressor is that a building would have to be constructed on the shoreline, similar to that required for hypolimnetic aeration. Because of the residential nature of Lake Oscawana and steep topography on the west side, it would be difficult to locate a site to place the building. This option is estimated to cost approximately $100,000.00.

An alternative scenario to conventional artificial circulation would be to use several smaller compressors distributed along the shoreline of the lake with each compressor moving air through tubing to an air diffuser. This method is known as airlift aeration and appears to be more efficient relative to more conventional circulation systems. Because Lake Oscawana has a large volume of anoxia, 6 compressors would be needed to power 24 air diffusers which would require 19,000 feet of air supply tubing. The compressors are approximately 3 ft x 3 ft and are relatively quiet compared to one large 50 HP compressor. The diffusers would be placed in areas of the lake deeper than 20 feet. The drawbacks to this type of system are similar to other aeration systems in that sites would have to be located to place the compressors. However, because of the smaller size of the compressors, it may be easier to locate places to site them. In addition to site problems, each generator needs a source of electricity.

Airlift aeration is more expensive relative to convention aeration. A cost estimate for Lake Oscawana for the compressors, air diffusers, and air supply tubing is $155,000.00. In addition to the cost of equipment there are other incidentals such as delivery and setup that will raise the price of this project to well over $200,000.00. Also, the monthly cost of operating the six compressors is approximately $2,600.00, assuming that the unit cost for electricity is $0.10 per kilowatt hour. However, it should be emphasized that any circulation / aeration system installed in Lake Oscawana would only be in operation during the growing season, which is generally from early April through the end of September.

Finally, there has been some concern over the potential for artificial circulation to lower the water temperature of surface waters. Eliminating thermal stratification results in a slight increase the weighted mean water column temperature, however, the question was raised that this could produce lower water temperatures in the surface waters and negatively impact the lake relative to swimming. In order to address this concern, Princeton Hydro reviewed both the scientific literature and its own company database.

Several studies have been conducted on the ecosystem-based impacts of artificial circulation and many have assessed the impact it has on surface waters. For example, the artificial circulation of a Colorado reservoir produced a 1-2^{o}C increase in the weighted mean summer temperature. Summer deep water temperatures increased to 6 ^{o}C, however, surface water temperatures were unaltered (Lackey, 1972). A similar study conducted on a lake in Michigan that was mixed with artificial circulation, produced similar results; bottom water temperatures substantially increased after artificial circulation was initiated while surface water temperatures were not greatly altered (US EPA, 1971).

Princeton Hydro implemented a detailed monitoring program of Chalottesburg Reservoir, a potable source of water located in northern New Jersey, in 2001 to assess the impacts associated with implementing artificial circulation. Water quality data were collected on the lake seven times through the course of the growing season (May through September) after the circulation system was installed in April 2001. The reservoir is horseshoe shaped with one end being circulated while the other, the one farthest from the intake, was not circulated and left as a control. The surface water temperatures of the circulated end (Station 4) were compared to the surface water temperatures of the control end (Station 1). In five of the seven monitoring events, the surface waters of the circulated end were lower than the control end of the reservoir. However, this decline in surface water temperatures was slight, varying between 0.5 and 2.0 ^{o}C. Thus, based on Princeton Hydro's study of Chalottesburg Reservoir, circulation of the water column resulted in only a small decrease in the surface water temperatures.

4.2 Phosphorus Inactivation

An alterative to aeration / circulation in reducing the internal phosphorus load of Lake Oscawana is nutrient inactivation. Unlike aeration / circulation, the long-term and maintenance costs associated with nutrient inactivation are substantially lower. However, as discussed below, other issues of concern are recognized with nutrient inactivation.

Nutrient inactivation is a chemical means of binding phosphorus and making it unavailable for algal uptake. While a variety of inorganic salts, including iron and calcium, can inactivate phosphorus, aluminum is the most commonly used in the United States, as it binds tightly to phosphorus over a wide range of environmental conditions, including under low or anoxic dissolved oxygen concentrations (Cook et al., 2005).

Aluminum sulfate (alum) or sodium aluminate has historically been used in lake restoration in the formation of a sediment blanket. When alum is added to a lake, a floc of aluminum hydroxide is formed and this floc binds with the phosphorus in the water, precipitating it to the bottom as it settles out. The settled floc creates a layer of aluminum hydroxide on the lake bottom that significantly retards the release of phosphorus from the sediments (US EPA, 1990; Cook et al., 2005). This is particularly useful under anoxic (oxygen depleted) conditions when the rate of phosphorus liberation is intensified. The formation of a blanket to control the release of phosphorus from the sediments has demonstrated to be more effective in lakes that have a relatively large internal load and have implemented some best management practices (BMP's) to control the external load.

A potential disadvantage associated with the application of alum is the possibility of aluminum toxicity. When alum is added to water, an aluminum hydroxide floc is formed at a pH between 6.0 and 8.0. However, the formation of the aluminum hydroxide forces the pH and alkalinity of the water to decrease at a rate which is dependent upon the initial alkalinity or buffering capacity of the water (Cook et al., 2005). Elevated concentrations of dissolved aluminum are toxic and can have a dramatic impact on the biota of a waterbody. In addition, Lake Oscawana has been reported to have a low buffering capacity which would make it prone to lower pH values (Kortmann, 1987).

Given the potential sensitivity of Lake Oscawana to changes in pH, if alum is seriously considered a bench test must be conducted to calculate the safe maximum dosage rate. That is, how much alum can be added to the lake before it exerts a potentially negative impact on the resident aquatic organisms must be quantified. While dosage rates are provided within the scientific literature, they are strongly dependent upon the specific water quality conditions of a given waterbody. Therefore, if an alum blanket is considered for Lake Oscawana, it is strongly recommended that a bench test be conducted for calculating the lake's particular dosage rate. This dosage rate, which is how much alum can be added before the pH becomes 6.2, is compared to the amount of alum required to bind with the internally generated phosphorus. If not enough alum can be added to the lake to bind with the internally generated phosphorus without posing a threat to the resident biota by aluminum toxicity, buffered alum such as sodium aluminate may be used instead of alum. Costs for the design, permitting, monitoring and implementation of an alum blanket will range from $150,000.00 to $250,000.00 Based on the lake's hydraulic residence time, the effectiveness of the alum blanket is estimated to last for approximately 7-10 years.

Based on the pollutant budget for Lake Oscawana, internal loading is the largest source of phosphorus, accounting for nearly 60% of the total annual phosphorus load. The application of an alum blanket would substantially reduce the magnitude of this internal load. Because the alum blanket will be deeper than 20 feet, it will not be subject to wind and wave action and should last 7-10 years.

A substantial amount of time and effort is required to determine if alum can be safely applied to Lake Oscawana and to obtain State approval to conduct such an application. Currently, there is not formal permitting process for the application of alum to a recreational waterbody for internal phosphorus inactivation. In addition Region 3 of NYS DEC has not to date granted approval for an alum treatment program. However, for similar projects in New York the application of alum to a recreational waterbody was permitted under the State Pollutant Discharge Elimination System (SPDES) program. Based on Princeton Hydro's experience, the permitting process would more than likely follow the outlined process:

1. Set a Scoping meeting with the Regional office of NYS DEC.
2. Establish the required permitting process
3. Submit a draft Environmental Impact Study
4. Conduct a public herring on the application of alum
5. Respond to public comment
6. Submit Final EIS and State Pollutant Discharge Elimination System permit

While this may not necessarily be the exact permitting process that would occur in Region 3, it is a reasonable estimate how it may proceed. If the LOCA is serious considering the use of alum as a mean of inactivating the internal phosphorus load in Lake Oscawana then conducting alum bench test, followed by a Scoping meeting with the regional office of NYS DEC should be considered.

4.3 Aquatic Plant Management

In order to effectively manage the aquatic plants in Lake Oscawana, a site specific Aquatic Plant Management Plan should be developed, adopted and implemented. Such a plan provides a objective and prioritized approach toward the short and long-term measures in managing aquatic plant growth. For example, the plan should focus on the eradication of the nuisance invasive species (i.e. Eurasian watermilfoil) and the control / management of the more desirable native species. In addition, such a plan is an absolute requirement in seeking State funds for the eradication of invasive species. The NY DEC has a very helpful primer on aquatic plant management and can be located on the NY DEC website at: http://www.dec.ny.gov/docs/water_pdf/ch6apr05.pdf

4.3.1 Mechanical Aquatic Plant Harvesting

The community of aquatic plants and filamentous mat algae distributed throughout the shallower, near shore sections of the lake serve to filter particulates and their adsorbed pollutants (i.e. phosphorus) from stormwater as it enters the lake. This positive feedback mechanism contributes toward increasing the water clarity of the open water section of the lake by filtering pollutant out before they reach the open waters. This is one of the reasons in-stream pollutant concentrations can appear high, while sub-surface open water concentrations remain low.

Other benefits associated with aquatic plants include the creation of habitat for fish, aquatic invertebrates and other organisms, refuge for young fish from piscivorous fishes, buffering the shoreline from wind and wave erosion, and providing dissolved oxygen through photosynthesis. In addition, aquatic plants can harbor other organisms on their surface such as diatoms, algae, and protozoans that serve as a food source for other aquatic organisms.

While aquatic plants provide a variety of ecological benefits, excessive densities can produce nuisance conditions that impact recreational activities such as fishing, boating, sailing and swimming. Some more ecologically-based impacts include reducing the diversity of the fishery community, as well as reducing DO and increasing nutrient availability as plant biomass decomposes. In addition, the dominance of the aquatic macrophyte community by exotic (non-native) species can exacerbate negative impacts on fish and wildlife, as well as reduce overall community diversity by out-competing more favorable, native species. Once exotic, invasive species such as Eurasian watermilfoil attain nuisance densities; complete eradication of the plant becomes extremely costly and difficult.

Due to its steep-sided morphometry, areal habitat for the establishment and growth of rooted submerged vegetation is limited in Lake Oscawana. However, the 2003 monitoring report (Northeast Aquatic Research) indicated that about 64 acres of the area between the depths of 0 to 10 feet has measurable amounts of aquatic plant growth. Eurasian watermilfoil accounted for almost half the area of aquatic plants and was confined to the deeper waters. Based on the report there was little change in the aquatic plant community from 1999 to 2002. However, since 2003, aquatic plants have expanded in coverage and have become more of a nuisance, particularly Eurasian watermilfoil. This increase in Eurasian watermilfoil over the last few years is more than likely due to the longer summer and milder winters. In addition, it should be noted that Eurasian watermilfoil has been observed growing in waters as deep as 12 ft.

Lake Oscawana currently uses a mechanical weed harvester to control nuisance aquatic plants around recreational areas such as swimming areas. However, the harvester is nearing the end of its useful life and consideration is being given to obtaining a new harvester. Harvesting nuisance aquatic plants has several advantages over other control methods. Mechanical harvesting can remove plant biomass and provide immediate relief in harvested areas. In addition, mechanical harvesting is not dependent on the use of aquatic pesticides which have the potential to impact non-target organisms.

Mechanical harvesting can also be used to enhance recreational fishing and ecological diversity. By harvesting in sections or strips in designated fishing or wildlife areas, cruising lanes can be created for predatory fish such as largemouth bass that would otherwise be unable to penetrate and feed in dense vegetation. Furthermore, mechanical harvesting removes nutrients from the lake via removal of plant tissue. For example, Lake Hopatcong in northern New Jersey utilizes harvested plant tissue as a component of its phosphorous removal strategy toward compliance of its TMDL. It has been documented that harvesting in Lake Hopatcong removes approximately 6-8% of the lake's total phosphorus load targeted for removal under its TMDL. However, while mechanical harvesting can serve as one component of a lake's overall pollutant management program, it alone will not reverse eutrophication.

As LOCA knows, mechanical harvesting can be very expensive and must be repeated at regular intervals during the growing season and does not completely eradicate the plants. In large lakes only selective aquatic plant harvesting is practical; harvesting around recreational areas, cutting lanes for boats and fish, and removing the shoots of canopy forming species should be done to encourage the growth of more desirable, native low-growing species. Moreover, because Eurasian watermilfoil propagates by fragmentation, mechanical harvesting has the potential to spread this plant to uncolonized locations. In addition, mechanical harvesting removes large numbers of young fish and invertebrates.

Despite the drawbacks, mechanical harvesting is still a viable management alternative for nuisance plant management in Lake Oscawana. In order for a mechanical harvester to be economically viable, the machinery has to be used continuously throughout the season and for a number of years (Cooke et al., 2005). In light of this fact, LOCA and the Lake Oscawana Advisory Committee may need to rethink their policy of only harvesting the near-shore areas where people swim. Economically, the "mid-lake" areas that were heavily infested with Eurasian watermilfoil in 2007 may need to be harvested as well, especially if the nuisance plant interferes with recreational activities such as fishing and boating.

Several methods exist to reduce the costs associated with mechanical harvesting (Smith, 1979):

- Maximizing equipment deployment through out the season.
- Minimizing crew and equipment mobilization time and costs.
- Preplanning harvesting strategies.

- Finding appropriate financing if needed.
- Implementing a responsive institutional system.
- Selecting appropriate equipment.

As previously cited, it must be emphasized that mechanical weed harvesting can benefit the lake's fishery by providing ecotones or transitional boundaries between stands of submerged aquatic vegetation and open water. Many species of fish, particularly largemouth bass, are better adapted to living and feeding in ecotone habitats. Thus, opening up a weed-infested cove with mechanical weed harvesting can enhance its recreational value. Additionally, such ecotone habitat may also enhance the effectiveness of biomanipulation by allowing piscivorous fish easier access to prey. Given the recreational and ecological benefits as well as the phosphorus-reducing potential of mechanical weed harvesting, this in-lake restoration technique should continue to be implemented in Lake Oscawana as the primary means of controlling nuisance densities of submerged vegetation.

4.3.2 Sterile Grass Carp

In addition to chemical and physical approaches for control of aquatic weeds, there are also a number of biological techniques that can be used to control excessive densities of aquatic plants. One of these biological techniques is the stocking of sterile grass carp.

Grass carp (*Ctenopharyngidon idella*) are a non-native species of fish that voraciously feeds on many species of aquatic plants. These fish have been well documented to effectively control excessive densities of nuisance aquatic plants throughout the United States. Moreover, their high growth rates and relatively broad diets make them particularly effective. However, since grass carp are a non-native species, only fish that have been certified as sterile are permissible for stocking in New York.

The stocking of grass carp in the State of New York involves an extensive permitting process for waterbodies larger than 5 acres. A series of calculations, investigations, and design work is required in order to file the required permits and determine the stocking rate. Before filing for the permits, the lake has to be monitored to determine the chemical and biological parameters of the lake. This should not be a problem as Lake Oscawana has been monitored for these parameters for a number of years. However, a detailed investigation of the aquatic plant data will need to be performed and an aquatic plant map constructed from these data will be needed for the permits. Again, such activities should be conducted under an Aquatic Plant Management Plan (Section 4.3).

If the estimate of 64 acres of the lake is covered with submerged vegetation (Section 4.3.1) and is combined with a stocking rate of 8 to 10 fish per vegetated acres, approximately 500 to 650 sterile grass carp could be stocked in Lake Oscawana. Depending on the selected stocking rate, which needs to be approved by NYS DEC, and the size of the fish, such a stocking program is estimated to cost between $6,500.00 and $10,000.00. This estimate does not include the development and filing of the required permit package or any monitoring activities.

In addition, a barrier will have to be engineered, approved by the NY DEC, and then installed at the lake outlet to prevent any grass carp escaping from the lake. There will be some additional permitting requirements for the installation of such a barrier. The design, permitting and installation of such a barrier are estimated to cost between $15,000.00 and $25,000.00, depending on the existing conditions of the outlet structure and the requirements of NYS DEC.

At this time, the stocking of sterile grass carp is not the recommended in-lake management technique of controlling nuisance densities of aquatic plants. While sterile grass carp are known to control nuisance densities of Eurasian watermilfoil, they do not remove nutrients as does mechanical weed harvesting. In fact, the feeding and excretory activities of the carp increase the availability of nutrients. This typically results in higher densities of phytoplankton algae and may lead to blooms and a reduction in water clarity. In addition, the carp can negatively impact desirable recreational fish species by reducing the availability of spawning habitat. Given these issues, sterile grass carp is not being considered for Lake Oscawana at this time.

4.3.3 Benthic Barriers

Benthic barriers are made of several different materials and work on the principle that rooted aquatic plants require light for photosynthesis and cannot grow through physical barriers. Benthic barriers have shown some success in controlling nuisance aquatic plants. They are placed on the lake bottom and are usually confined to small areas such as swimming areas, boat docks, piers, and lakefront properties. Benthic barriers are constructed of various materials such as polyethylene, polypropylene, burlap, and screening materials.

Benthic barriers have several advantages over other aquatic plant control measures. They can be installed in shallow areas where harvesters cannot gain access. They are nontoxic and usually require no special licenses or permits. However, some regions of NYS DEC are beginning to regulate the installation of benthic barriers. Thus, if LOCA members are interested in using benthic barrier should contact the regional office prior to any installations for clarification on this issue..

At least over shallow, small areas, benthic barriers are easy to install. However, benthic barriers also have several disadvantages compared to other control measures. They are relatively expensive ($0.25 - $0.45 / square foot) and are hard to install in large, deep areas. Furthermore, application of benthic barriers in deeper water requires SCUBA divers. In addition, barriers need to be staked or weighted down with bricks or rocks to keep them in place. In addition, barriers require periodic cleanings since sediment accumulation over the barrier can allow plant growth.

One particular benthic barrier that has shown some success is Aquascreen®. Aquascreen® is a fiberglass screen coated with polyvinyl chloride and comes in rolls of 7 by 100 ft. The screen is rolled out along the bottom in overlapping layers which are then staked down. The advantage to using screens is that gas can permeate through the screen which eliminates gas buildup, thereby allowing the screen to remain on the bottom. However, like all other barriers, Aquascreen® must be periodically removed and cleaned to maintain performance. For Lake Oscawana, the installation of such barriers should only be considered in shallow waters adjacent to docks or other structures.

4.3.4 Aquatic Weevils

Another management technique that can be used to control excessive densities of Eurasian watermilfoil (EWM) is the use of the milfoil weevil *Euhrychiopsis lecontei*. This weevil is a milfoil (*Myriophyllum spp.*) specialist that feeds and develops only on plants in the *Myriophyllum* genus. In addition, it is a native of North America and not an exotic species like grass carp or Eurasian watermilfoil. This is a biological technique, unlike mechanical harvesting and herbicides. The goal of the stocking of a lake or pond with the weevil is to augment the weevil population above "background" or natural levels.

Milfoil weevils have been shown to be successful in reducing the biomass of Eurasian watermilfoil in several instances. However, there are several disadvantages that need to be addressed. First, control of EWM using weevils requires more time than other control measures and does not produce immediate results that lake residents like to see. In some instances, noticeable control may not appear for over a year. Secondly, due to long-established predator-prey relationships, native insect populations may not remain at sufficient levels to control EWM which allows EWM to return to nuisance levels. Thus, stocking large amounts of milfoil weevils are necessary to attain adequate control and override these predator-prey relationships. Unfortunately this makes this management technique very expensive and in some instances cost-prohibitive. Lastly, recent research indicates that milfoil weevils require large amounts of "natural" shoreline (Johnson et al. 2000; Jester, 2000). This means that the milfoil weevil may not be suitable for lakes with large amounts of developed shoreline and mowed lawns.

If it is assumed that 50 of the 64 acres of submerged macrophyte habitat is covered with EWM, it is estimated that a weevil stocking program would cost between $200,000.00 and $385,000.00. This is estimating a stocking rate of 3,000 to 6,000 weevils per acre and does include additional monitoring. Finally, it should be emphasized that the weevils feed exclusively on species of milfoil and will not control other genera of macrophytes or filamentous mat algae.

4.3.5 Chemical Control of Nuisance Aquatic plants

A number of aquatic plant control management techniques can be utilized as part of a Management Plan. Probably the most well known and frequently implemented technique is the use of contact herbicides. These products function by "burning" the plant tissue upon contact. An alternative to contact herbicides are systemic herbicides, primarily those with the active ingredients fluridone and triclopyr. These function by interfering with the plant's internal metabolism and other biochemical processes.

Contact aquatic herbicides provide immediate, short-term relief or control of excessive densities of a nuisance plant(s). Thus, the primary advantages of contact herbicides include their fairly immediate (days to weeks) reduction in nuisance plant densities and their relatively low product costs. Contact herbicides are also much less expensive than systemic herbicides. Endothall, diquat, and 2,4-D are contact herbicides that are currently used for aquatic weed control. Each has its own distinct advantages and disadvantages.

The disadvantages of using contact herbicides include potential impacts on non-target organisms, a depletion of oxygen concentrations as a result of bacterial decomposition of the dead plant material, and the recycling of nutrients back into the water column that would otherwise be bound in plant biomass. For example, planktonic algal blooms sometimes occur after the application of contact herbicides (due to increased nutrient recycling). In addition, because contact herbicides only control the above-sediment portion of the plant, the roots are left intact thereby allowing re-growth of the plant.

In contrast to contact herbicides, a systemic herbicide affects the targeted plant internally. The uptake of the herbicide's active ingredient disrupts biochemical functions thereby killing the plant. Systemic herbicides, such as products that have fluridone as their active ingredient, are assimilated through the roots and into the plant tissue early in the growing season. There they begin to disrupt the production of chlorophyll pigments, which are used in photosynthesis. This effectively “starves” the plant and it dies. Fluridone (Sonar®) and glyphosate (Renovate®) are the two systemic herbicides currently being used for aquatic plant control.

There are a number of advantages to using systemic herbicides as opposed to contact herbicides. First, contact herbicides may require multiple applications through the course of one growing season to obtain an acceptable level of control. In contrast, if properly timed and executed, one fluridone application can result in an entire year of control. Systemic herbicides do not leave an intact root system. In some cases, two or three years of control may be realized with systemic herbicides. Furthermore, systemic herbicides have been shown to exhibit selectivity against exotic plants such as Eurasian watermilfoil while doing minor harm to beneficial native plants (Petty et al. 1998).

There are also some disadvantages to using systemic herbicides. Product costs for systemic herbicides are higher than for contact herbicides. However, less product is used for systemic treatments, thereby mitigating some of the increased cost. In addition, systemic herbicides require longer treatment times than contact herbicides and therefore do not provide immediate relief from nuisance aquatic plants. For example, fluridone can take 30 days to manifest some observable degree of plant control. Moreover, because of this lag time, appropriate concentrations of systemic herbicides need to be maintained.

In spite of being proven to be relatively safe and effective, aquatic herbicides have been met with resistance from some lake stakeholders and governmental agencies. The current regulatory atmosphere in New York is not especially conducive to the use of aquatic herbicides on waterbodies such as Lake Oscawana. The permitting process for using aquatic herbicides in New York State is a long and expensive process and does not guarantee approval. In addition to the required permits, an Environmental Impact Statement will more than likely be required prior to any application of a registered herbicide in Lake Oscawana. Given these permitting / regulatory complications and the anticipated level of local resistance, the use of aquatic herbicides (contact or systemic) for the control of Eurasian watermilfoil is not recommended for Lake Oscawana.

4.3.6 Selective Dredging of Lake Oscawana

Dredging is the removal of settled or accumulated material (i.e. sediments) from a waterbody. Surface runoff transports soil and other particulate matter to receiving waterbodies such as Lake Oscawana. In addition, an increase in impervious surfaces such as those associated with residential and commercial land (i.e. rooftops, parking lots, sidewalks) results in stormwater runoff being piped and conveyed to receiving streams at higher velocities. This increased energy behind the stormwater typically contributes toward streambank de-stabilization and erosion, which can contribute to the TSS and TP pollutant loads. In addition to eroded soils, another potential source of accumulated sediments is partially decomposed organic matter such as aquatic plants, algal cells, and fallen leaf litter.

Depending on the amount and distribution of unconsolidated material, a dredging project would enhance the ecological and recreational value of Lake Oscawana. Specifically, the removal of all or most of this unconsolidated material will increase the mean depth and increase circulation of the lake. Increasing the mean depth of the lake will contribute toward reducing the densities of filamentous mat algae and aquatic vegetation (for details see below). In turn, this will provide more open water areas for canoeing and boating as well as increase the amount of aquatic habitat.

A whole lake dredging of Lake Oscawana would be extremely expensive and may not be necessary depending on the amount of unconsolidated material in the deeper sections of the lake. More than likely a selective dredging of the lake is required, where unconsolidated material in nearshore areas and coves would be removed.

There are essentially three phases to a dredging project: data collection, development of project plans and permitting, and implementation / post-project restoration. Each phase of a dredging project is summarized below:

Data Collection – A large amount of topographic, bathymetric, and physical / chemical data need to be collected prior to developing a dredging plan. First, an updated bathymetric survey needs to be conducted that quantifies water depth and the thickness / distribution of the unconsolidated sediment.

It is recommended that hydrographic surveying methods as detailed in the US ACOE Engineering Manual 1110-2-1003, *Hydrographic Surveying* (January 2002) be used to conduct the bathymetric survey of Lake Oscawana. Such methodology has been accepted by NYS DEC and US ACOE in the submission of the necessary permits to implement a dredging project. A dual frequency fathometer would be used for the survey in order to measure water depth and the thickness of the unconsolidated sediment. The fathometer is directly tied into Global Positioning Systems (GPS), so in addition to water depth and sediment thickness, data are consistently collected on the exact position of the survey transects. The standard raw accuracy of the fathometer sounding device is 1/10 of an inch. However, the survey data will be regularly cross-checked with a calibrated probe. The resulting maps and plans generated through this bathymetric survey will be in a format and level of detail that can be directly utilized to obtain the necessary State and local permits for the implementation of a dredging project.

In addition to the bathymetric survey, established shoreline and upland survey points need to be collected adjacent to areas of the lake that are considered for dredging, as well as sites where equipment will be entering and exiting the lake. Property boundary surveys of impacted areas should also be conducted by a licensed surveyor.

In addition to updating the bathymetric survey some physical (percent solids, percent organics and grain size analysis) and chemical testing of the sediments should be conducted in order to determine if the quality of the material and to assure that the material is deemed as non-hazardous. Such chemical testing of the sediments is absolutely critical, particularly if a third party will be accepting the material as non-structural fill. It is recommended that at least three samples be collected and analyzed for Target Analyte Pollutants and Toxicity Characteristic Leaching Procedure (TCLP). The TCLP essentially simulates the movement of water through soil or fill (i.e. such as a landfill) to determine if any potential pollutant may migrate.

In addition to the TCLP some additional analyses should be conducted to assess potential ecological impacts associated with the sediments. For example, bulk sediment heavy metal concentrations should be compared to Sediment Quality Thresholds (NYSDEC-DFWMR, 1999, NYSDEC, 2004). Essentially, the sediment quality (i.e. bioaccumulation and biotoxicity) can be placed into one of three Classes, based on Sediment Quality Thresholds (NYSDEC, 2004). The classification of the Lake Oscawana sediments will aid in determining both the "permitability" and costs of removal and disposal.

Development of the Dredging Plan and Permitting – Once all of the data are collected the actual Dredging Plan can be developed and the necessary permits can be obtained. Essentially, the results of the bathymetric survey will be used to generate a series of permit-grade planar and cross-sectional maps of water depth and thickness of unconsolidated material in Lake Oscawana. In addition to these maps, the topographic and chemical sediment data will be used to develop and design a site specific dredging plan for Lake Oscawana. The dredging plan will provide site specific cost estimates of dredging the lake based on the amount of material targeted for removal, potential access points into the lake from the shoreline, temporary near shore storage areas, and potential final disposal sites for the removed material.

With the Dredging Plan in place, the necessary permits can be submitted to the appropriate agencies. Based on existing conditions of Lake Oscawana as well as the possible dredging action, permits will need to be submitted to both NYS DEC / US ACOE, perhaps under a Joint application form. The potential for County and local permits (i.e. Soil and Erosion control, wetland mitigation) will need to be addressed as well.

Implementation of Dredging Project and Post-Restoration of the Site – Once the Dredging Plan is complete and all permits / approvals are secured, the dredging can be scheduled. Typically, it is recommended to conduct dredging in the fall / early winter when lake activities are at a minimum. In addition, lowering the water level, exposing the majority of the sediment to the atmosphere, and using conventional equipment (i.e. backhoe, trackhoe, dragline bucket) to remove the material is the recommended approach. While hydraulic dredging can be lower in cost on a cubic yard basis, it tends to be more expensive and complicated by the end of the project due to the need for additional permitting and a larger amount of near-site land for temporary disposal of the liquid dredged material.

In addition to the actual removal of the sediment, LOCA may want to develop bid specifications and host a mandatory bidders meeting to select an experienced and cost effective contractor to implement the project. Post-restoration of the shoreline and impacted wetlands will also need to be considered in both the dredging plan and in the development of any bid specifications.

Proposed Strategy for Dredging Lake Oscawana

It is recommended that dredging not be seriously considered until at least one or a few of the in-lake remediation steps discussed above and the stormwater BMP projects have been implemented, in order to address the source of the problem (high TSS loads entering the lake). The first step in the process should be a lake-wide bathymetric survey and the collection of a set of sediment samples from a location well known to have a large amount of unconsolidated material. The sediment samples should be analyzed for a variety of physical and chemical parameters to aid in quantifying the feasibility of selective dredging in Lake Oscawana.

5.0 Watershed (Long Term) Restoration Measures

In contrast to in-lake restoration techniques, watershed based techniques focus on the cause of eutrophication rather than the symptoms. Watershed techniques are not as visible as in-lake techniques and tend to take more time to produce their desired results because sediments within the watershed contain a large pool of nutrients accumulated over many years. However, they are absolutely vital in reducing the pollutant load and producing long-term improvement in the water quality of lakes. Unless watershed pollutant inputs are reduced, any long-term benefits from in-lake treatments may not be realized.

Watershed control measures are designed to reduce non-point source (NPS) pollution. NPS pollution is very diffuse and is generated over a relatively large area and produced by a wide variety of sources. Some examples of NPS pollutant sources include lawn and garden fertilizers, septic leachate, pet and wildlife wastes, surface runoff from paved surfaces, construction sites, agricultural areas and the atmosphere. This type of pollution is in sharp contrast to point source pollution, where the pollutants are generated and discharged from a specific point or source. An example of a point source is a sewage treatment plant. Relatively speaking, point source pollution is easy to control. If a sewage treatment plant is responsible for the problem, efforts and money need only to control that one source. Unfortunately, NPS pollutants can often be more difficult and expensive to control than point source pollutants. Nevertheless, where NPS pollutants account for all or a large fraction of the total pollutant load, this source of pollution needs to be controlled if long-term improvements in water quality are to be realized.

One of the reasons NPS pollution is difficult to control is that it does not respect municipal or property boundaries. Since it is generated over the entire watershed, as well as via atmospheric sources, the organization concerned with controlling pollutant loading may not be within jurisdictional limitations of the affected community. However, sometimes the community responsible for the water quality of a given waterbody does have control over shoreline areas. Therefore, the watershed restoration techniques presented below for Lake Oscawana focuses mainly on reducing the pollutant load from those lands immediately adjacent to the lake. However, it should be noted that any watershed-based management measures, particularly those associated with stormwater that are implemented within the Lake Oscawana watershed will benefit the Town of Putnam Valley from both a water quality and regulatory perspective by addressing its Municipal Separate Storm Sewer System (MS4) permit. Thus, there should be a more regional movement, beyond the Lake Oscawana watershed alone, in seeking funds to implement some of the projects discussed.

General Watershed Strategy for Lake Oscawana

As discussed in Section 1.1, the highest “developed” pollutant loads originate from sub-watersheds 1 and 5 (Tables 4-6 in Appendix A and Figure 5 in Appendix C). This conclusion is based on using a robust surface runoff pollutant model and agrees well with the long-term water quality data set. For example, as identified Section 2.4 Stream #4 had consistently elevated TP (Chart 4) and nitrate+nitrite-N (Chart 5) concentrations relative to the other sampling sites.

Stream #4 enters Lake Oscawana from the southern end, originating from sub-watershed 1. Thus, the measured water quality data agrees well with the results of the model. Given these observed conditions, most of the structural stormwater recommendations described below focus on reducing the pollutant loads originating from sub-watersheds 1 and 5. However, of these two sub-watersheds, sub-watershed 1 projects should be prioritized over sub-watershed 5 due to the high nutrient concentrations measured in its contributing inlet (Stream #4).

Total Maximum Daily Load (TMDL) for Phosphorus in Lake Oscawana

A TMDL for total phosphorus (TP) in Lake Oscawana was prepared in July 2008 by the Cadmus Group, Inc. for both US EPA (Region 2) and New York State Department of Environmental Conservation. Based on the TMDL, the existing, external annual TP load for Lake Oscawana needs to be reduced by 9% in order to attain an acceptable external load. Specifically, the existing annual TP load is 663 lbs and the targeted (allocated) load is 600 lbs, requiring a reduction of 63 lbs. The TMDL document recommends a combination of stormwater management and septic management in addressing the watershed-based TP load in order to comply with the TMDL. Thus, the recommended watershed measures described below are designed to attain this 63 lbs reduction in TP.

5.1 Structural Best Management Practices

Structural Best Management Practices (BMPs) are physical devices or systems designed for storm water control and the reduction of the nonpoint source pollutant load. These BMPs are designed to intercept and passively treat runoff through settling, filtration, biological uptake or a combination of these measures. Typically, they are sized for the one year frequency storm, also referred to as the water quality storm. Most structural BMP's require a certain degree of maintenance for maximum efficiency.

There are a wide range of structural BMPs that are well documented to be highly effective in reducing NPS pollution, particularly TSS and phosphorus. Many of these BMPs are described in great detail in the New York State Stormwater Management Design Manual. In fact, in April of this year NYS DEC augmented the Manual with a new chapter devoted to the enhanced removal of phosphorus. Three treatment performance goals were identified in this model that is worth citing:

- Through a continuous simulation model, the stormwater structure should not effective bypass more than 15% of the runoff from the site.
- The median effluent concentration of particulate phosphorus shall be at or below 0.1 mg/L.
- The median effluent concentration of dissolved phosphorus shall be at or below 0.05 mg/L.

Thus, New York State is making a direct and pro-active effect to integrate phosphorus removal criteria into the design of stormwater BMPs and the development of Watershed Restoration Plans.

5.1.1 Manufactured Stormwater Treatment Devices

A portion of the land within the immediate Lake Oscawana watershed is currently residential and commercial. A large portion of surface runoff from this urbanized land flows over impervious areas, through stormwater pipes directly into the lake. Given the close proximity of these areas to the lake, large structural BMPs such as those identified in the State's Stormwater Manual (i.e. extended detention basins or retention ponds) would be extremely difficult to implement due to the limitation of available land. Such conditions are very common in lake communities where much of the nearshore land is composed of small (< 0.5 - 1 acre) lots owned by private landowners. Therefore, stormwater retrofits are recommended for implementation, particularly in sub-watersheds 1 and 5.

Stormwater retrofits are essentially modifications or enhancements that can be implemented to an existing stormwater conveyance system to improve the system's NPS pollutant reduction capacity. The advantages to such retrofits are that they require substantially smaller amounts of space for installation and are lower in cost relative to larger BMP's. However, as with any BMP, retrofits will require a certain degree of maintenance to optimize their effectiveness. In addition, the frequency of maintenance for retrofits may be higher than larger BMP'S, especially during particularly wet years. In spite of the required maintenance, stormwater retrofits are a very cost effective means of reducing the NPS pollutant loads (i.e. nutrients and suspended solids) that enter receiving waterways via stormwater surface runoff.

Standard catch basins have little, if any, positive impact on water quality. The replacement of existing catch basins with water quality inlets is a method of increasing the water quality of storm runoff and is particularly well-suited for residential areas. Water quality inlets are specially designed catch basins which remove sediments, nutrients, and trash from collected surface runoff. These inlets can be used to replace existing catch basins without extensive modifications to the existing conveyance (pipe) system. There are a number of different designs available for water quality inlets, but all rely on the same general techniques for pollutant removal. They all remove pollutants by using various methods to collect trash and settle out sediments. Another design consists of 3 separate chambers that also function to slow water down and remove sediment. Furthermore, some water quality inlets also incorporate some type of filter media to remove dissolved nutrients, particularly phosphorus. In addition to trapping sediments and nutrients, water quality inlets can also be designed to remove petroleum hydrocarbons.

Proper maintenance is essential in order for the retrofits to achieve effective pollutant removal since deposited pollutants are only permanently removed during pump-outs. The normal method used to clean out many of these structures is to pump out the contents of each chamber; this should be done twice a year, once in late fall after all the leaves have fallen and once after the spring thaw, once all de-icing/snow clearing activities have ceased. However, additional pump-outs may be required after particularly large storm events. Proper maintenance enhances pollutant removal and helps prevent re-suspension of sediment particles. **In fact, if the stormwater retrofits cannot be pumped out at the recommended intervals then they shouldn't be considered for use.** The pump-outs should be performed by a licensed waste management company or the municipality.

Due to financial constraints, the upgrade of the catch basins should be conducted on a sub-watershed basis with prioritization given to basins immediately adjacent to the shoreline in sub-watershed 1 and sub-watershed 5. However, prior to implementing a series of stormwater retrofit projects, it is strongly recommended that the existing stormwater conveyance system be mapped. The field data could be collected with GPS technology and placed into a GIS format to develop digitized maps. In turn, the maps can be placed over other types of watershed data (i.e. slopes, soils, structures) to locate and target specific sites for stormwater retrofits. Finally, the local watershed data would be used to select the most cost effective retrofit for each targeted location.
Provided below is a list of some of the water quality inlet Manufactured Treatment Devices that could be installed within the Lake Oscawana watershed. The installation and cost of each water quality inlet is highly dependent upon site specific conditions that need to be assessed. Some water quality inlets can be retrofitted to existing catch basins and others replace the basin. Still others could be installed where there is no existing stormwater conveyance system but limitations in available land prevent the use of more conventional BMPs. More detailed descriptions of these retrofits can be found in Appendix B.

- ***Nutrient Separating Baffle Box*** – Comprised of 3 sediment settling chambers and a filtration screen system that collects vegetation and litter. A boom located between the screen system and a skimmer collects and absorbs hydrocarbons.
- ***Aqua-filter™*** – The Aqua-filter™ treatment system consists of two steps to remove sediment, floating debris and free oil in the first step with a Swirl Concentrator™ . The second step consists of a filtration unit which refines and enhances stormwater; the filtration unit can substantially reduce dissolved phosphorus concentrations.
- ***Aqua-Swirl™-*** Uses vortex separation to remove sediment, floating debris, and free-oil. Larger than the average catch basin so it usually replaces the existing basin.
- ***Aqua-Guardian™*** – Can fit into existing catch basin. Removes coarse sediment, trash/debris, and pollutants such as dissolved oil, nutrients and metal. Requires more frequent clean-outs than the larger devices. Uses a filtering media to remove dissolved phosphorus.
- ***Stormceptor*** – similar to a water quality inlet in that is collects primarily particulate material. However, these retrofits tend to have higher pollutant removal efficiencies.
- ***Grated Inlet Skimmer Box*** – Fits into any size grated inlet to capture leaves, trash, and hydrocarbons. Can be retrofitted with iron oxide for the removal of dissolved phosphorus.

In order to install any of these structures, additional site specific information is required. However the amount of required information is dependent on the size and specific structure. For examples, some of the smaller structures such as the Grated Inlet Skimmer Box are installed into existing drop inlet catch basins. Thus, for this structure some measurements of the existing catch basin are required. However, for others such as the Nutrient Separating Baffle Box and the

Aqua-filter system, a considerable amount of survey work, engineering design and planning is involved.

In order to identify potential locations for the installation of such manufactured treatment devices, Princeton Hydro conducted a site visit of Lake Oscawana watershed on 21 January 2008, which at this time some field reconnaissance work was done. It should be noted that this field visit was in no means comprehensive; additional such field surveys should be conducted to identify additional locations. It would also be beneficial to conduct such future surveys during rain events to observe the movement and drainage of stormwater through the watershed.

No formal topographic or property boundary surveys were conducted during the January 2008 site visit. Such survey work is absolutely necessary in the development of engineering plans for the installation of the larger structures. However, the January 2008 field survey provided an excellent starting point in the identification of potential stormwater projects that would reduce the pollutant loads entering Lake Oscawana, particularly in the high priority watersheds of 1 and 5. For convenience, the five potential projects are summarized below with estimated costs for design and implementation.

Recommended Stormwater Projects for Lake Oscawana:

1. Upgrade / retrofit a series of 15 existing catch basins along West Shore Drive with smaller structures such as Aqua-Guardians. Some of these catch basins are located in sub-watershed 1, while others are located in sub-watershed 2, however, it should be noted that all sites are located within the MS4 zones within the watershed. The survey work, design, replacement of existing catch basins and installation of Aqua-Guardians is estimated to cost approximately $90,000.00.

2. Installation of a stormwater structure, such as a Nutrient Separating Baffle Box or Aqua-filter along 80 Cayuga Road / Abele Park. This is a high prioritization project located in sub-watershed 1 and is in the MS4 zone. The survey work, design, engineering calculations, possible permitting and installation of the structure is estimated to cost approximately $150,000.00.

3. Installation of a stormwater structure, such as a Nutrient Separating Baffle Box or Aqua-filter along Noswel Park Road. This is a high prioritization project located in sub-watershed 5. However, while this project is in a high prioritized sub-watershed, it is the only one of the five recommended projects that is not in the MS4 zone. The survey work, design, engineering calculations, possible permitting and installation of the structure is estimated to cost approximately $225,000.00.

4. Upgrade / retrofit a series of 25-30 existing catch basins along Chippewa Road, Winnebago Road and Sioux Road, with smaller structures such as Aqua-Guardians or Grated Inlet Skimmer Boxes. This project is actually in a low prioritization area (sub-watershed 4), however, this "cluster" of catch basins would make maintaining them easier in terms of scheduling pump-outs. In addition, these proposed stormwater

upgrades are located in the watershed's MS4 zone. The survey work, design, replacement of existing catch basins and installation of retrofits is estimated to cost approximately $150,000.00.

5. Installation of a large stormwater structure, such as a Nutrient Separating Baffle Box, adjacent to Northview Beach. This is a moderate prioritization project located in sub-watershed 3, which is also in the MS4 zone. The survey work, design, engineering calculations, possible permitting and installation of the structure is estimated to cost approximately $250,000.00.

Please note the estimated costs are subject to change based on the size of the drainage area targeted for treatment, which in turn impacts the size of the BMP. In addition, the estimated costs do not include any upgrades / modifications that may be required on the existing network of stormwater pipes that may be required. Also, prior to any engineering design work is initiated, it is strongly recommended that property boundary surveys be conducted at each site to identify private / public landowners and the potential existence of easements / right-of-ways.

5.2 Nonstructural Best Management Practices

Nonstructural best management practices (BMPs) are designed to minimize the generation of pollutants at their source. They typically involve source control strategies that decrease the use of potential pollutants or minimize their release into the environment. They thus function to reduce or eliminate pollutants before they enter stormwater runoff. Nonstructural BMPs rely primarily on changing standard operating procedures and observed lifestyles of community members. Since the success of these BMPs depends on changes in the lake user's behavior, a strong educational / public outreach program is necessary.

An aggressive public education program, focusing on septic management, fertilizer / detergent management, aquascaping and the preservation of vegetated lands would encourage the implementation of nonstructural BMPs. Fact sheets and other educational materials should be developed and distributed to residents living in the Lake Oscawana Watershed. Local workshops can also be held to educate the lake residents and distribute educational material. It cannot be overstated that public education is a major requirement for these types of BMP's to be successful and needs to be a long-term program that consistently reminds stakeholders on how their actions and behavior impact the water quality, ecological and recreational value of the lake.

5.2.1 Septic System Management

Failing or improperly maintained septic systems can contribute large amounts of pollutants to a nearby waterbody. As the pollutant budget for Lake Oscawana indicates, septic system loading almost ties stormwater surface runoff as the second highest source of phosphorus entering the lake. Based on the septic model used in this study (Section1.2) septic leachate is estimated to contribute 185 kg (407 lbs) of phosphorus per year to Lake Oscawana. Given these data, watershed management for Lake Oscawana must include reducing this source of phosphorus to improve upon and protect water quality conditions. The most efficient method of controlling this source of phosphorus is to develop a septic system management program.

Developing an On-Site Wastewater Treatment System Management Program (EPA 2005)

Homeowners are usually responsible for the operation and maintenance of their individual On-Site Wastewater Treatment System (OWTS); however, in many cases the necessary information and/or training are not provided to homeowners for the successful management of their septic system. Furthermore, local regulators often lack the legal authority to hold homeowners responsible for properly managing and maintaining their OWTS. Thus, local lake communities often adopt local ordinances to provide the required legal powers to support OWTS management and to take the necessary actions when public or water resources are threatened. From a long-term perspective such a management plan should include the identification of existing systems, operation and maintenance requirements, periodic inspections, monitoring, financial support, and data management. However, the first step in the long-term development of such a plan is to educate local stakeholders on how their septic systems operate and what they can do to manage and protect their systems to minimize environmental impacts.

Based on the current conditions, the development or enhancement of a management program should begin. The US EPA has identified five management approaches which can be used to determine the best management program for the community. Since the community is near a waterbody, either the Operating Permit Model or Maintenance Contract Model should probably be used. The Operating Permit Model is applicable to areas of moderate environmental sensitivity such as bathing/water contact recreational areas. Under this model, there are performance and monitoring requirements, engineered designs are allowed but may provide prescriptive designs for specific sites, regulatory oversight by issuing renewable operating permits, inventory of all systems, tracking operating permits and compliance monitoring.

The second model, Maintenance Contract Model, is applicable in areas with low to moderate environmental sensitivity. Under this program it is required that the systems are properly located and constructed, there are more complex treatment options, service contracts must be maintained, an inventory of all systems is kept, and contracts will be tracked.

A description of each of the five management models and guidance on how to implement them can be found at http://www.epa.gov/owm/septic/pubs/septic_guidelines.pdf. This is an extremely helpful document for any entity considering implementing a septic system maintenance program. Another equally helpful document is the US EPA Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems and can be accessed at: http://www.epa.gov/OW-OWM.html/septic/pubs/onsite_handbook.pdf This manual provides more detailed guidance on how to select, evaluate, develop, and implement the Management Guidelines. These two documents overlap somewhat, however they provide very detailed guidelines on how to structure and implement a septic management plan. In addition, both documents (especially the second) provide a wealth of references and resources for additional information.

When maintained and managed properly, OWTS are often less expensive than having a centralized plant, while providing the same services. Properly managing an OWTS can result in lower replacement and repair costs and increase property value. Furthermore, these systems can be installed as needed, thus decreasing large upfront capital costs associated with centralized sewage treatment plants. Additionally, an OWTS can aid in recharging groundwater aquifers and maintaining dry season flow in streams.

Thus, the proper management of an OWTS is important for the continued function of the system, health of the environment, and human health. For these reasons, establishing effective management programs can increase awareness of septic management, and thus ensure that the OWTS are being managed properly. The benefits of having an OWTS management program include: reduced costs for repairs, operation, maintenance, and replacement, longer system life, improved system performance, increased reliability, and higher property values.

Septic system maintenance

The maintenance of a septic system, such as soil absorption systems, is important for proper functioning of the system. The EPA (USEPA 2003) has identified four maintenance activities to ensure the proper functionality of the septic system.

- The septic system should be **inspected regularly** and pumped (by a State-licensed contractor) as needed. Inspections are recommended every one to three years, whereas, pumping should take place every three to five years. Typically, every three years for year-round residences and every five years for seasonal residences. The inspection should include locating the system, uncovering access holes, flushing the toilets, checking for signs of backup, measuring the scum and sludge layers, checking the conditions of the outlet and inlet baffles, key joints, and tank, and inspecting mechanical components (Vogel 2005).

- **Pumping** needs are determined by the amount of sludge in the system; pumping should occur when the sludge layer is one third the liquid depth or when the tank is one third full. The frequency of pumping is a function of the number of people in a household, amount of water generated, volume of solids in the wastewater, and size of the septic tank. When the tank is pumped it should be done though the manhole. These two activities are the best and most cost-efficient way to keep the septic system functioning properly.

- In order to prolong the health of the septic system, **water should be used efficiently**. The average indoor water use per person in a typical single-family home is approximately 70 gallons/day (USEPA 2003). Reducing the amount of water entering the septic system will prolong its life and the time needed between pumps. Basic ways to reduce the amount of water use in a home include using high-efficiency toilets, low-flow shower heads, running full loads of laundry, and fixing leaky faucets.

  Also, **hazardous wastes (paints, varnish, pesticides, etc.) and other solids (cat litter, paper towels, fats, dental floss, etc.) should not be flushed or put down drains.** Chemicals can damage the biological activities occurring in the system and are also capable of contaminating ground/ surface water; whereas, other solids can clog the drainage field and increase the frequency between pumping events. Reducing or eliminating the use of garbage disposals can reduce the amount of suspended solids and nutrients entering a septic tank. Additionally, chemical additives for septic tank operation should not be used since there is little evidence that they perform their advertised function (Water Quality Program Committee 1996).

- Lastly, the **drain field needs to be maintained** since it is a vital part of the septic system. Drain fields should only be planted with grasses since trees and shrubs are capable of damaging the drain field. Also, you should not allow vehicles to drive or livestock to graze on the drain field because they can compact the soil and damage drainage pipes.

Additionally, excess water (from stormwater runoff, sump-pump drains, etc.) should be diverted from the drain field.

Implementing an On-Site Wastewater Treatment System Management Program

The first step in implementing an OWTS management program is identifying the location, type, condition, and number of septic systems. This should be done as a minimum. This information will be helpful for determining how to best manage the OWTS. LOCA should use this information to compile a database on current systems surrounding the lake.

Collecting data on the potential impact of lakefront septic systems on water quality would be valuable in conveying to the watershed stakeholders the need and value of septic management. Specifically, a fluorescence meter could be used to detect traces of a fluorescent compounds that are flushed through near-shore septic systems. The detection of these compounds within the lake would indicate the presence of a system or a group of systems where the leachfield provides inadequate treatment of phosphorus originating from the septic wastewater. Once shoreline areas are identified as "hot spots" in terms of being potential sources of phosphorus, some discrete water quality sampling could be conducted to more accurately identify the exact system or systems responsible for the phosphorus release.

The advantage to using fluorescence – conductivity meter is that the entire shoreline of the lake could be surveyed for potential septic related "hot spots". The disadvantage to this method is that the resulting data does not provide information on the exact system or systems for the phosphorus release, nor does the method provide a quantification of the septic-generated phosphorus load. Furthermore, after the "hot spots" have been located, discrete water sampling is required to specifically identify and quantify the phosphorus load.

Another strategy that can be used to identify problem septic systems is to conduct an infrared aerial analysis. Specifically, an aerial fly-over is conducted and the area is photographed with near infra-red film. The acquisition of the data may be through the use of remote sensing applications (SPOT, LANDSET) or low altitude reconnaissance. Hydraulically stressed septic systems will have a more intense pink hue as a result of more vegetation growing over the leachfield. Such hydraulically stressed septic systems should be net sources of phosphorus for Lake Oscawana.

While conducting a near infrared aerial analysis will not quantify the phosphorus load attributable to each septic system, it will identify those systems that are likely net contributors to the lake's annual phosphorus load. Thus, the major advantage to the near infrared aerial analyses is that all of the septic systems around Lake Oscawana can be assessed at the same time and at a relatively low cost.

The implementation of a septic management plan combined with an aggressive public education campaign should provide the residents of Lake Oscawana with information on how they can minimize individual contributions to the annual phosphorus load. In addition, a local ordinance could be passed by Putnam County that would require mandatory septic system pump-outs every

3-5 years. Based on a comprehensive and nationwide evaluation of septic systems under a variety of environmental conditions, US EPA developed guidance on the frequency of pump-outs that should be followed for lake front systems. The evaluation determined that year-round, lake front systems should be pumped every three years while seasonally used systems should be pumped-out at least every 5 years. A lake front system was defined as having its leachfield within 300 feet of the shoreline or the bank of a stream that enters the lake.

LOCA should coordinate with Putnam Valley Planning Board to encourage the Putnam County Health Department to adopt an ordinance requiring septic system management. As stated in the Putnam Valley Master Plan, Putnam Valley should consider the establishment of one or more septic management districts. These districts could implement a permitting process that licenses septic systems and ensures proper maintenance and regular pump-outs by way of regular inspection. In order to obtain or renew a septic system license the system should be required to undergo a routine inspection and show proof of required pump-outs. The management district could determine when a system is failing and require modification or replacement and possibly offering a source of funding for these activities. In addition, the management district should develop a septic system maintenance manual to be distributed with each license. A portion of the funding for the septic management program could come from a fee which is charged when the license is issued or renewed. More importantly, regulatory authority would have to be granted by the Putnam County Department of Health to provide the management district with the means to enforce the regulations and penalty structure.

Finally, it should be emphasized that maintaining and/or upgrading existing septic systems, as well as developing planning tools to design and locate new septic systems with minimal environmental impacts, is not only critical for compliance with the TP-based TMDL. Such measures will also contribute toward reducing other septic-based pollutants (i.e. nitrate-N, *E. coli*, fecal coliform) entering Lake Oscawana. In turn, health and recreational impacts (i.e. the closing of local beaches) associated with septic systems will be avoided or at least minimized. Thus, the septic management component of this Management Plan needs to be strongly integrated into its long-term implementation.

5.3 Alternative Landscaping (Lakescaping)

Alternative landscaping is strongly recommended for Lake Oscawana because it reduces soil erosion, discourages geese on the lawn, and eliminates the need for ongoing fertilization of yard areas, all of which contribute to NPS pollution. The goal of alternative landscaping is to return a majority of the shoreline to a vegetated state. This is accomplished by replacing monoculture lawns with a more diverse array of native grasses, trees, and shrubs and establishing aquatic plants along the shoreline. In addition, this customized buffer zone can be accomplished without impairing lake views from the house. An excellent guide to alternative landscaping; "Lakescaping for Wildlife and Water Quality", can be obtained from the Minnesota Department of Natural Resources (1-888-646-6367) for $19.95. In addition the New York State Federation of Lakes Association has a wealth of information on "lakescaping" and has a contest each year for the best lakescaped project.

Lawn areas require a high degree of maintenance; most lawns species are non-native and require additional watering, fertilization, and pesticides. Native vegetation should be retained as much as possible on steep slopes, swales, excessively drained soils, and areas with high water tables or adjacent to surface waters. It cannot be emphasized enough that native plants are adapted to existing soils and climate conditions and, therefore, do not require nutrient supplements or additional maintenance such as watering, which can leach nutrients into the lake.

Lawns ending at the waters edge should be discouraged and avoided. Lake Oscawana has an abundance of lawns ending at the lakes' edge. Shoreline lawns are a major source of nutrients via storm runoff and lawn watering. A buffer strip of native vegetation should be maintained along the shoreline to help stabilize the shoreline and to act as a sink for lawn fertilizers that would normally enter the lake. Obviously, the wider the buffer, the more effective it will be in intercepting NPS pollutants entering the lake. Therefore, where specific sites permit, the vegetative buffer should be at least 10 and 20 ft. wide, depending on slope. Steeper slopes require wider vegetative buffers.

If a lawn area is desired and conditions permit, grasses that are adapted to low amounts of moisture and nitrogen should be selected. This will reduce the application of fertilizers and minimize maintenance. For example, fine fescue and perennial rye grasses are some suitable grasses that should be planted rather than the commonly used bluegrass. In general, the annual nitrogen requirement for fescue is about 2 lbs per 1,000 ft^2, while the nitrogen requirement is 4 to 7 lbs per 100 ft^2 for bluegrass. It should also be noted that grass clippings and leaves should never be disposed of in the lake, and this practice should be discouraged.

Another alternative to a grassed lawn is a ground cover. Pachysandra (in shady areas), ivy, periwinkle and other evergreen ground covers are among the alternative ground covers which require little maintenance and are drought tolerant. Other alternatives to lawn areas include: (1) native woodland species, (2) perennial or self-sowing wildflowers, and (3) low-growing deciduous or evergreen shrubs. In addition, a variety of aquatic plants can be planted; pickerel weed, arrowhead, and lizard tail are non-invasive species that can be planted at the water's edge. Rose mallow and yellow or blue flag iris can be used to provide color, while bulrush and common three square bulrush will add texture.

Unfortunately, alternative landscaping ("lakescaping") is often resisted by property owners as a method to control lawn runoff and nutrient loading into a lake. Unlike some other management techniques such as the use of chemicals to control nuisance vegetation, lakescaping is a long term management technique that does not provide immediate results. One option is to encourage and possibly even subsidize a few willing property owners to try this technique, thereby building local expertise and encouraging other property owners to try this technique. Lakescaping projects can range in price from $2,400.00-$10,000.00 per acre or $8.00 to $25.00 per linear foot depending on if re-grading / additional stabilization of the shoreline is required.

5.4 Lawn/Garden Fertilization Management

Another nonstructural BMP technique for residential landscaping is fertilizer management. Significant nutrient loading can result from over-application of lawn fertilizers in urban and suburban areas. For example, a watershed based inventory of two sub-watersheds in the Musconetcong watershed in New Jersey, revealed that the majority of the NPS pollutants entering Lake Hopatcong originated from either septic systems or residential lawns (Coastal, 1997).

Limiting the amount of fertilizer applied to the minimum quantity needed for optimum plant growth minimizes the potential for surface or groundwater contamination. Not only will such a program reduce the amount of pollutants entering Lake Oscawana, but it will also maximize the effectiveness of fertilizer applied per dollar spent. However, it must be noted that the effectiveness of a fertilizer management program depends upon cumulative efforts within the watershed. This means that an aggressive educational/public outreach program will be required to implement this as well as other nonstructural BMP's.

Maintaining a near neutral soil pH is critical for the maximum assimilation of soil nutrients. Acidic soils (low pH) make essential nutrients unavailable for uptake and may result in increased leaching of nutrients to the lake. For lawns, pH values should be between 6 and 7, depending on the type of grass. Liming a lawn can move the soil pH towards a neutral value of 7, where the chemical reactions in the soil are such that elements nitrogen and phosphorus are more available for plant uptake. Lime also improves the soil structure and creates an environment that is more conducive for microorganisms that decompose organic matter. Liming is best done in the fall, since its effects are more gradual than those of fertilizers.

The use of lawn fertilizers represents a controllable nonpoint source of phosphorus for Lake Oscawana. Turf grasses are typically limited in growth by nitrogen and/or potassium and need only small amounts of phosphorus. Additional phosphorus added to the soil ends up leaching out and entering ground and/or surface waters. Thus, by encouraging lake residents to use non-phosphorus fertilizers (i.e. Lake Side or similar fertilizers available from a number of commercial sources), it is conceivable to substantially decrease the external load of phosphorus to the lake. For examples, studies in Minnesota have revealed that by simply switching from phosphorus to non-phosphorus fertilizers, the individual on-lot phosphorus load decrease by 12-18%.

Non-phosphorus fertilizers are increasingly used around lakes; in fact some municipalities have banned the use of phosphorus fertilizers. In contrast to turf grass, aquatic plants and algae are limited in their growth by phosphorus, so applying fertilizers with excess phosphorus only results in the degradation of ground and lake water. LOCA should work with a promote local hardware store to sell non-phosphorus fertilizers. If a phosphorus-containing fertilizer must be used, the pH of the soil should be tested. Phosphorus binds with soils at an optimum level when soil pH is approximately 6.5. **Homeowners with lawns should be encouraged to join the Putnam County's "turf love" program, where they can have their soil tested for pH and also become educated on the proper techniques of lawn care that minimizes negative effects on water quality.**

The timing of fertilizer application is just as important as the amount being applied. Applications should coincide with the needs of the lawn. Most lawns in the northeast do not require equal amounts of or constant levels of nutrients throughout the year. Typical lawns are commonly composed of grass types that grow rapidly in the spring and fall, but grow slowly during the hot, dry summer months. Therefore, fertilizer is primarily needed only in the spring and fall. Spring fertilization helps to "build up" the grass and protect the lawn from weeds and pests. Fall fertilization provides a healthier, hardier turf longer into the colder months. In addition, fertilization should occur when the soil is moist; however, applications should not be performed immediately prior to a forecasted rainstorm and should never be performed when the ground is frozen.

5.5 Preservation of Existing Wetlands and Forested Areas

Several wetland areas exist around Lake Oscawana, an especially large wetland is located on the east side of the lake and is known as the Lost River Swamp. In addition, another sizeable wetland exists at the northern end of the lake. These wetlands should not be disturbed as they help to minimize local flooding, act as a nutrient sink (especially phosphorus) and provide food and habitat for wildlife. Currently there is a 100 ft. buffer strip around the lake and inlet streams, however if these wetlands are privately owned the Township should consider purchasing them. In addition, the GIS data indicate that a large portion of the Lake Oscawana watershed is forested. Forested lands reduce sedimentation, act as a nutrient sink, and reduce runoff, thereby lowering the amount of nutrients and sediment entering the lake. Efforts should be made to preserve as much forested land as possible.

Finally, it should be mentioned that monitoring the water quality of Lake Oscawana should continue in the future. The long-term database generated to date has been absolutely essential in the refinement of the annual TP budget, assessing various in-lake and watershed management measures, and developing the overall Management Plan. However, in addition to the existing water quality monitoring program, it is recommended to add the collection and analysis of phytoplankton and zooplankton (identified to at least genus), as well as the collection and analysis of water samples for chlorophyll *a*, a photosynthetic pigment all algae possess. These additional parameters will provide values insight into the ecological and recreational states of Lake Oscawana. In addition, measuring chlorophyll *a* will serve as an "ecological endpoint" relative to how the lake is responding to the implementation of the Management Plan and assessing progress in moving toward compliance with the TP TMDL.

6.0 Summary of the Lake Management Plan

The following provides, in outline form, a summary or synopsis of the Lake Oscawana Management Plan as presented above. Sources of pollutants are listed in order of priority based on their relative contribution. Atmospheric deposition is not discussed as there is little that be done to control this source of pollution.

Internal Regeneration of Phosphorus

- Given that internal loading is the largest contributor of phosphorus to Lake Oscawana, priority should be given to lowering this source of nutrients.
- Consider the implementation of artificial circulation as the primary means of controlling the internal phosphorus load. Thought will need to be given on finding places for the compressor(s) and running electricity.
- Consider the use of an alum treatment as a secondary means of reducing the internal phosphorus load. Perform a bench test to determine whether an alum treatment is possible or whether the use of buffered alum is necessary. If the bench testing is successful, set up a Scoping meeting with the regional office NY DEC to discuss the permit process.

Septic System Leachate

- Lake Oscawana needs a septic management plan if any reductions in internal regeneration of phosphorus are to be realized.
- A comprehensive septic management plan should include mandatory pump-outs based on whether a residence is full-time or seasonal. Mandatory maintenance should also be required to operate a septic system.
- The Putnam County Health Department has the ultimate jurisdiction concerning on-site wastewater treatment facilities. In order for the management plan to have any regulatory authority, it will need to be approved by the Health Department.

Surface Runoff/Watershed Management

- Seek funds to implement at least one of the five stormwater projects proposed for NPS reduction in the Lake Oscawana watershed.
- Identify additional locations where stormwater is directed into the lake and consider other BMP for those locations to reduce the suspended solids and phosphorus loads entering the lake. Sub-watersheds 1 and 5 should be prioritized for these BMPs since they have the highest developed and commercial pollutant loading.

- LOCA has already made phosphorus-free fertilizer available at the local hardware store. Efforts should be made to educate lake/watershed residents on the use of phosphate-free fertilizers and detergents. Products that contain phosphorus can be a major source of nutrients to a waterbody.

- Efforts should be made to reduce the amount of lawn area on the shoreline of the lake. Lawns are a major source of nutrients and pesticides. Buffer strips should be encouraged between lawns and the shoreline. Lake residents should know that buffer strips can be constructed without obstructing lake views. An excellent resource book for "lakescaping" is mentioned in the report. A "lakescaping" project should be subsidized to demonstrate that there are lake-friendly alternatives to grassed yards at the shoreline of the lake.

Nuisance Aquatic Plant Management

- Lake Oscawana is experiencing increasing amounts of nuisance aquatic plants similar to many other lakes in Mid-Atlantic states. LOCA should continue to harvest nuisance plants around recreational areas and boating lanes.

- Another aquatic plant inventory should be performed. This will aid in determining areas where plant control efforts such as aquatic herbicides can be concentrated. Although the use of aquatic herbicides in New York State is severely limited, their use should still be considered.

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Appendix A

Figures

Appendix B

Sub-Watershed Developed and Commercial Pollutant Loads

Table 4: Annual Total Nitrogen Pollutant Loads for the Lake Oscawana Watershed

Sub-watershed	TN load (kg/yr)	Sub-watershed	Developed TN load (kg/yr)	Sub-watershed	Commercial TN load (kg/yr)
4	974.5	5	413.3	5	385.0
5	813.1	1	242.3	1	225.3
3	636.0	3	155.2	4	152.7
2	305.9	4	152.7	3	126.9
1	283.3	2	32.3	2	32.3
		Median	155.2	Median	152.7
Total	3012.8	Total	995.8	Total	922.2

Table 5: Annual Total Phosphorus Pollutant Loads for the Lake Oscawana Watershed

Sub-watershed	TP load (kg/yr)	Sub-watershed	Developed TP load (kg/yr)	Sub-watershed	Commercial TP load (kg/yr)
4	68.4	5	22.0	5	18.7
5	46.4	1	13.1	1	11.2
3	41.2	3	8.8	4	7.1
2	22.1	4	7.1	3	5.6
1	16.0	2	1.4	2	1.4
		Median	8.8	Median	7.1
Total	194.1	Total	52.4	Total	44

Table 6: Annual Total Suspended Solid Pollutant Loads for the Lake Oscawana Watershed

Sub-watershed	TSS load(kg/yr)	Sub-watershed	Developed TSS load (kg/yr)	Sub-watershed	Commercial TSS load (kg/yr)
4	97660.8	5	51850.4	5	51041.0
5	85196.4	1	30432.4	1	29946.7
3	60095.8	4	20183.7	4	20183.7
1	34135.2	3	17502.7	3	16693.3
2	30230.0	2	4249.2	2	4249.2
		Median	20183.7	Median	20183.7
Total	307318.3	Total	124218.3	Total	122113.9

Appendix C

Water Quality Inlet Retrofits

Manufactured Treatment Device:
Nutrient Separating Baffle Box

Except where otherwise noted, the information presented in this factsheet has been provided by the manufacturer, Suntree Technologies Inc. www.suntreetech.com

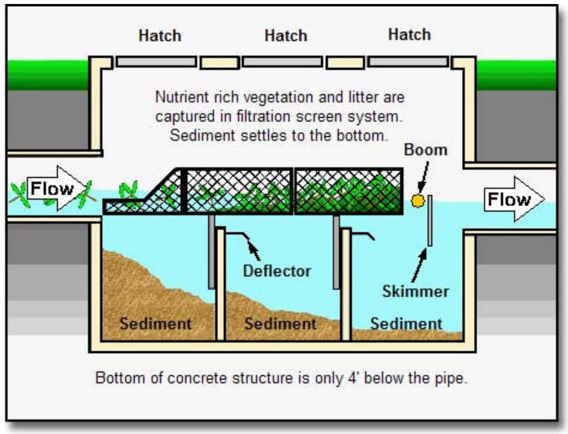
Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality measure or waterbody (NJDEP 2004). The Nutrient Separating Baffle Box is comprised of three sediment settling chambers and a filtration screen system that collects vegetation and litter. A boom located between the screen system and a skimmer collects and absorbs hydrocarbons.

Advantages:

- Captures foliage, litter, sediment, and hydrocarbons.
- Almost no head loss makes retrofitting possible and easy.
- Pre-assembly makes installation fast and easy.
- Separates foliage and litter from water and sediment.
- Will not go septic between storm events.
- Installs within the existing easement of the drain pipe.
- Treats the entire water flow of the storm pipe.

Disadvantages:

- Require significant maintenance to remove accumulated sediment (EPA 2001).
- Limited capacity in removing dissolved nutrients.



Estimated Costs:

An average Nutrient Separating Baffle Box costs approximately $12,000 for the unit itself.

Maintenance Requirements:

The Nutrient Separating Baffle Box needs to be cleaned out at least once a year, but probably more depending on the frequency of storm events.

Ascribed Pollutant Removal Efficiencies:
Up to 90%

Manufactured Treatment Device: Aqua-Filter™

Except where otherwise noted, the information presented in this factsheet has been provided by the manufacturer, AquaShield Inc. <www.aquashieldinc.com> and the EPA < http://www.epa.gov/Region1/assistance/ceitts/stormwater/techs/aquafiltersys.html>

Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality measure or waterbody (NJDEP 2004). The Aqua-Filter™ treatment consists of two steps to remove sediment, floating debris and free-oil in the first step with a Swirl Concentrator™, and to remove soluble and insoluble hydrocarbons, fine silts and clays, nutrients, and certain heavy metals in the second step.

Advantages:

- Removes sediment (TSS), floating debris (litter), and free-oil.
- Removes soluble and insoluble hydrocarbons, fine silts and clays, nutrients, and certain heavy metals.
- Flexible design allows for easy retrofitting in existing facilities.
- Fast installation.
- Relatively easy maintenance.

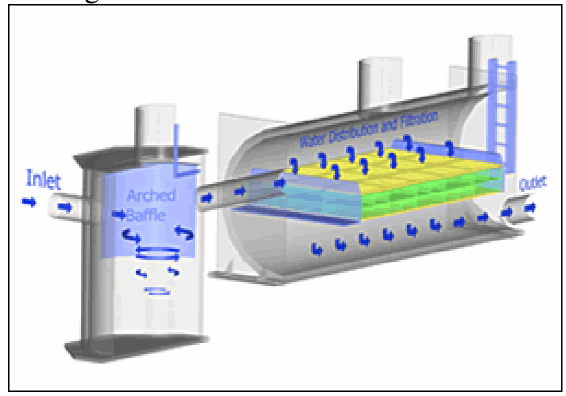
Disadvantages:

Estimated Costs:

The Aqua-Filter™ system is usually custom engineered and site-specific so costs will be different for every situation. Discounts for volume purchases are available for qualified customers.

Maintenance Requirements:

The first step is to inspect and cleanout the Swirl Concentrator pre-treatment chamber. Free-floating oil and floatable debris can be directly observed and removed through the 32-inch service access provided. If cleanout is needed, a vacuum truck can be used to remove the accumulated sediment and debris.



The second step is to inspect and cleanout the Aqua-Filter™ filtration chamber. Inspection of the filtration chambers can be performed from the surface by observing the color change of the filter media from its original light color to dark brown. If the filter bags need replacing, entry into the system is required.

Ascribed Pollutant Removal Efficiencies:

The performance of AquaShield's filtration technology has recently been verified by the California Environmental Protection Agency's Environmental Technology Certification Program (cert. # 00-03-001) for the removal of 90% - 95% of dissolved petroleum and oils. In addition, third party monitoring shows the Aqua-Filter™ Stormwater Filtration System removes as much as 88.9% TSS, 98.9% dissolved petroleum and oils, with notable reductions in Phosphorous and Nitrogen.

Manufactured Treatment Device: Aqua-Swirl™

Except where otherwise noted, the information presented in this fact sheet has been provided by the manufacturer, AquaShield Inc. <www.aquashieldinc.com> and the EPA < http://www.epa.gov/Region1/assistance/ceitts/stormwater/techs/aquaswirl.html>

Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality measure or waterbody (NJDEP 2004). The Aqua-Swirl™ uses vortex separation to remove sediment, floating debris and free-oil. This device is larger than the average catch basin and therefore typically replaces them.

Advantages:

- Removes sediment (TSS), floating debris (litter), and free-oil.
- Flexible design allows for easy retrofitting in existing facilities.
- Easy installation.
- Relatively easy maintenance.

Disadvantages:

- Limited capacity in removing dissolved nutrients.

Estimated Costs:

The Aqua-Swirl™ system is usually custom engineered and site-specific so costs will be different for every situation. Discounts for volume purchases are available for qualified customers.

Maintenance Requirements:

The Aqua-Swirl™ needs to be cleaned when the sediment pile is within 30” of the water surface. The amount of time it takes for the sediment to reach this level is dependent on frequency and

duration of storm events, as well as the drainage area. A vacuum truck can be used to clean out the system.

Ascribed Pollutant Removal Efficiencies:

The Aqua-Swirl™ system is designed to remove 80% of TSS on an annual basis.

Manufactured Treatment Device: Stormceptor

Except where otherwise noted, the information presented in this factsheet has been provided by the manufacturer, Imbrium Systems, Inc. <www.stormceptor.com> and the EPA http://www.epa.gov/Region1/assistance/ceitts/stormwater/techs/aquaguard.html

Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality measure or waterbody (NJDEP 2004). The stormceptor removes suspended solids and free oil.

Stormceptor slows incoming water to create a non-turbulent treatment environment, allowing free oils to rise and sediment to settle. Patented scour prevention technology ensures pollutants are captured and contained during all rainfall events.

Advantages:

- Simple to design and specify.
- Capable of removing 80% of yearly sediment load.
- Straightforward maintenance.
- Treats "first flush"

Disadvantages:

- Requires a minimum 24" of cover above the crown of the pipe.
- Requires pump-out by vacuum truck.

Stormceptor®
Stormwater pollutant removal (STC)

Maintenance Requirements

Pump-out is required when sediment depth reaches 15 % of storage capacity.

Estimated Costs

Approximately $5800, but can vary depending on site-specific factors.

Manufactured Treatment Device:
Grated Inlet Skimmer Box

Except where otherwise noted, the information presented in this factsheet has been provided by the manufacturer, Suntree Technologies Inc. www.suntreetech.com

Manufactured treatment devices are intended to capture sediments, metals, hydrocarbons, floatables, and/or other pollutants in stormwater runoff before being conveyed to a storm sewer system, additional stormwater quality measure or waterbody (NJDEP 2004). Stormwater treatment system for a grated inlet Provides multi-stage filtration.

The Grate Inlet Skimmer Box is a multistage stormwater treatment device that fits into any grated inlet. The device uses three different sieves: Fine at the bottom, medium at the middle and coarse at the top. As the device fills with stormwater, fine sediments are deposited on the bottom while leaves and trash accumulate above the sediments. As stormwater enters the device, it passes over a boom which removes hydrocarbons.

Advantages:

- Can be sized to fit any grated inlet.
- Components are easily removed for cleaning.
- Will filter leaves, trash, and hydrocarbons.
- Boom can be filled with iron oxide to provide nutrient removal capacity.
- Probably the least expensive MTD. Around $1000.

Disadvantages:

- Needs frequent cleaning, can accumulate several hundred pounds of sediment and debris.
- Nutrient retention capacity unknown at this time.

Approximate Costs

The Grated Inlet Skimmer Box is usually custom fitted and site-specific so costs will be different for every situation.