Crooked Lake
Watershed Implementation Plan
Town of Tully, Onondaga County, New York

Prepared for:

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Contents

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1.0 Introduction

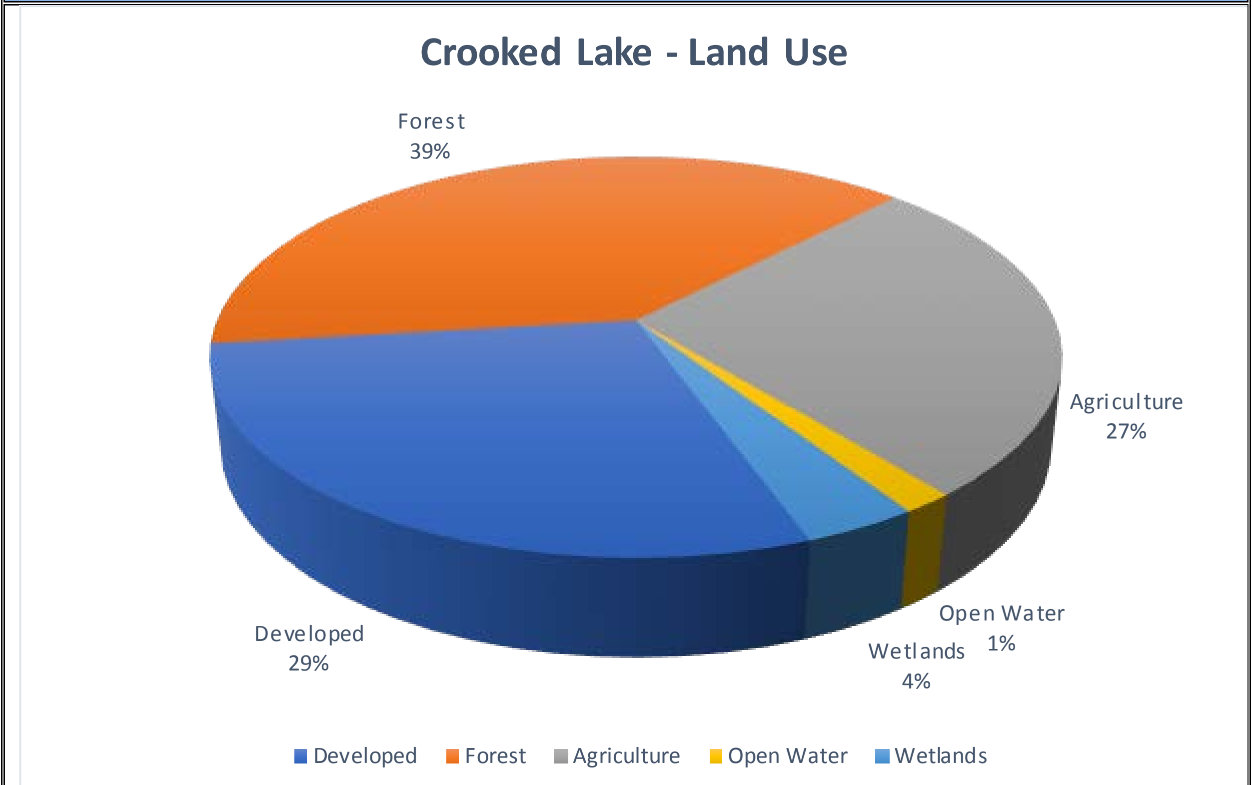
Crooked Lake, located in the town of Tully, Onondaga County, New York, is part of a kettle lake system. Historically, this lake has suffered from symptoms of eutrophication such as elevated phosphorus concentrations, lack of oxygen (anoxia), algal blooms and dense aquatic vegetation. While the water quality and hydrology of Crooked Lake has been studied in the past there has not been a concerted effort to develop a watershed plan for this waterbody. As part of this project, Princeton Hydro, in concert with the Cortland-Onondaga Federation of Kettle Lake Associations (C-OFKLA), Cortland County Soil and Water Conservation District and the Syracuse University Environmental Finance Center, has prepared small-scale Watershed Implementation Plans for Crooked Lake, Tully Lake, Song Lake and Little York Lake. Each plan is comprised of several inter-related components aimed to characterize the water quality of the lake, assess the external and internal phosphorus load, characterize the land use of the watershed and areas where best management practices (BMPs) may be implemented, and to correlate reductions in nutrient loading from each BMP into the nutrient budget for each lake. This plan is considered 'small-scale' given that only a single water quality sampling event was conducted and only ½ day was available to survey the watershed for areas which may benefit from BMPs. As such, this plan does not constitute an extensive lake and watershed management plan. Ultimately, this document may be utilized to seek funding sources to implement the projects contained herein and may be utilized in a larger context for lake management.

2.0 Lake and Watershed Characteristics

Crooked Lake is a 43 ha (106 ac) kettle lake located in the southern portion of Onondaga county, New York. Like most kettle lakes, it's characterized by relatively deep depths with a maximum depth of approximately 21 m (70 ft) in the southern portion of the lake. Crooked Lake has a shoreline development index (SDI) of 2.06 which is higher than Song Lake (1.46) and Little York Lake (1.44) but lower than Tully Lake (2.66). The shoreline development index is a unitless figure which relates the shoreline length of the lake to the circumference of a perfect circle of the same area. The irregular shape of the Crooked Lake shoreline therefore lends to the greater propensity for development. The watershed of Crooked Lake (Appendix I, Figure 1) encompasses 590 ha (1,459 ac) resulting in a watershed to lake ratio of 14:1. Typically, watershed to lake ratio values greater than 6 are indicative of a lake which is susceptible to higher levels of nutrient and sediment loading from the watershed.

Watershed land use categories are displayed graphically in Appendix I, Figure 2 and broken down by category in Figure 2.1.

Figure 2.1: Crooked Lake – Watershed Land Use



Forest represents the dominant land use in the watershed with a coverage of 231 ha (571 ac) located predominantly along the western portion of the watershed. Developed lands, including residential land use and the ski area, represent 170 ha (419 ac). Residential land is located along the majority of the shoreline and southern portions of the lake while the ski area is located southwest of the lake proper. The third greatest land use category is agriculture which comprises 158 ha (391 ac), located predominately along the west ridge.

The hydrology of Crooked Lake is unique with the lake residing in both the St. Lawrence and Susquehanna River basins. Historically, the lake was landlocked with no perennial inflow or outflow (USGS, 2011). Currently, inflow to the lake is derived from tributary flow from Song Mountain to the west and via groundwater derived from the western ridge. Outflow from Crooked lake includes evaporation, surface water outflow through a man-made outlet canal to the north and through groundwater losses to the north, east and south of the lake (USGS, 2011).

3.0 Water Quality Monitoring

3.1 Introduction and Methodology

Princeton Hydro conducted limited water quality monitoring of Crooked Lake to characterize the extent of thermal stratification, dissolved oxygen depletion and internal loading of phosphorus. This monitoring was conducted during a single event on July 11, 2017. During this event, Princeton Hydro established a monitoring station at a deep portion of the lake. Maximum depth was recorded and water transparency was measured with a Secchi disc. *In-situ* data collection consisted of measuring temperature, specific conductance, dissolved oxygen, dissolved oxygen percent saturation and pH, at 1 m intervals, throughout the water column. All *in-situ* measures were made utilizing a calibrated Hach MS5 water quality meter tethered to a Hydrolab surveyor. Discrete samples were also collected approximately 0.5 m below the surface and 1 m above the sediments for the analysis of total phosphorus (TP) and soluble reactive phosphorus (SRP). Upon collection, samples were placed on ice to 4°C and forwarded under chain-of-custody procedures to Environmental Compliance Monitoring of Hillsborough, NJ for analysis. Finally, assessment of the plankton (phytoplankton and zooplankton) was conducted through the deployment of a plankton tow net throughout the water column. Upon collection, this sample was preserved with Lugol's solution and analyzed for relative abundance and community composition by Princeton Hydro. The results of this single sampling event are presented below.

3.2 Results

Crooked Lake was thermally stratified at the time of sampling with temperatures ranging from 5.10°C at 21 m to 24.92°C at the surface (Z_{max} = 21.9 m). Dissolved oxygen was ample in the upper 3 m of the water column with concentrations all greater than 100% saturation. DO became depleted with depth with anoxic (no oxygen) conditions recorded from 11 m to the bottom. pH values in the lake were variable, ranging from 6.63 at 18 m to 8.65 at 1 m. Variations in dissolved oxygen and pH throughout the water column were due to elevated primary productivity in the upper 3 m of the water column contrasting with higher rates of bacterial respiration in the hypolimnion. Secchi disc transparency for Crooked Lake was 2.8 m at the time of sampling. The results of the *in-situ* sampling are presented in table 3.1 while temperature and DO is presented graphically in figure 3.1.

Discrete samples for phosphorus showed surface water concentrations of TP as 0.01 mg/L while SRP was 0.005 mg/L. In contrast, deep water samples were 0.14 mg/L for TP and 0.029 mg/L for SRP. Typically, TP concentrations should remain below approximately 0.03 mg/L while SRP concentrations should remain below approximately 0.005 mg/L to preclude nuisance algal growth. The disparity between surface and deep TP concentrations, in conjunction with extensive hypolimnetic anoxia, are strong indicators of internal P loading in Crooked Lake.

Phytoplankton samples from the deep station at Crooked Lake showed dominance to be exerted by the cyanobacteria *Anabaena*. In addition, the cyanobacteria *Coelosphaerium, Microcystis,* and *Aphanizomenon* were identified, albeit in lower densities. Several chlorophytes, diatoms, chrysophytes and dinoflagellates were identified in lower densities. Zooplankton were diverse with the cladoceran *Daphnia* exerting dominance over the community. The copepod *Cyclops* and copepod nauplii were also common at the time of sampling. Several rotifers were also identified in low concentrations.

Phytoplankton samples were also collected from the beach and analyzed for community composition. Algal densities were generally lower at this station with all genera identified listed as 'present' or 'rare.' *Anabaena* was again identified in low densities along with *Coelosphaerium, Microcystis,* and *Aphanizomenon.* Results of the plankton analysis are presented in table 3.2.

Table 3.1: Crooked Lake – *In-situ* Data

Kettle Lakes - *In-situ* Data - 7/11/17								
Station	Max	Secchi	Depth	Temp	SpC	DO	DO %	pH
	(m)	(m)	(m)	(C)	(mS/cm)	mg/L	(%)	(units)
Crooked	21.9	2.8	0.1	24.92	0.157	9.95	120.0	8.63
			1.0	24.11	0.156	9.94	118.4	8.65
			2.0	23.85	0.156	9.95	117.8	8.64
			3.0	22.55	0.162	10.69	123.8	7.85
			4.0	17.80	0.166	7.52	79.1	7.24
			5.0	12.45	0.174	5.63	52.8	7.02
			6.0	9.72	0.176	3.66	32.1	6.84
			7.0	8.17	0.173	3.87	32.8	6.79
			8.0	6.36	0.175	2.27	18.4	6.72
			9.0	5.78	0.173	2.85	22.8	6.71
			10.0	5.58	0.174	2.43	19.3	6.69
			11.0	5.35	0.176	0.93	7.3	6.67
			12.0	5.32	0.177	0.00	0.0	6.67
			13.0	5.31	0.177	0.00	0.0	6.67
			14.0	5.24	0.178	0.00	0.0	6.66
			15.0	5.20	0.179	0.00	0.0	6.65
			16.0	5.19	0.179	0.00	0.0	6.68
			17.0	5.18	0.179	0.00	0.0	6.64
			18.0	5.13	0.181	0.00	0.0	6.63
			19.0	5.12	0.183	0.00	0.0	6.66
			20.0	5.10	0.185	0.00	0.0	6.65
			21.0	5.10	0.185	0.00	0.0	6.66

Figure 3.1: Crooked Lake – Temperature and Dissolved Oxygen Profile

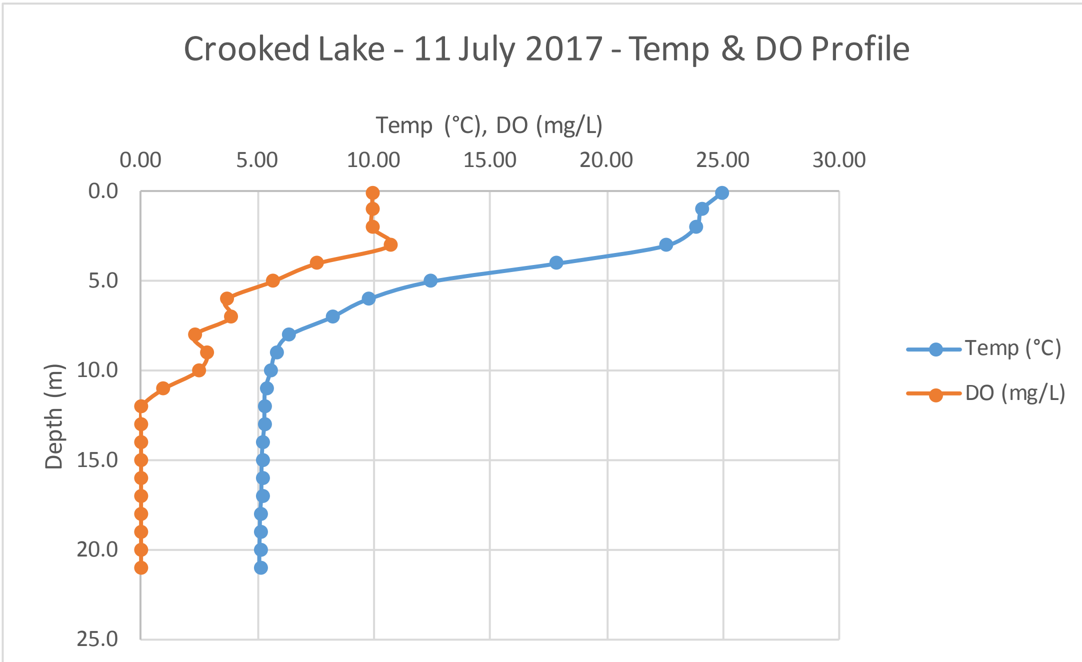


Table 3.2: Crooked Lake – Plankton Data

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Crooked Lake			**Sampling Date: 7/11/2017**			**Examination Date: 7/17/2017**		
Site 1: Deep	**Site 2: Beach**							
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophya (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Asterionella		R	*Sphaerocystis*		R	*Anabaena*	A	P
Fragilaria	R					*Coelosphaerium*	C	R
Tabellaria	P					*Microcystis*	P	P
Navicula		R				*Aphanizomenon*	C	P
Chrysophyta (Golden Algae)						**Pyrrhophyta (Dinoflagellates)**		
Chrysosphaerella	R					*Ceratium*	C	
Dinobryon	P							
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Daphnia	A		*Cyclops sp.*	C		*Keratella*	P	
			D Nauplius	C		*Kellicottia*	R	
			Diaptomus	P		*Asplanchna*	R	
						Polyarthra	R	
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton Genera	9	7						
Total Zooplankton Genera	8	0						
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R);					

4.0 Pollutant Loading Budget

4.1 Introduction

In order to properly analyze the trophic state of Crooked Lake and decide on appropriate watershed and in-lake management techniques a comprehensive nutrient budget must first be developed. In this sense all pollutant inputs must be identified and quantified in order to assess those areas which contribute a disproportional amount of that load and their relative influence on lake productivity. The pollutants of concern are total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS). Phosphorus and nitrogen are those two nutrients most critical to plant and algal growth and as such, increases in these nutrients generally lead to increased lake productivity. While both nutrients are modeled the nutrient of primary concern is phosphorus. In most temperate freshwater ecosystems this is the limiting nutrient, that is, the nutrient that is least available in relation to biological demand, and as such, small increases in phosphorus loading may result in exponential increases in algal and weed growth. There are several sources, both external and internal, of phosphorus loading to freshwater systems and each of these potential sources must be evaluated to develop a proper loading estimate. Total suspended solids represent the total amount of inorganic and organic particles within the water column and are the prime determinant of water clarity. High TSS concentrations may be associated with “muddy” water clarity and are generally the result of excessive sediment loading and suspensions of algal particles. Primary sources of sediment loading to the lake are generally derived through erosion of watershed soils and stream banks. Sediment loading generally results in the formation of sediment deltas and infilling of near shore areas thereby increasing aquatic weed habitat and providing the fertile substrate for benthic, filamentous algae. In addition, as phosphorus is often tightly bound to soil particles, increases in sediment loading are commonly correlated with increases in total phosphorus loading.

To address the issues of nutrient loading to trophic response Princeton Hydro conducted a comprehensive pollutant model which served to quantify both external and internal sources of nutrient loading. Those sources of nutrients which were quantified in this study include the following:

External

- Watershed as based on land use and land cover
- Atmospheric deposition
- Septic systems
- Waterfowl
- Point sources

Internal

- Sediment phosphorus release under oxic and anoxic conditions

4.2 Methodology

Watershed Loading

Watershed based nutrient loading is often times the largest contributor of nutrients and sediments to the receiving waterbody. The watershed area and land use types in conjunction with the soils and slopes which comprise the watershed are all prime determinants of the magnitude of nutrient loading to a lake system. For the purpose of calculating the watershed based nutrient load Princeton Hydro utilized the Unit Areal Loading (UAL) approach. The UAL approach is the recommended pollutant modeling technique as per 40 CFR Part 35, Appendix A, the USEPA's "Guidance for Diagnostic-Feasibility Studies." This modeling approach is widely used by both USEPA and NYSDEC, and Princeton Hydro has applied it to compute the nutrient and sediment loads for well over 200 lakes and reservoirs located throughout the mid-Atlantic and New England states. The unit areal loading modeling approach is based on the premise that land use activities throughout a watershed have a direct impact on nutrient release and transport to a receiving waterbody. Essentially, those land uses which are disturbed (e.g. urban, commercial, and agricultural lands) serve to transport more pollutants to a receiving waterbody than those which are undisturbed (e.g. forest and wetlands). For the application of this model Princeton Hydro first utilized topography data provided by the New York State GIS Clearinghouse to delineate the watershed boundary of Crooked Lake. Following this delineation land use / land cover data was clipped to this boundary. This data was subsequently reviewed for accuracy utilizing recent aerial photography and reclassified. This information was then utilized as the basis for the selection of pollutant export coefficients, in the units of (Kilogram of pollutant / Hectare / Year), which were most suitable for the watershed given prevailing soils, slopes, geology, and climatic conditions. Sources of export coefficients chosen for the Crooked Lake watershed were derived primarily from the scientific literature which included but was not limited to those published by Reckhow, 1980 and Uttomark et al, 1974.

Septic

Septic systems serve as the primary method for treating human wastes in the Crooked Lake watershed. Even when the systems are fully operational in their primary function they may contribute phosphorus to the nearby lake. Loading may be attributable to many factors including poor siting as a result of low depth to bedrock, poor soil infiltration or high seasonal water table. In addition, many lakeside houses and septic systems that were originally designed for seasonal use transition into full-time residences and are not properly sized and maintained for this increase in use. For the determination of septic system phosphorus loads to the lake Princeton Hydro first calculated the number of residences within the zone of influence of the lake. For this study, the zone of influence represents those systems within 100 m (330 ft.) of the lake or other waterways per recommendations from the USEPA. Following this determination, Princeton Hydro utilized census data to determine the population served by these systems. Upon this determination, Princeton Hydro applied the phosphorus export coefficient of 0.165 kg/capita/yr to these systems. This export coefficient was developed by Princeton Hydro utilizing empirical septic leachate data on Greenwood Lake (NY/NJ). Nitrogen loading from septic systems was not modeled for this study.

Waterfowl

Crooked Lake provided Princeton Hydro with estimates of wintering Canada Goose (*Branta canadensis*) populations on the lake. Their population estimates were approximately 1,000 geese roosting for a period of 12-hours per day from October through December. To compute the pollutant load derived from these waterfowl Princeton Hydro utilized population data in concert with a phosphorus loading coefficient of

0.49 grams of P/animal/day derived from Manny et. al (1975) to determine the annual P load derived from roosting waterfowl over a 12-hour period per day from October through December.

Atmospheric Deposition

The final modeled external input of nutrients and sediments to the lake was that of the atmosphere. Sediments and their bound nutrients may be precipitated as dryfall (dust) or through stripping during rainfall or snow events. While generally recognized as a small source of loading to many waterbodies atmospheric loading may play a critical role in large lakes or in those waterbodies with small watersheds.

This load was calculated using empirically derived loading coefficients (Schueler, 1992, Uttormark, et al. 1974, USEPA 1980 and Owe, et al. 1982) of phosphorus, nitrogen and sediment sources during dryfall and wetfall (rain / snow).

Internal Loading Assessment

A critical component in the development of this WIP was the assessment of the internal phosphorus load for Crooked Lake. Kettle lakes in this region, formed by glacial retreat, are generally categorized by relatively deep depths and relatively small watershed areas. These morphometric characteristics, combined with eutrophication resultant from developed watersheds, may lead to deep water anoxia (no oxygen). When this occurs, phosphorus, which is typically chemically bound to iron in the lake sediments, becomes released to the overlying water whereby it becomes accessible to algae for growth.

Internal loading assessment for Crooked Lake was determined through an evaluation of historical data collected through the Citizens Statewide Lake Assessment Program (CSLAP) program including temperature and dissolved oxygen stratification patterns and surface and deep-water total phosphorus concentrations. This data was supplemented through sampling conducted by Princeton Hydro in July 2017. During a single event, Princeton Hydro collected *in-situ* temperature, specific conductance, pH and dissolved oxygen data in profile throughout the water column at the deepest portion of the lake. In addition, samples were collected for total phosphorus and soluble reactive phosphorus in the surface and deep waters of the lake (Section 3). This data was utilized in concert with bathymetric data provided by the NYSDEC to determine the temporal and spatial extent of internal loading in Crooked Lake. Finally, this information was utilized to help determine export coefficients from the scientific literature for internal phosphorus loading rates under oxic (with oxygen) and anoxic (no oxygen) conditions. The internal loading period was estimated at a total of 120 days per year, 45 of these days were under anoxic conditions while the remainder were under oxic loading. These rates were then applied to Crooked Lake to determine the annual internal phosphorus load.

Point Source

There is a single point source discharge with available data located in the Crooked Lake watershed. This point source is the Song Mountain Ski Resort located at 42.77383°N, -76.17544°W. Pollutant loading data for total phosphorus, total suspended solids, and total Kjeldahl nitrogen was available for 2013 to 2017 from the USEPA Enforcement and Compliance History Online (ECHO) database. For this study, Princeton Hydro calculated the mean annual load for 2013 through 2016 and applied this load to the overall nutrient budget.

4.3 Results

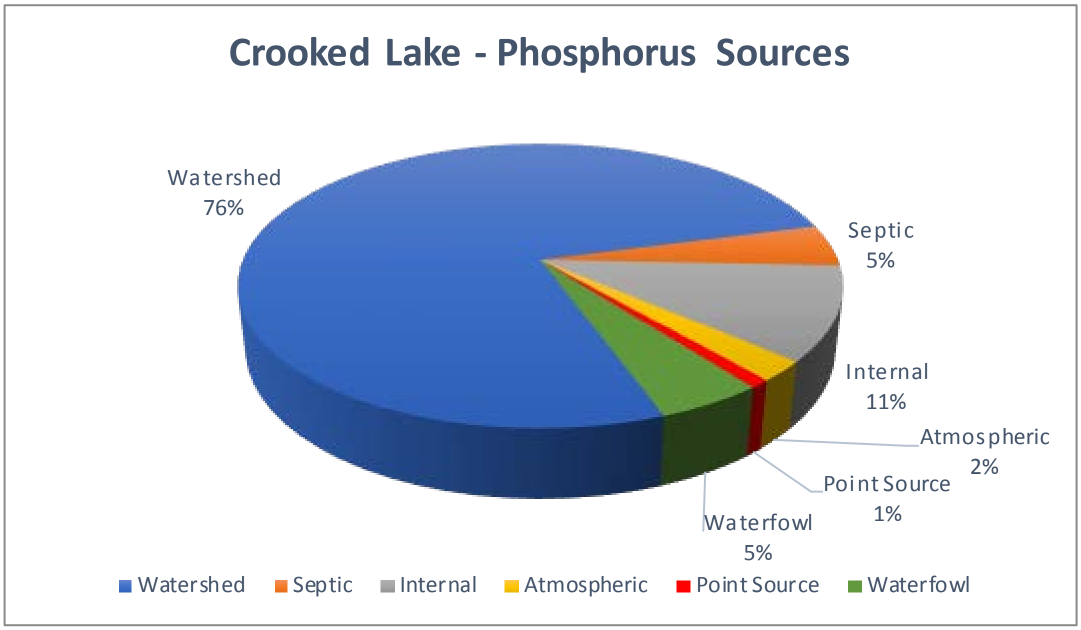
Summary results for nutrient loading to the lake are presented in table 4.1.

Table 4.1: Crooked Lake Pollutant Loading Summary

Crooked Lake - Nutrient Loading Summary							
	Watershed	Septic	Internal	Atmospheric	Point Source	Waterfowl	Sum
TN (kg/yr)	7,567	n/a	n/a	429	20	n/a	8,016
TP (kg/yr)	356	22	50	11	4	23	466
TSS (kg/yr	398,577	n/a	n/a	300	26	n/a	398,904

On an annual basis, 8,016 kg (17,672 lbs) of nitrogen, 466 kg (1,027 lbs) of phosphorus and 398,904 kg (879,433 lbs) of sediments are transported to Crooked Lake. A breakdown of the sources of phosphorus to Crooked Lake are hereby presented in figures 4.1 and 4.2.

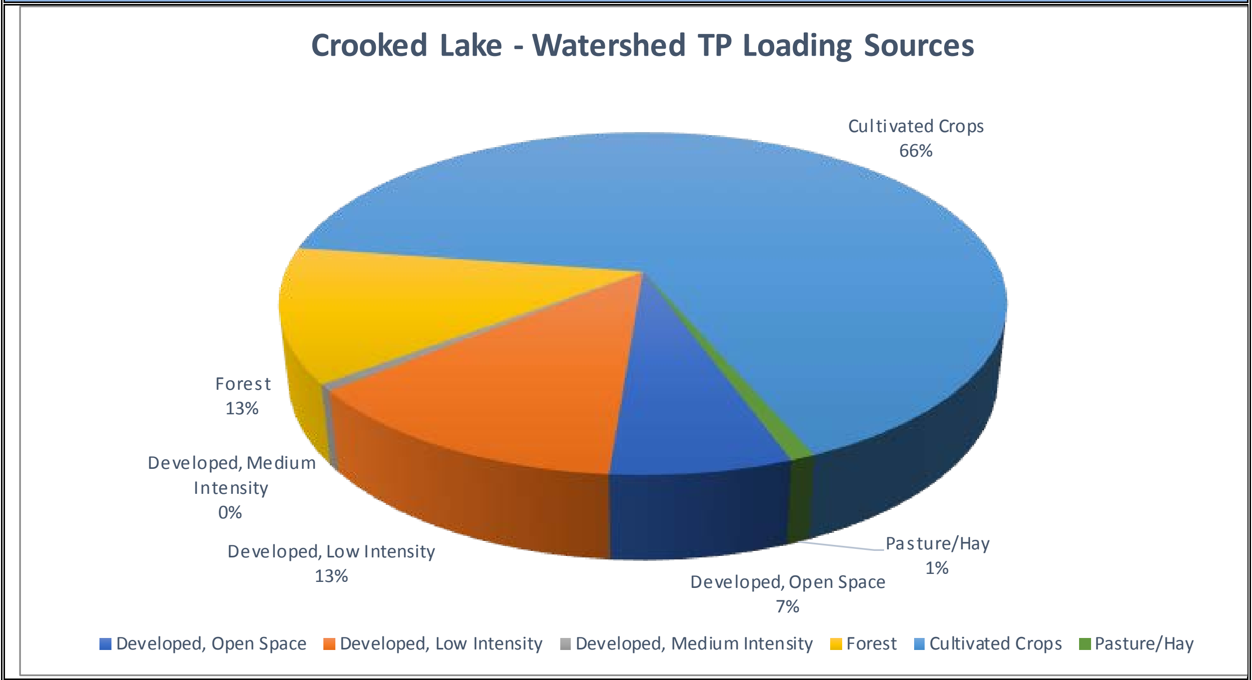
Figure 4.1: Crooked Lake TP Sources



The primary source of phosphors loading to Crooked Lake is derived by external, watershed based sources which contribute 76% to the annual phosphorus budget. Internal loading accounts for 11% of the annual load while septic systems and waterfowl each contribute 5% towards the annual phosphorus load.

Watershed sources of total phosphorus are broken down according to land use area in figure 4.2. Agriculture represents the primary land derived phosphorus source with cultivated crops and pasture / hay contributing 67% of the watershed based load. Developed land is the second greatest source with 20% of the load. Of this, residential loading, described as 'Developed, Low Intensity' comprises 13% of the load while the ski area, described as 'Developed, Open Space' comprises 7% of the load. Forested land contributes 13% of the watershed based load. Please note, open water and wetlands are also present in the watershed and represent a phosphorus attenuation of 8 kg/TP/yr.

Figure 4.2: Crooked Lake – Watershed TP Source



Watershed based BMPs will need to focus on phosphorus derived from both agriculture and residential land use. While residential ('Developed, Low Intensity'), and associated septic systems are lower contributors than agriculture, this source is the closest in proximity to the lake proper and may have pronounced, acute impacts on lake water quality. The following section will detail the results of a watershed walk conducted by Princeton Hydro in May 2017. Please note, this section is not an exhaustive survey of the watershed. Specifically, many areas, such as agricultural lands, that are on private land or are otherwise inaccessible are excluded from this report but will very likely need managed to reach nutrient reduction goals. This section will provide examples of watershed issues which could benefit from better management and provide information on approximate costs, nutrient reduction and maintenance opportunities for each section.

5.0 Watershed Disturbance and Best Management Practices

In anthropogenically altered watersheds, land use practices have been changed in ways that consequently alter the hydrologic cycle and increase pollutant loading to a lake. For this document, the term 'pollutant,' refers primarily to phosphorus, nitrogen and sediment but may also include salts, heavy metals or pesticides. Some of these pollutants are contributed directly to a lake, but, more commonly, these pollutants are derived from diffuse 'non-point sources.' Non-point source pollution is a term which relates to the contribution of sediments, phosphorus and nitrogen to waterways through land and stream bank erosion, stormwater and septic.

The watersheds of the Kettle Lakes were historically dominated by forest and wetlands. With development came the clearing of forests and modification of wetlands, either through infilling, draining or flow alteration. The current land use of the Crooked Lake watershed is comprised of a mixture of these forests and wetlands but also the human dominated land uses of residential housing, agriculture and transportation infrastructure. The anthropogenic land use changes reduced vegetative cover, exposed soils, increased impervious areas and introduced pollutants through fertilizers, road salts and byproducts of human materials. These changes ultimately lead to a marked change in the hydrology of the watershed in such a way that infiltration and groundwater recharge was likely reduced while the volume and rate of stormwater based surface discharge increased. Ultimately, this change in stormwater leads to stream channel downcutting, widening and bank instability leading to instream erosion. This geomorphic change results in a disconnect between streams and their floodplains and results in increased sediment and nutrient loading to lakes.

To mitigate non-point source pollution, we look to implement watershed best management practices. Watershed best management practices focus on structures, retrofits and even behaviors that may help reduce pollution to a waterway. Princeton Hydro focuses primarily on the selection and utilization of best management practices which fit in with Green Infrastructure. Green Infrastructure is a water management approach that seeks to mimic the natural environment and associated natural processes. These processes include sedimentation, filtration / flow resistance, bio-uptake, recharge, decomposition and bioretainment. Many of the structures or techniques listed below aim to utilize soils and vegetation to mimic these processes found in nature. In doing so, these techniques may serve to not only reduce nutrients to a lake but also serve as habitat for aquatic and terrestrial organisms in an increasingly fragmented landscape.

The following section details the results of a watershed walk conducted over a half-day in May 2017 by Princeton Hydro and various stakeholders including members of Syracuse University, C-OFOKLA, local residents and members of Cortland County Soil and Water Conservation District. This walk aimed to photo-document areas of non-point source pollution which may benefit from the inclusion of best management practices. This summary is not an exhaustive survey of watershed conditions or BMP recommendations but provides specific examples of areas that can be improved. Furthermore, prior to the implementation of any BMP there will likely be additional, site specific, information needed such as: Utility, topographic and/or transportation surveys, stormwater engineering calculations, property ownership assessment, geologic or soil assessments, local, state and/or federal permits, etc.

Recommendation of BMP types are included along with rough estimates for costs and pollutant removal. Costs are based on similar projects conducted by Princeton Hydro but are very site specific upon a myriad of factors. Pollutant removal was computed based on removal estimates provided by various BMP manuals including those issued by the States of New York and Pennsylvania. A summary of the types of maintenance associated with each BMP is also listed. Finally, recommendations on the priority of each BMP are listed as 'low', 'medium', and 'high.' These priorities are based on several factors including overall cost, ease of installation, permitting requirements, the need for cooperation from various government entities and pollutant removal. In general, those projects which may be easily implemented with minimal permitting and cost while providing ecological and pollutant removal benefits are rated as 'High.' This is particularly the case for those sites which occur on public property. Sites of high cost, extensive permitting or those on private property may be more difficult to implement and are therefore given a lower rating.

A summary of recommended BMPs is presented first (table 5.1) followed by a breakdown of each site. A figure showing the location of each BMP is presented in Appendix I. Please note, estimated BMP costs are for material and implementation but do not include any necessary engineering or associated permitting.

Table 5.1: Crooked Lake - Watershed BMP Summary

Site	BMP	Estimated Cost ($)	Pollutants Removed (kg/yr)			Priority
			TSS	TP	TN	
1	Storage	$10,000 - $15,000	Variable	Variable	Variable	High
1	Silt Fence	$1.20/ft	Variable	Variable	Variable	High
2a	Riparian	$1,750/ac	180	0.3	1.4	Medium
2a	Bioswale, or	$35,000	450	0.32	1.1	High
2a	3-chambered baffle box	$50,000 - $200,000	375	0.15	1.4	Low
2a	Streambank Stabilization	$45,000	450	0.32	1.1	High
2b	Forebay	$75,000 - $100,000	100,000	75	750	Medium
3	Shoreline Buffer	$5,000 - $10,000/lot	400	0.3	1.0	High
4	Riparian Buffer	$1,750/ac	400	0.3	1.0	High
4	Culvert Replacement	$35,000 - $75,000	Variable	Variable	Variable	Low

Site 1: Song Mountain – Storage Area

Figure 5.1: Song Mountain Erosion

Site Location and Description: *42.77425°N, 76.15573°W* - Gravel storage mound at the base of Song Mountain

Issues: Improper storage and erosion control leading to stormwater runoff with incised gullies.

BMP Recommendation: Ideally, material storage areas should consist of a structure which covers building materials, road salts etc. If a structure cannot be erected, reinforced silt fence should be implemented. If possible, sheet flow should be directed towards a vegetated area for energy dissipation.

Cost: Temporary fabric storage containers can be purchased and installed for approximately $10,000 - $15,000. A benefit to such structures is that they can be moved and utilized in other areas as needs change. The cost for reinforced silt fence is approximately $1.20 per foot.

Pollutant Removal: variable

Maintenance: Check on silt fence after runoff events and remove accumulated sediments when they reach half the height of the fence.

Priority: High

Examples of the recommended BMPs are provided below.

Figure 5.2: Example of Outdoor Storage Container

Figure 5.3: Example of Reinforced Silt Fence

Site 2a: Song Mountain – Inlet stream to detention basin

Site Location and Description: *42.77499°N, 76.15915°W* – Inlet stream passing next to equipment maintenance area and roadway to extended detention basin

Issues: Lack of riparian buffer, large gravel lot, disconnection of stream from floodplain

BMP Recommendation: Install riparian buffer along stream – Ideally the riparian buffer should be 200' in width with a minimum width of 50-100'. Direct flow from maintenance area to manufactured treatment device for sediment removal or to vegetated swale prior to entering stream. Utilization of MTD will require additional stormwater infrastructure (i.e. piping) since none is currently in place. Stabilize 150 linear feet of stream prior to road crossing.

Cost: *Riparian buffer* - approximately $1,750 per acre for plants, materials and labor. *Maintenance Area MTD (3 chambered baffle box) - $50,000* - $200,000, *Maintenance Area Bioswale* - $35,000. *Stream Stabilization* – $45,000.

Pollutant Removal: *Riparian buffer* – TSS 180 kg/yr, TP 0.3 kg/yr, TN 1.4 kg/yr. *Three-chambered baffle box* – TSS 375 kg/yr, TP 0.15 kg/yr, TN 1.4 kg/yr. *Bioswale* – TSS 450 kg/yr, TP 0.32 kg/yr, TN 1.1 kg/yr. *Stream stabilization* – TSS 450 kg/yr, TP 0.32 kg/yr, TN 1.1 kg/yr

Maintenance: *Riparian buffer* – Remove invasives and replant any dead natives annually. *MTD* – check for and remove sediment routinely. *Bioswale* – Check for and remove invasives annually. Check for a remove sediment build up routinely. *Stream Stabilization* – Check for integrity twice a year.

Priority: Low to High (See table 5.1)

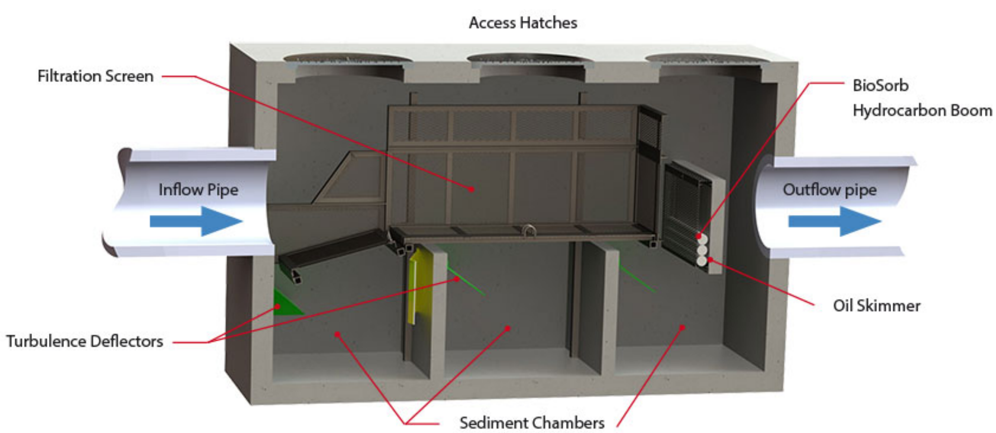
Examples of the recommended BMPs are provided below.

Figure 5.4: Song Mountain Erosion

Figure 5.5: Riparian Buffer

Source: PACD

Figure 5.6: Three-Chambered Baffle Box



Source: Suntree Technologies

Figure 5.7: Streambank Stabilization - Before
 Source: Princeton Hydro
Figure 5.8: Streambank Stabilization - After
 Source: Princeton Hydro

Site 2b: Song Mountain – Detention Basin

Site Location and Description: *42.77499°N, 76.15915°W* – Detention basin utilized for water withdraw

Issues: Scour from upgradient stream and roadside transporting sediment to pond. Mitigate upstream erosion (site 2a) and construct forebay to capture and remove sediments.

BMP Recommendation: Constructed forebay

Cost: approximately $75,000 - $100,000

Maintenance: Remove sediment from forebay every five to six years, or after 50% loss of capacity.

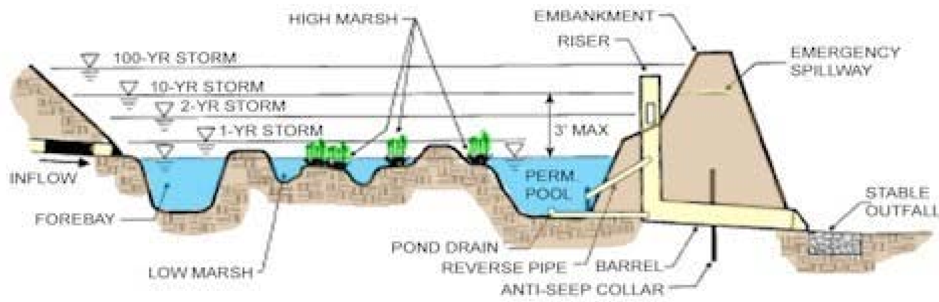
Pollutant Removal: TSS 100,000 kg/yr, TP 75 kg/yr, TN 750 kg/yr. *Pollutant removal estimates based off of wet pond, less 50% due to steep slopes. Actual removals will be highly variable.*

Priority: Medium

Examples of the recommended BMPs are provided below.

Figure 5.9: Crooked Lake - Song Mountain Erosion

Figure 5.10: Example of Constructed Forebay in Extended Detention Basin



Source: Pennsylvania Department of Environmental Protection

Site 3: Crooked Lake Shoreline

Site Location and Description: *42.786851°N, 76.153338°W* and various points along shoreline – Opportunities for lake buffer creation

Issues: Turf grass to lake shore provides no filtering of pollutants and sediments and is prone to erosion from wind and waves

BMP Recommendation: Create lake shore buffer with native plants

Cost: Estimated cost approximately $5,000 - $10,000 per lot

Pollutant Removal: TSS 400 kg/yr, TP 0.3 kg/yr, TN 1.0 kg/yr

Maintenance: Check and remove invasive species, check and replace any dead plants

Priority: High

Examples of the recommended BMPs are provided below.

Figure 5.11: Crooked Lake – Examples of Shoreline Buffer Opportunities

Figure 5.12: Example of Lakeshore Buffer Conversion

Source: Mr. Josue Cruz

Site 4a: Northwest Stream

Site Location and Description: *42.79279°N, 76.15470°W* Stream with poor buffer and perched culvert. *Similar conditions noted at 42.77596°N / 76.15459°W (4b - Song Lake Road) and N42.77692° W76.15348° (4c- Lake Road)*

Issues: Inadequate riparian buffer width on stream between agricultural and residential land use. Perched culvert leading to plunge pool and stream scour increasing sediment transport. Perched culvert a barrier to fish passage.

BMP Recommendation: Establish 475 feet of riparian buffer along stream. Reconstruct road crossing with open bottom design culvert or similar.

Cost: *Riparian buffer* - $1,750 / ac. *Culvert Replacement and Stream Restoration* - $35,000 - $75,000

Pollutant Removal: *Riparian Buffer* - TSS 400 kg/yr, TP 0.3 kg/yr, TN 1.0 kg/yr

Maintenance: *Riparian Buffer* - Check and remove invasive species, check and replace any dead plants. *Culvert / Stream Restoration* – Check integrity twice a year or after significant storm events.

Priority: Low to High (see table 5.1)

Examples of the recommended BMPs are provided below.

Figure 5.13: Crooked Lake – Stream with Perched Culvert and Inadequate Riparian Buffer

Figure 5.14: Perched Culvert – Before and After

Horseshoe Brook

Before (October 2012) After (July 2013)

Source: Trout Unlimited

Septic Management

Much of the residential land surrounding Crooked Lake utilizes septic systems for treatment of human wastes. The soils, slopes and water table surrounding the lake make on-site wastewater treatment a critical issue for the health of the lake relative to phosphorus loading. Review of the Septic Tank Absorption Field ratings derived from the National Resources Conservation Service show the soils surrounding the lake to range from 'somewhat limited' to 'very limited' in their ability to adequately treat wastes. The estimated total phosphorus load derived from septic systems is 5% of the total load. While a small percentage, the proximity of the systems to the lake impart a higher importance on septic maintenance.

At a minimum, septic tanks should be pumped out every three years. Maintaining this pumpout schedule may reduce phosphorus loading from this source by 20 - 30% (Day, 2001). In addition, water conservation measures should be implemented at each residence. Lowering the burden on the septic system will allow for reduced nutrient transport to shallow groundwater, and ultimately, Crooked Lake.

Incentivizing the maintenance of septic systems through providing monetary benefits for completing pumpout or maintenance, or through providing reduced costs for these services, has been implemented successfully locally through the Song Lake Property Owners Association. Similar programs should be implemented on a municipal level to encourage all residents to keep their systems up to date and in good working order.

Finally, the type and age of septic systems may play a significant role in their functionality and contribution of nutrients to the watershed. This study merely looked at the presence of such systems without conducting a detailed assessment of whether systems need upgraded or replaced. Princeton Hydro recommends implementing such a study with backing by the local municipality and C-OFOKLA.

Lawn Fertilizers

Lawn fertilizers are often an acute source of nutrient pollution to lakes. Often, these products are applied in spring or fall and are quickly washed away during precipitation events directly into the lake where they fuel algal blooms. Currently, New York bans phosphorus fertilizers under ECL § 17-2101 et seq. This law, applicable to all persons, states the use of phosphorus fertilizers on lawns or non-agricultural turf is restricted. Only fertilizers with less than 0.67 %/w phosphate may be applied legally. Furthermore, applications between December 1 and April 1 are prohibited. An application buffer of 20 feet from a waterway or paved surface was also implemented as part of this rule.

Prior to application of any fertilizers, homeowners should have their soil tested by the local agricultural district or similar entity. This testing will provide empirical data on the amount of nutrients in the soil and need for any additional nutrients. Often times, phosphorus is present in abundance in soils and does not need additional application. Many times, the pH of the soil needs adjusted with lime thereby raising pH to a level where the phosphorus that is present in the soil becomes biologically available for turf grass. If fertilizers are needed, homeowners should look for and use phosphorus free fertilizers. Fertilizers are typically labeled with three vales (N-P-K) representing the proportion of nitrogen – phosphorus – potassium in the product. As such, look for fertilizers with a middle number of zero (e.g. 24-0-12) or a bag with 'lake friendly' on the front.

Educational campaigns about the 2012 State rule banning phosphorus fertilizer should be conducted routinely for watershed residents.

Deicers

There is considerable concern in the kettle lakes region of the impact of salts on the water quality of the lakes. Road salts (chloride) are commonly applied not only to driveways but also on state roads and interstate 81. The major issue with the application of road salts is that chloride is a conservative ion that is not readily sorbed onto mineral sources or involved in many significant biochemical reactions. As such, this ion persists in soils and ground and surface water. Ultimately, increases in chloride levels follow increases in watershed development and impervious area. These increases may alter the composition of the lake food web through changes in the invertebrate, plankton and fishery structures.

Management of road salts is a complex subject due to the human safety aspect. When possible, those who apply road salts should look into alternative deicers such as calcium magnesium acetate. Additives, such as natural beet sugars, lower the temperature of brine used to pretreat roads and has been documented in reducing overall salt use. such as Furthermore, where possible, setbacks should be established so that deicing compounds are not applied near surface water sources.

6.0 In-lake Phosphorus Management

In Crooked Lake, 11% of the annual phosphorus load is estimated to be derived from internal sediment release. This load is small relative to other sources but may provide an acute source of nutrients during the peak of the growing season. While watershed management should be the primary focus for Crooked Lake, the following provides options for controlling internal loading.

There are several ways to manage internal loading of phosphorus in lake systems. These techniques focus on the maintenance of oxygen in the hypolimnion of the lake or the 'sealing' of lake sediments through the application of chemical flocculant or inactivation products. In addition, floating wetland islands may be utilized to assimilate phosphorus from the epilimnion. While floating wetlands islands will not control internal loading, they serve as a chemical free in-lake measure to reduce the overall phosphorus load in the lake.

Aeration

Aeration for internal phosphorus control focuses on the maintenance of dissolved oxygen in the hypolimnion thereby serving to keep the redox potential at such a level as to mitigate large scale internal release of phosphorus and metals. Aeration systems for lake management typically fall under the categories of systems which disrupt thermal stratification, such as submerged diffuser systems, or systems which keep stratification in place, such as hypolimnetic aeration systems. Typically, the latter is utilized when there is the desire to maintain cold-water fishery habitat while destratification systems are commonly utilized in relatively shallow lakes.

For Crooked Lake, a hypolimnetic aeration unit, or similar, would likely be the desired type of unit. Additional, full year monitoring would be necessary to accurately characterize the stratification patterns, carbon demand and phosphorus loading rates to size and spec a system. Estimated costs for monitoring, sizing, material and installation are significant and would be upwards of $150,000 not including annual operating costs. At this time, Princeton Hydro does not recommend such a system for Crooked Lake until more extensive watershed nutrient management is completed.

Nutrient Inactivation

Nutrient inactivation in lakes occurs through the application of a chemical, typically an aluminum or lanthanum/clay based product. Typically, phosphorus is bound to iron in the sediments through a relatively weak molecular bond which is broken under anoxic conditions. In contrast, the bond between phosphorus and nutrient inactivation products is stronger and therefore is not broken, or is broken more slowly, under anoxic conditions.

The products commonly utilized in lake management for nutrient inactivation includes aluminum sulfate (alum) or alum surrogates such as polyaluminum chloride. More recently, the utilization of lanthanum modified bentonite clay based products, such as the proprietary Phoslock©, have been utilized when there are concerns about alum toxicity or regulatory restraints on the use of such products. The latter is currently the case in New York State which has placed an indefinite moratorium on the utilization of alum for lake management purposes. While Phoslock is utilized with efficacy for phosphorus 'stripping' in lakes, where P is removed from the water column, the efficacy of control of sediment released P under anoxic conditions is relatively low while costs are much higher than aluminum based products. As such, this management measure is not currently recommended for Crooked Lake. Alum, if permitted in the future by NYSDEC, could be a feasible and relatively inexpensive product for sealing the profundal sediments thereby preventing phosphorus release. The cost for such an application, including monitoring, permitting, application and follow up monitoring would likely range between $75,000 to $125,000. Typically, internal load control using alum has an effective lifespan of approximately 5 to 7 years.

Floating Wetland Islands

Floating wetland islands (FWIs) are a relatively new technique in lake management that uses biomimicry to assimilate and process nutrients that would otherwise stimulate algal growth. FWIs are structures composed of woven, recycled plastic material. Vegetation is planted directly in the plastic matrix of the islands with peat and then these structures are deployed in the lake. Once positioned, these units are anchored, typically with rope and cinder blocks. The vegetation grows on the FWIs with their roots growing down through the plastic matrix into the lake. The combination of the root structure and plastic matrix relates to a very high surface area which subsequently serves as habitat for bacteria and biofilm. It is estimated that one 250 ft^2 island has a surface area equal to approximately one acre of natural wetland. Once installed, the FWI serves as a nutrient sink whereby the plants and microbial community associated with the root mass and plastic matrix assimilate phosphorus. In turn, a portion of this phosphorus may be incorporated up the food chain and transported out of the lake system. Diverting this phosphorus reduces the amount of phosphorus which may be assimilated by harmful algae. Studies by Princeton Hydro have shown that one (1) 250 ft^2 island has the potential to sequester up to 10 lbs of phosphorus per year. Given that each pound of phosphorus has the potential to produce up to 1,100 lbs of algae per year, each island has the potential to mitigate 11,000 lbs of wet algae biomass annually.

Floating wetland islands are less costly than the measures mentioned above but do not directly address internal loading. Instead, they remove phosphorus from the epilimnion during the growing season. The cost for a single 250 ft^2 island, including plants and installation, is roughly $10,000. Approximately five (5) islands would be recommended for Crooked Lake to be placed in shallow areas that are known to receive storm inflow. These units would be installed in conjunction with a holistic watershed / in-lake management plan and as such are viewed as a piece of an overall management approach.

Harvesting

Macrophyte harvesting is currently conducted on Tully Lake and Little York Lake. In addition to removing nuisance densities of aquatic plants, harvesting has the added benefit of removing the nutrients contained within the plant biomass. For example, Princeton Hydro quantified the phosphorus concentration in SAV at Lake Hopatcong in New Jersey. The mean P concentration in this wet SAV biomass was 2,216 mg/kg. Plant removal from Tully and Little York Lake was estimated at approximately 100 tons wet weight thereby resulting in a removal of approximately 200 kg of P per year. Princeton Hydro recommends the possible expansion of harvesting to Crooked Lake to minimize issues with nuisance plants and to help remove P from the lake.

7.0 Summary

Princeton Hydro, along with project partners, conducted a miniature watershed implementation plan for Crooked Lake. This plan aimed to characterize the water quality and pollutant load to the lake and to identify areas in the watershed that may be contributing nutrients to the waterbody that could benefit from best management practices. Ultimately, this plan may be integrated into a full-scale watershed implementation plan or lake management plan to contribute towards the restoration of the lake. In addition, this plan may serve as a jump-off point for securing funding for the projects identified herein.

Phosphorus loading to Crooked Lake was estimated to occur primarily from the watershed which contributes 76% of the P load followed by internal loading (11%) and septic systems/waterfowl (5% each). Of the watershed sources, agriculture was deemed the primary contributor followed by developed lands and associated septic systems. Watershed BMPs will need to focus on controlling nutrient loading from both agriculture and developed land to reduce phosphorus loading to the lake. The internal phosphorus load to the lake is relatively minor compared to that of the watershed load but is pronounced in that it occurs during the growing season. At this time, large scale measures to control internal P, such as alum or an aeration system, should not be conducted until the external nutrient load is brought under control. Smaller scale measures, such as floating wetland islands, may be implemented at any time.

Princeton Hydro recommends the adoption of this plan by the town of Tully. The successful implementation of this, and any, watershed plan is contingent on the cooperation of multiple stakeholders of varied interests. Finally, Princeton Hydro would like to thank the local residents, C-OFOKLA, Syracuse University and the Cortland County Soil and Water Conservation District for all of their input, help and support during this project.

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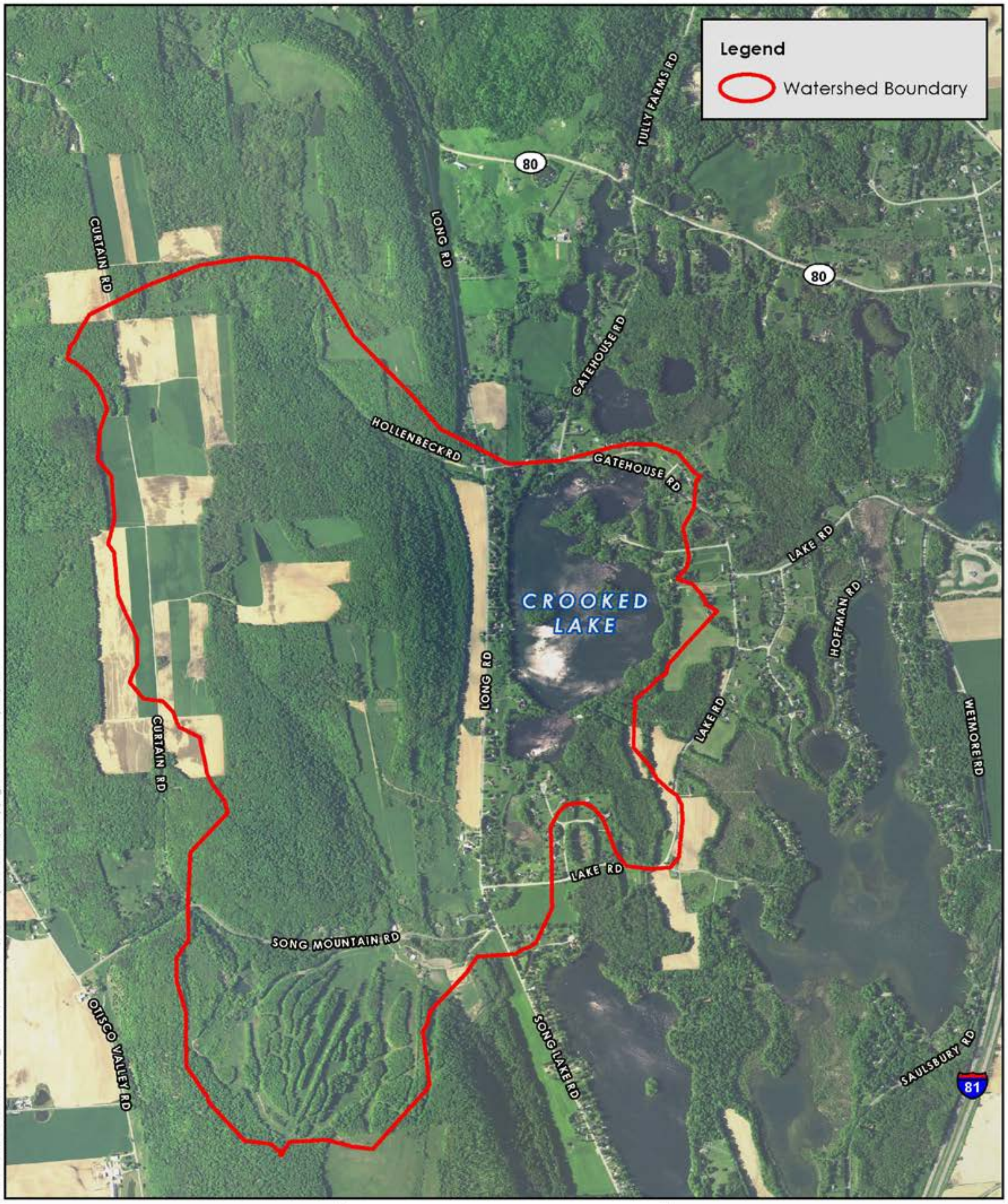
Appendix I



CROOKED LAKE WATERSHED

CROOKED LAKE
WATERSHED IMPLEMENTATION PLAN
TOWN OF TULLY
ONONDAGA COUNTY, NEW YORK

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. 2015 Cortland county orthophotography obtained from the National Agriculture Imagery Program (NAIP).

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Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet

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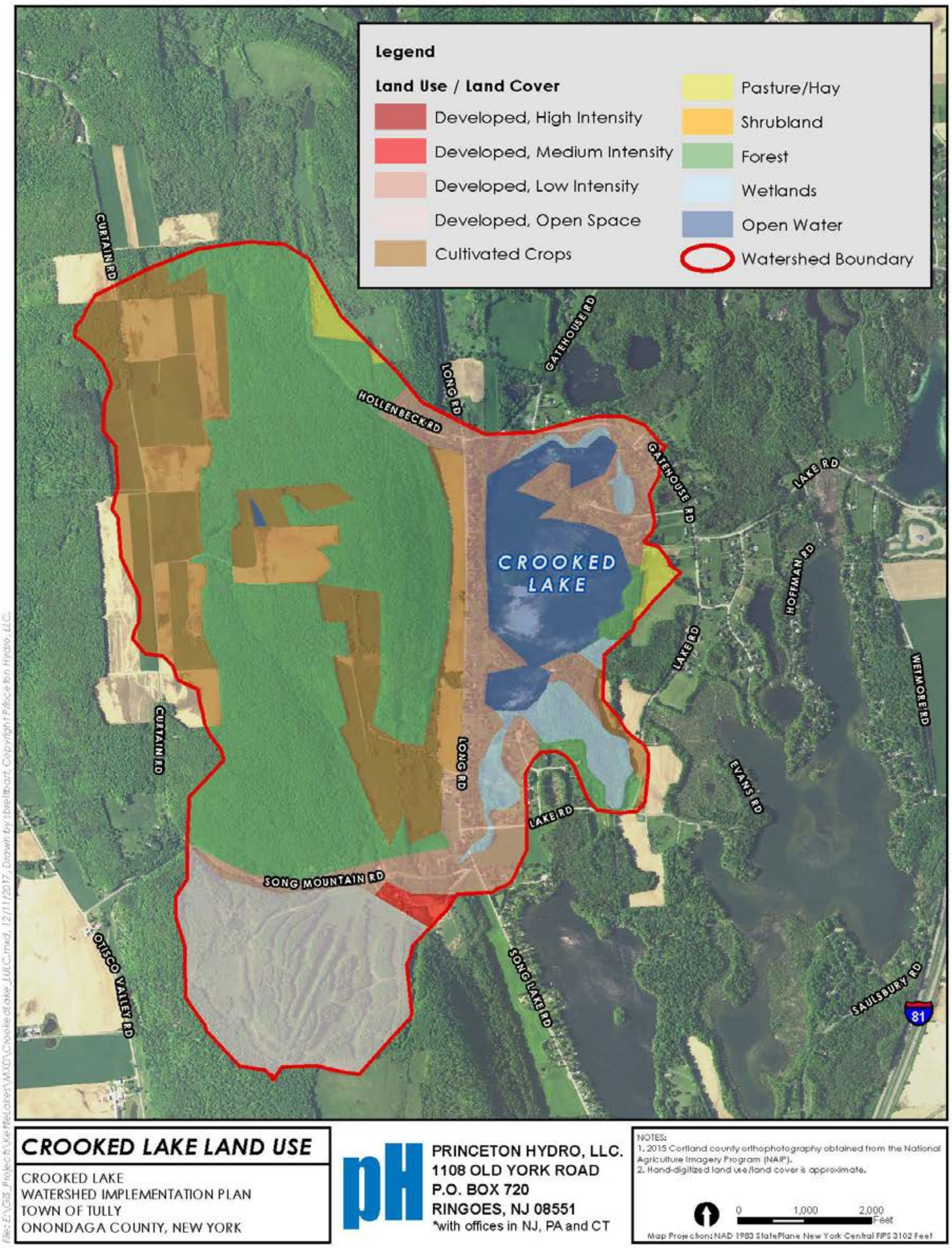
Legend
Land Use / Land Cover
Developed, High Intensity
Developed, Medium Intensity
Developed, Low Intensity
Developed, Open Space
Cultivated Crops
Pasture/Hay
Shrubland
Forest
Wetlands
Open Water
Watershed Boundary
CROOKED LAKE
CURTAIN RD
HOLLENBECK RD
LONG RD
GATEHOUSE RD
LAKE RD
HOFFMAN RD
WETMORE RD
EVANS RD
SONG MOUNTAIN RD
SONG LAKE RD
OTISCO VALLEY RD
SAULSBURY RD
81
CROOKED LAKE LAND USE
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WATERSHED IMPLEMENTATION PLAN
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2. Hand-digitized land use/land cover is approximate.
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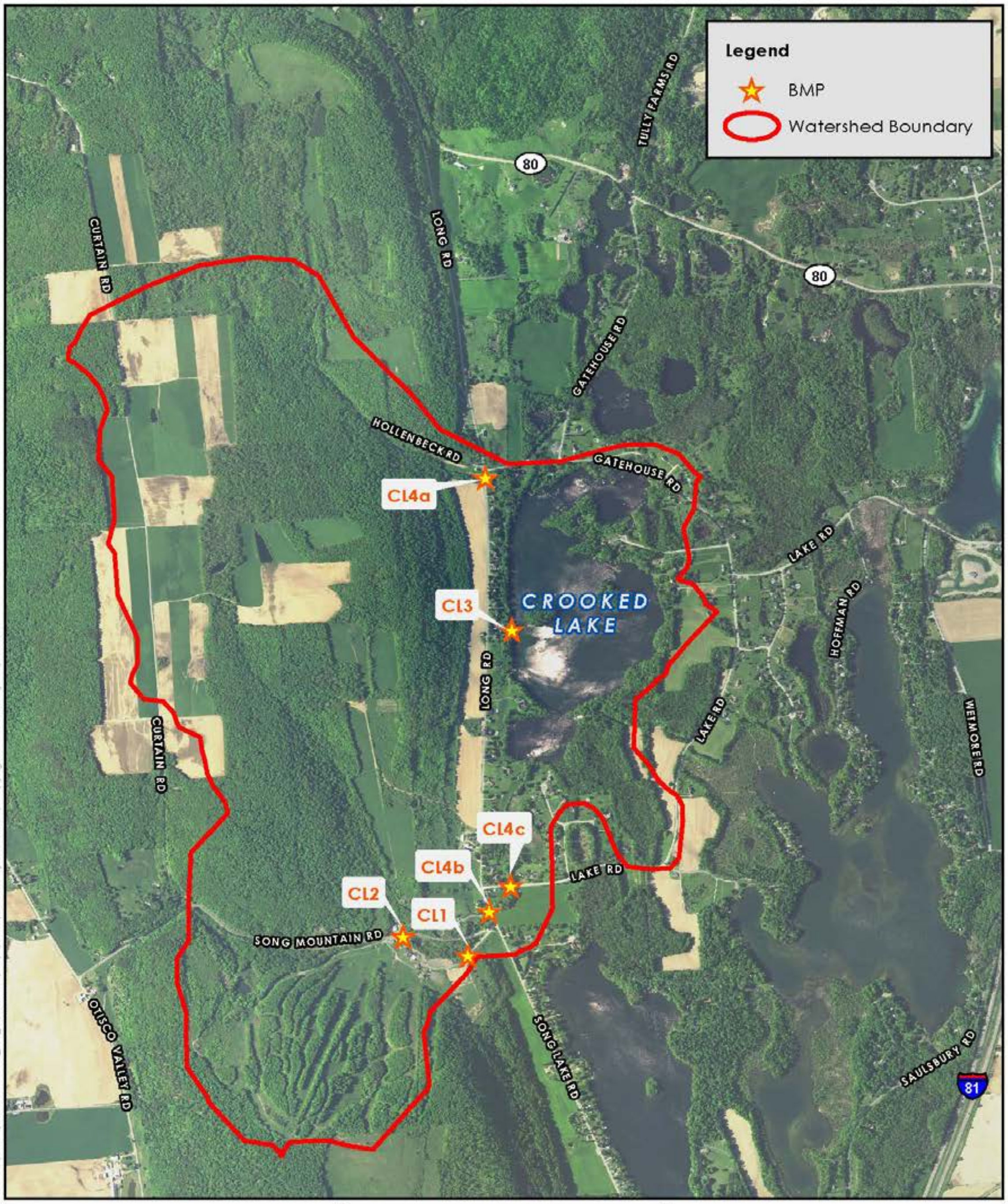
Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet



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CROOKED LAKE BMPS

CROOKED LAKE
WATERSHED IMPLEMENTATION PLAN
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Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet

Little York Lake
Watershed Implementation Plan
Town of Preble, Cortland County, New York

Prepared for:

Cortland-Onondaga Federation of Kettle Lake Associations
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Contents

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1.0 Introduction

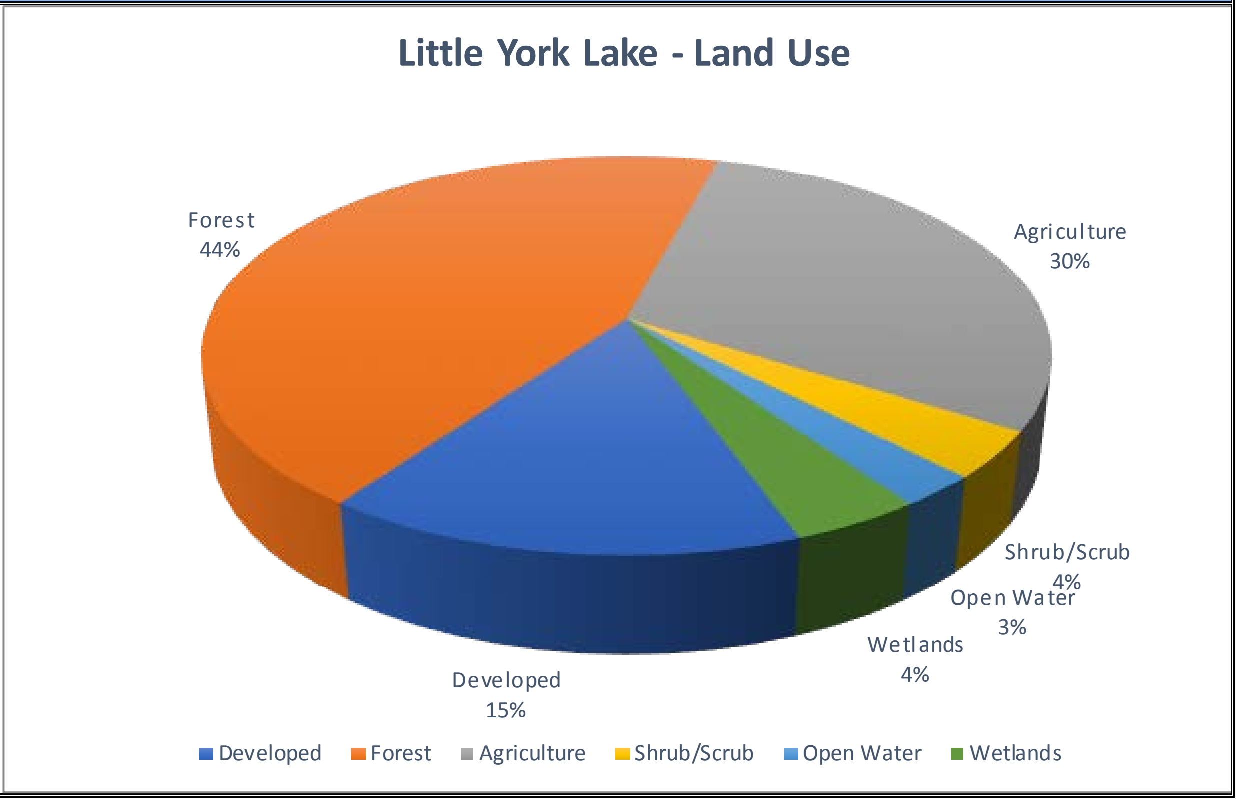
Little York Lake, located in the town of Preble, Cortland County, New York, is part of a kettle lake system. Historically, this lake has suffered from symptoms of eutrophication such as elevated phosphorus concentrations, lack of oxygen (anoxia), algal blooms and dense aquatic vegetation. Furthermore, this lake has suffered from invasions of aquatic invasive species including zebra mussel (*Dreissena polymorpha*) and Eurasian watermilfoil (*Myriophyllum spicatum*). As part of this project, Princeton Hydro, in concert with the Cortland-Onondaga Federation of Kettle Lake Associations (C-OFKLA), Cortland County Soil and Water Conservation District and the Syracuse University Environmental Finance Center, has prepared small-scale Watershed Implementation Plans for Little York Lake, Tully Lake, Song Lake and Crooked Lake. Each plan is comprised of several inter-related components aimed to characterize the water quality of the lake, assess the external and internal phosphorus load, characterize the land use of the watershed and areas where best management practices (BMPs) may be implemented, and to correlate reductions in nutrient loading from each BMP into the nutrient budget for each lake. This plan is considered 'small-scale' given that only a single water quality sampling event was conducted and only ½ day was available to survey the watershed for areas which may benefit from BMPs. As such, this plan does not constitute an extensive lake and watershed management plan. Ultimately, this document may be utilized to seek funding sources to implement the projects contained herein and may be utilized in a larger context for lake management.

2.0 Lake and Watershed Characteristics

Little York Lake is a 41 ha (101 ac) kettle lake located in Cortland county, New York. The lake has a mean depth of 3.5 m (11.5 ft) and a deep maximum depth of approximately 23 m (75 ft) located in the northern basin of the lake. The shape of Little York lake is irregular leading to a shoreline of 3.4 km (2.1 mi) resulting in a shoreline development index (SDI) of 1.44. The shoreline development index is a unitless figure which relates the length of shoreline to the circumference of a perfectly circular lake of the same area. Many kettle and volcanic cirque lakes have smaller indices while larger index values are associated with the potential for higher development pressure and nutrient loading to a lake. For comparison, the SDI of Song and Tully Lakes are 1.46 and 2.66, respectively. The watershed of Little York Lake (Appendix I, Figure 1) encompasses 7,809 ha (19,296 ac) resulting in a watershed to lake ratio of 191:1. This ratio is, by far, the highest of the four kettle lakes investigated for this project. For comparison, the watershed ratios of Song, Tully and Crooked lakes are 9:1, 29:1 and 14:1, respectively. Typically, watershed to lake ratio values greater than 6 are indicative of a lake which is susceptible to higher levels of nutrient and sediment loading from the watershed.

Watershed land use categories are displayed graphically in Appendix I, Figure 2 and broken down by category in figure 2.1.

Figure 2.1: Little York Lake – Watershed Land Use



Forest represents the dominant land use in the watershed with a coverage of 3,459 ha (8,548 ac) located predominantly the northern, western and eastern ridges. Agriculture represents the second most prevalent land use category, comprising 2,321 ha (5,736 ac) of the watershed while developed lands comprise the third most prevalent land use category, comprising 1,204 ha (2,975 ac).

The inflow of Little York lake is derived from the west branch of the Tioughnioga River and groundwater. Outflow from Little York Lake continues the west branch of the Tioughnioga River for approximately eight (8) miles before it joins with the east branch to form the Tioughnioga River which subsequently flows into the Susquehanna River. The hydrology of Little York Lake is drastically different than that of Song and Crooked Lakes and different in scale to that of Tully Lake given the large watershed and resultant riverine influence. This hydrologic input, combined with the unique shape and depths of Little York Lake, likely impact phosphorus retention and cycling in a different manner than that of the aforementioned lakes.

3.0 Water Quality Monitoring

3.1 Introduction and Methodology

Princeton Hydro conducted limited water quality monitoring of Little York Lake to characterize the extent of thermal stratification, dissolved oxygen depletion and internal loading of phosphorus. This monitoring was conducted during a single event on July 12, 2017. During this event, Princeton Hydro established a monitoring station at a deep portion of the lake. Maximum depth was recorded and water transparency was measured with a Secchi disc. *In-situ* data collection consisted of measuring temperature, specific conductance, dissolved oxygen, dissolved oxygen percent saturation and pH, at 1 m intervals, throughout the water column. All *in-situ* measures were made utilizing a calibrated Hach MS5 water quality meter tethered to a Hydrolab surveyor. Discrete samples were also collected approximately 0.5 m below the surface and 1 m above the sediments for the analysis of total phosphorus (TP) and soluble reactive phosphorus (SRP). Upon collection, samples were placed on ice to 4°C and forwarded under chain-of-custody procedures to Environmental Compliance Monitoring of Hillsborough, NJ for analysis. Finally, assessment of the plankton (phytoplankton and zooplankton) was conducted through the deployment of a plankton tow net throughout the water column. Upon collection, this sample was preserved with Lugol's solution and analyzed for relative abundance and community composition by Princeton Hydro. The results of this single sampling event are presented below.

3.2 Results

Little York Lake was thermally stratified at the time of sampling with temperatures ranging from 4.79°C at 22 m to 23.86°C at the surface (Z_{max} = 22.5 m). The epilimnion of Little York Lake was in the upper 2 m of the water column while the thermocline extended from 3 m to approximately 10 m. The hypolimnion extended from 10 m to lake bottom. Dissolved oxygen concentrations ranged from zero at 22 m to 10.72 mg/L (127.2%) in the surface. Anoxic conditions were recorded from 19 m to the lake bottom while hypoxic conditions were measured between 15 m and 18 m. pH values were variable throughout the water column ranging from 7.25 at 21 m to 8.27 in the surface. A positive heterograde was measured at approximately 4-5 m noted by an increase in dissolved oxygen at this depth. Transparency was excellent at the time of sampling with a Secchi disc measure of 3.6 m.

Discrete measures for phosphorus metrics in the surface waters of Little York Lake resulted in TP concentrations of 0.01 mg/L and SRP concentrations of 0.003 mg/L. TP concentrations in the deep waters of Little York Lake were non-detectable (ND < 0.01 mg/L) while SRP concentrations were 0.004 mg/L. These low concentrations were surprising given the extent of thermal stratification and anoxia measured at the time of sampling. Historical TP concentrations, as measured during CSLAP monitoring, exhibit similar patterns of low phosphorus with deep water concentrations not showing excessive variation from surface concentrations. The exception to this was on 16 July 2015 and 26 August 2015 when deep water concentrations were markedly higher than those measured in the surface (figure 3.2). Lower than expected hypolimnetic TP concentrations may be related to several variables including flushing from the West Branch Tioughnioga River and the phosphorus, iron, sulfur and calcium content of the lake sediments. Further analysis of internal loading from Little York Lake, through sediment core release experiments or similar.

The phytoplankton community at Little York Lake was comprised of relatively low densities of cyanobacteria, chlorophytes, diatoms, chrysophytes and dinoflagellates. Co-dominance in the community was exerted between the dinoflagellate *Ceratium* and the chrysophyte *Chrysophaerella* with both listed as 'common.' The zooplankton community was dominated by the copepod *Cyclops* with lower densities of copepod nauplii and various cladocerans and rotifers.

The plankton community at the beach station showed relatively low algal densities with the community dominated by the diatoms *Fragilaria* and *Synedra*. No cyanobacteria were identified at the beach at the time of sampling. The only zooplankter identified at the beach was the copepod *Cyclops.*

Table 3.1: Little York Lake – *In-situ* Data

Kettle Lakes *in-situ* 7/12/17								
Station	Max	Secchi	Depth	Temp	SpC	DO	DO %	pH
	(m)	(m)	(m)	(C)	(mS/cm)	mg/L	(%)	(units)
Little York	22.5	3.6	0.1	23.86	0.498	10.72	127.2	8.27
			1.0	23.85	0.498	10.71	127.2	8.26
			2.0	22.44	0.505	8.88	102.6	7.98
			3.0	20.28	0.517	7.91	87.6	7.82
			4.0	16.53	0.514	10.03	103.0	8.04
			5.0	12.78	0.486	10.16	96.2	8.04
			6.0	10.26	0.489	7.67	68.6	7.70
			7.0	8.36	0.503	5.63	48.1	7.50
			8.0	6.98	0.522	4.12	34.1	7.42
			9.0	6.18	0.532	3.43	27.7	7.36
			10.0	5.74	0.537	3.24	25.9	7.35
			11.0	5.45	0.541	2.87	22.8	7.34
			12.0	5.34	0.541	2.63	20.8	7.35
			13.0	5.17	0.544	2.38	18.7	7.34
			14.0	5.07	0.545	2.24	17.6	7.33
			15.0	5.00	0.546	1.56	12.2	7.32
			16.0	4.96	0.547	1.24	9.7	7.31
			17.0	4.94	0.547	1.15	9.0	7.31
			18.0	4.89	0.547	1.21	9.5	7.31
			19.0	4.83	0.549	0.44	3.5	7.26
			20.0	4.80	0.549	0.00	0.0	7.27
			21.0	4.79	0.549	0.00	0.0	7.25
			22.0	4.79	0.549	0.00	0.0	7.28

Figure 3.1: Little York Lake – Temperature and Dissolved Oxygen Profile

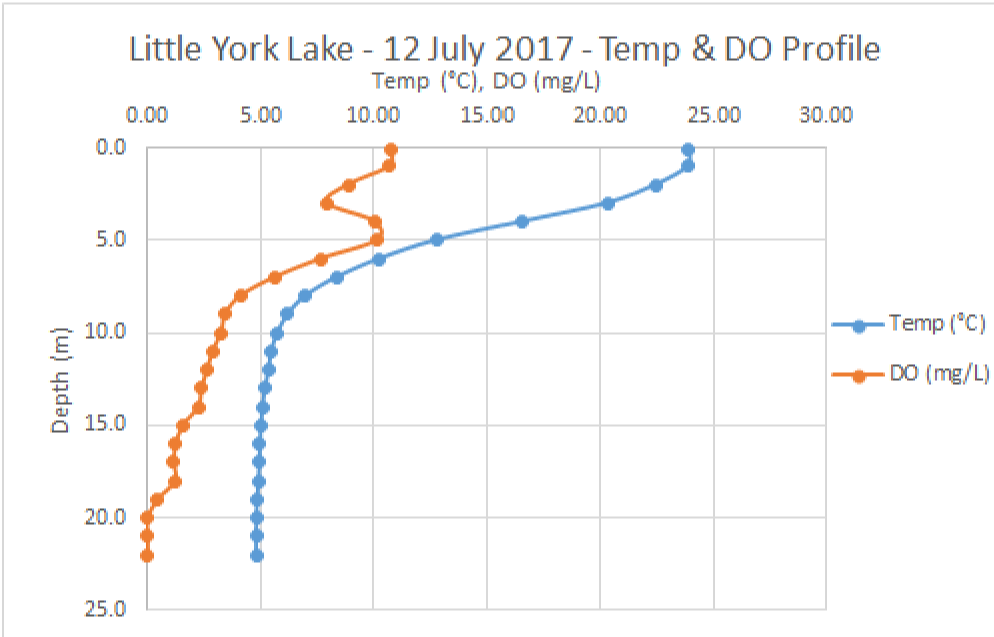


Figure 3.2: Little York Lake – Historical TP (CSLAP Data)

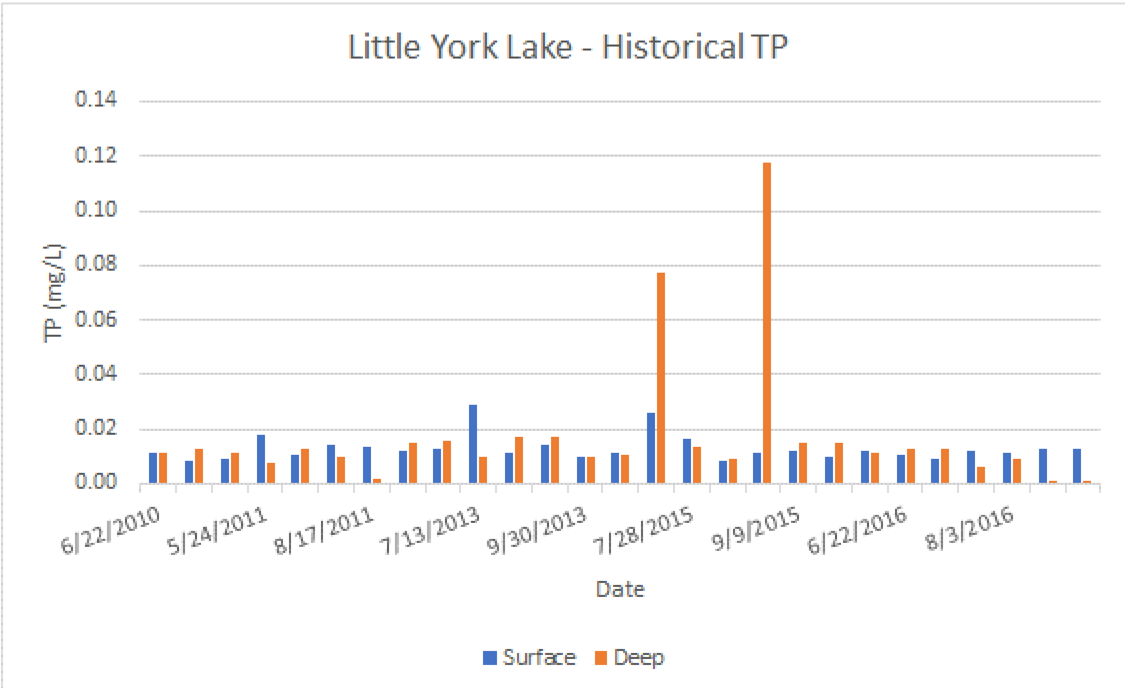


Table 3.2: Little York Lake – Plankton Data

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Kettle Lakes			**Sampling Date: 7/12/2017**			**Examination Date: 7/17/2017**		
Site 1: Litte York Lake Deep			**Site 2: Little York Lake Beach**					
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophya (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Asterionella	R		*Sphaerocystis*	R		*Anabaena*	R	
Fragilaria	P	C	*Pediastrum*	R		*Microcystis*	R	
Tabellaria	P	P	*Staurastrum*	R				
Synedra	P	C	*Mougeotia*		P			
Chrysophyta (Golden Algae)						**Pyrrhophyta (Dinoflagellates)**		
Chrysophaerella	C					*Ceratium*	C	
Dinobryon	P							
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Bosmina sp.	P		*Cyclops sp.*	A	R	*Keratella*	P	
Daphnia	P		*D Nauplius*	C		*Kellicottia*	P	
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton Genera	12	4						
Total Zooplankton Genera	6	1						
Sample Volume (mL)			**Phytoplankton Key: Bloom (B), Abundant (A) Common (C), Present (P), and Rare (R)**					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous					

4.0 Pollutant Loading Budget

4.1 Introduction

In order to properly analyze the trophic state of Little York Lake and decide on appropriate watershed and in-lake management techniques a comprehensive nutrient budget must first be developed. In this sense all pollutant inputs must be identified and quantified in order to assess those areas which contribute a disproportional amount of that load and their relative influence on lake productivity. The pollutants of concern are total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS). Phosphorus and nitrogen are those two nutrients most critical to plant and algal growth and as such, increases in these nutrients generally lead to increased lake productivity. While both nutrients are modeled the nutrient of primary concern is phosphorus. In most temperate freshwater ecosystems this is the limiting nutrient, that is, the nutrient that is least available in relation to biological demand, and as such, small increases in phosphorus loading may result in exponential increases in algal and weed growth. There are several sources, both external and internal, of phosphorus loading to freshwater systems and each of these potential sources must be evaluated to develop a proper loading estimate. Total suspended solids represent the total amount of inorganic and organic particles within the water column and are the prime determinant of water clarity. High TSS concentrations may be associated with "muddy" water clarity and are generally the result of excessive sediment loading and suspensions of algal particles. Primary sources of sediment loading to the lake are generally derived through erosion of watershed soils and stream banks. Sediment loading generally results in the formation of sediment deltas and infilling of near shore areas thereby increasing aquatic weed habitat and providing the fertile substrate for benthic, filamentous algae. In addition, as phosphorus is often tightly bound to soil particles, increases in sediment loading are commonly correlated with increases in total phosphorus loading.

To address the issues of nutrient loading to trophic response Princeton Hydro conducted a comprehensive pollutant model which served to quantify both external and internal sources of nutrient loading. Those sources of nutrients which were quantified in this study include the following:

External

- Watershed as based on land use and land cover
- Atmospheric deposition
- Septic systems
- Point Sources
- Concentrated Animal Feedlot Operations (CAFO)

Internal

- Sediment phosphorus release under oxic and anoxic conditions

4.2 Methodology

Watershed Loading

Watershed based nutrient loading is often times the largest contributor of nutrients and sediments to the receiving waterbody. The watershed area and land uses in conjunction with the soils and slopes which comprise the watershed are all prime determinants of the magnitude of nutrient loading to a lake system. For the purpose of calculating the watershed based nutrient load Princeton Hydro utilized the Unit Areal Loading (UAL) approach. The UAL approach is the recommended pollutant modeling technique as per 40 CFR Part 35, Appendix A, the USEPA's "Guidance for Diagnostic-Feasibility Studies." This modeling approach is widely used by both USEPA and NYSDEC, and Princeton Hydro has applied it to compute the nutrient and sediment loads for well over 200 lakes and reservoirs located throughout the mid-Atlantic and New England states. The unit areal loading modeling approach is based on the premise that land use activities throughout a watershed have a direct impact on nutrient release and transport to a receiving waterbody. Essentially, those land uses which are disturbed (i.e. urban, commercial, and agricultural lands) serve to transport more pollutants to a receiving waterbody than those which are undisturbed (i.e. forest and wetlands). For the application of this model Princeton Hydro first utilized topography data provided by the New York State GIS Clearinghouse to delineate the watershed boundary of Little York Lake. Following this delineation land use / land cover data was clipped to this boundary. This data was subsequently reviewed for accuracy utilizing recent aerial photography and reclassified. This information was then utilized as the basis for the selection of pollutant export coefficients, in the units of (Kilogram of pollutant / Hectare / Year), which were most suitable for the watershed given prevailing soils, slopes, geology, and climatic conditions. Sources of export coefficients chosen for the Little York Lake watershed were derived primarily from the scientific literature which included but was not limited to those published by Reckhow, 1980 and Uttomark et al, 1974.

Septic

Septic systems serve as the primary method for treating wastes in the Little York Lake watershed. Even when the systems are fully operational in their primary function they may contribute phosphorus to the nearby lake. Loading may be attributable to many factors including poor siting as a result of low depth to bedrock, poor soil infiltration or high seasonal water table. In addition, many lakeside houses and septic systems that were originally designed for seasonal use transition into full-time residences and are not properly sized and maintained for this increase in use. For the determination of septic system loads to the lake Princeton Hydro first calculated the number of residences within the zone of influence of the lake or other waterways. For this study, the zone of influence represents those systems within 100 m (330 ft.) of the lake or other waterways per recommendations from the USEPA. Following this determination, Princeton Hydro utilized census data to determine the population served by these systems. Upon this determination, Princeton Hydro applied the phosphorus export coefficient of 0.165 kg/capita/yr to these systems. This export coefficient was developed by Princeton Hydro utilizing empirical septic leachate data on Greenwood Lake (NY/NJ). Nitrogen loading from septic systems was not modeled for this study.

Atmospheric Deposition

Sediments and their bound nutrients may be precipitated as dryfall (dust) or through stripping during rainfall or snow events. While generally recognized as a small source of loading to many waterbodies atmospheric loading may play a critical role in large lakes or in those waterbodies with small watersheds.

This load was calculated using empirically derived loading coefficients (Schueler, 1992, Uttormark, et al. 1974, USEPA 1980 and Owe, et al. 1982) of phosphorus, nitrogen and sediment sources during dryfall and wetfall (rain / snow).

Internal Loading Assessment

A critical component in the development of this WIP was the assessment of the internal phosphorus load for Little York Lake. Kettle lakes in this region, formed by glacial retreat, are categorized by relatively deep depths and small watershed areas. These morphological characteristics, combined with eutrophication resultant from developed watersheds, may lead to deep water anoxia (no oxygen). When this occurs, phosphorus, which is typically chemically bound to iron in the lake sediments, becomes released to the overlying water whereby it becomes accessible to algae for growth.

Internal loading assessment for Little York Lake was determined through an evaluation of historical data collected through the CSLAP program including temperature and dissolved oxygen stratification patterns and surface and deep-water total phosphorus concentrations. This data was supplemented through sampling conducted by Princeton Hydro in July 2017. During a single event, Princeton Hydro collected *in-situ* temperature, specific conductance, pH and dissolved oxygen data in profile throughout the water column at the deepest portion of the lake. In addition, samples were collected for total phosphorus and soluble reactive phosphorus in the surface and deep waters of the lake. This data was utilized in concert with bathymetric data provided by the NYSDEC to determine the temporal and spatial extent of internal loading in Little York Lake. Finally, this information was utilized to help determine export coefficients from the scientific literature for internal phosphorus loading rates under oxic (with oxygen) and anoxic (no oxygen) conditions. The internal loading period was estimated at a total of 120 days per year, 45 of these days were under anoxic conditions while the remainder were under oxic loading. These rates were then applied to Little York Lake to determine the annual internal phosphorus load.

Concentrated Animal Feedlot Operations

A Concentrated Animal Feeding Operation (CAFO) is an animal feeding operation (farm) that meets certain animal size thresholds and that also confines animals for 45 days or more in any 12-month period in an area that does not produce vegetation. New York State has more than 500 CAFOs, the majority of which are dairy farms with 300 or more cows and associated livestock operations (NYSDEC, 2017). Animal feeding operations may produce significant nutrient loads through the feeding and defecation of farm animals which may be subsequently transferred to streams or groundwater sources. To effectively manage nutrient loading from feedlot operations, NYSDEC has implemented general permits for these facilities. As part of these regulations, each CAFO implements conservation practices for nutrient management to minimize non-point source pollution of nitrogen and phosphorus.

The computation of nutrient loading from CAFO operations is an inherently difficult process. Daily feeding, grazing, waste handling and spreading, spatial proximity to waterways, climate and a myriad of other site-specific factors regulate nutrient loading from any one facility. For this study, Princeton Hydro aimed to compute a general load of nitrogen and phosphorus from each facility. This load may be utilized as a general estimate but does not include site-specific conservation or nutrient mitigation processes that may be implemented at each property.

For the computation of nutrient loading from CAFOs, Princeton Hydro first identified the location of CAFOs in the watershed through data provided by NYSDEC Division of Water. This database provided the location of each CAFO and animal population data. Three CAFOs were identified in the Little York Lake watershed. One of these operations was entirely located within the watershed boundary while the other two were on the watershed boundary. For the determination of the loads from each CAFO Princeton Hydro first determined the number of animals in each CAFO and converted these to animal equivalent units (AEUs). For those CAFOs only located partially within the watershed boundary, Princeton Hydro area weighted the animal population data. Following this determination, pollutant loading coefficients for nitrogen and phosphorus, derived from the *Mapshed* modeling program, were applied to determine the annual pollutant load. The loading coefficient for nitrogen was 0.44 kg N/AEU/day while that for phosphorus was 0.07 kg P/AEU/day (Evans, 2014). For the computation of the load which is available for export from the site to the watershed, Princeton Hydro applied a loss rate. For this study, Princeton Hydro assumed that 5% of the annual nutrient load is available for transport to the watershed. This loss rate is lower than the 20% assumed utilizing the *Mapshed* program. Finally, the majority of animal operations likely spread manure at various fields, some of which may not even be in the watershed, as such, the estimates contained herein should be utilized with the aforementioned points in consideration.

Macrophyte Harvesting – Nutrient Removal

The final component in assessing the nutrient budget for Little York Lake was the integration of macrophyte harvesting. This management measure is utilized primarily to control nuisance levels of aquatic vegetation but has the added benefit of removing those nutrients contained within plant biomass from the lake thereby serving as an in-lake bmp. For this study, Princeton Hydro received estimated mass removed per year from the Cortland County Soil and Water Conservation District. This value was estimated to range between 100 to 250 tons per year, wet weight. Princeton Hydro utilized the low estimate (100 tons/year) in conjunction with a phosphorus value of 2,216 mg/kg of P to compute the mass of phosphorus removed from the lake on an annual basis. The plant phosphorus concentration data was obtained from Princeton Hydro's in-house database on macrophyte phosphorus concentrations derived from work conducted on Lake Hopatcong in New Jersey.

4.3 Results

Summary results for nutrient loading to the lake are presented in table 4.1.

Table 4.1: Little York Lake Pollutant Loading Summary

Little York Lake - Nutrient Loading Summary

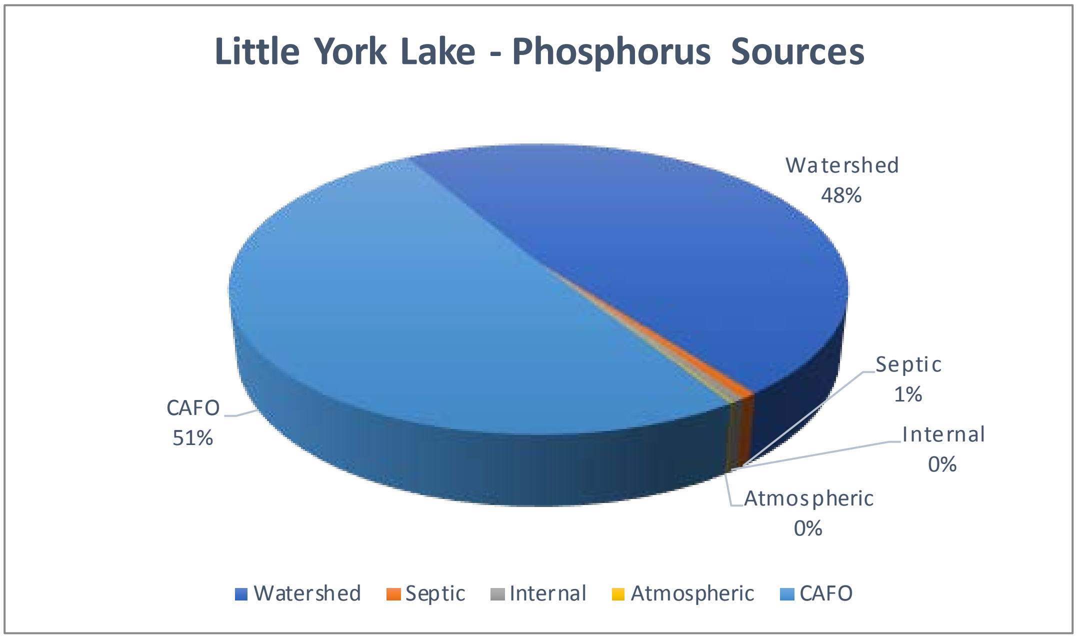
	Watershed	Septic	Internal	Atmospheric	CAFO	Harvesting	Sum
TN (kg/yr)	75,636	N/A	N/A	409	26,440	N/A	102,484
TP (kg/yr)	3,994	57	48	10	4,206	-201	8,114
TSS (kg/yr)	4,928,000	N/A	N/A	286	N/A	N/A	4,928,286

*Direct

**includes septic, internal, atmospheric and point from tully / song with lake retention factored in

On an annual basis, 102,484 kg (225,939 lbs) of nitrogen, 8,114kg (17,888 lbs) of phosphorus and 4,928,286 kg (10,865,011 lbs) of sediments are transported to Little York lake. A breakdown of the sources of phosphorus to Little York Lake are hereby presented in figures 4.1 and 4.2.

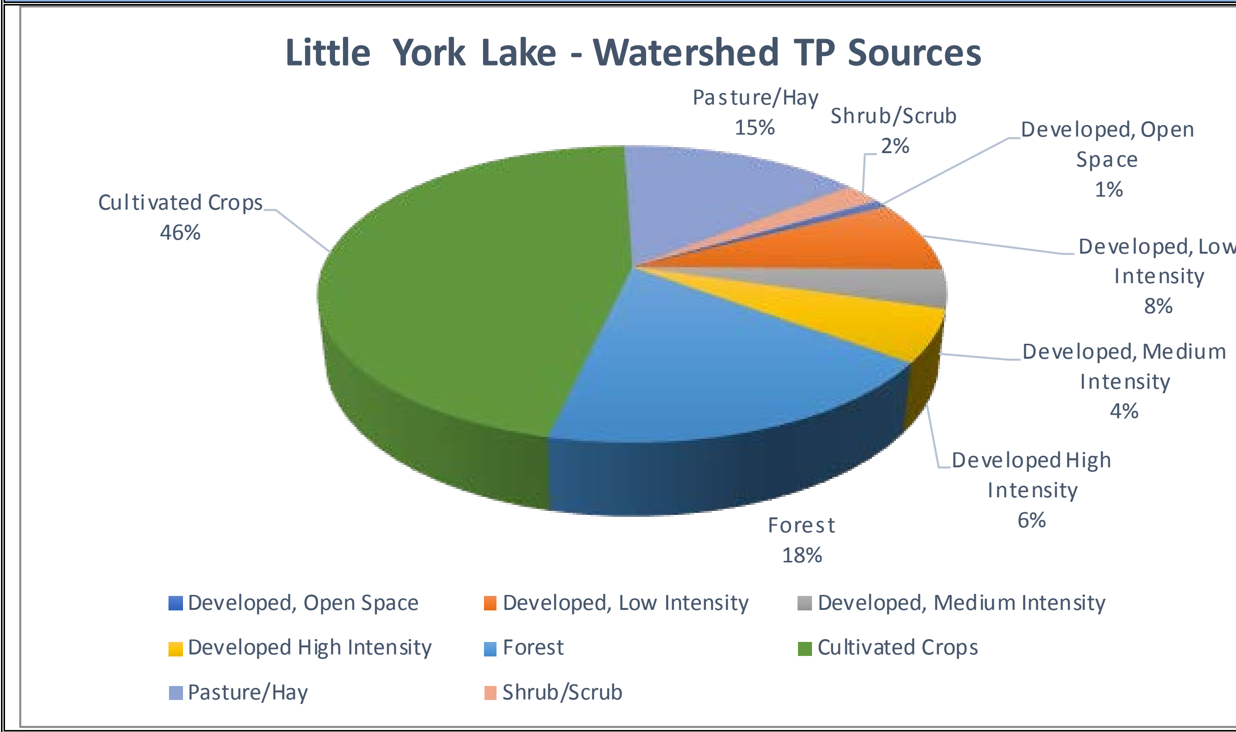
Figure 4.1: Little York Lake TP Loading Summary



The primary source of phosphors loading to Little York Lake is derived from concentrated animal feeding operations with 51% of the annual load. The second greatest source is derived from direct watershed loading which comprises 48% of the load. The remaining loading sources (Septic, internal and atmospheric) are all 1% or less of the annual load. The small percentage of these loading sources is due to the large watershed of Little York Lake and types of activities which occur in the watershed.

Given the magnitude of the CAFO load it will be necessary to place focus on these facilities. Each facility should already have a nutrient management plan in place that will need to be adhered to diligently to prevent watershed pollution. A breakdown of the watershed based load, excluding CAFO loading, is presented in figure 4.2. Agriculture represents the primary land derived phosphorus source with cultivated crops and pasture / hay contributing 61% of the watershed based load. Developed land is the second greatest source with 19% of the load while forested land contributes 18% of the watershed based load. Please note, open water and wetlands are also present in the watershed and represent phosphorus attenuation of 132.7 kg/TP/yr.

Figure 4.2: Little York Lake – Watershed TP Loading



Watershed based BMPs will need to focus on phosphorus derived from both agriculture and developed land use for the successful reductions in nutrient loading to the lake. The following section will detail the results of a watershed walk conducted by Princeton Hydro in May 2017. Please note, this section is not an exhaustive survey of the watershed. Specifically, many areas, such as agricultural lands, that are on private land or are otherwise inaccessible are excluded from this report but will very likely need managed to reach nutrient reduction goals. This section will provide examples of watershed issues which could benefit from better management and provide information on approximate costs, nutrient reduction and maintenance opportunities for each section.

5.0 Watershed Disturbance and Best Management Practices

In anthropogenically altered watersheds, land use practices have been changed in ways that consequently alter the hydrologic cycle and increase pollutant loading to a lake. For this document, the term 'pollutant,' refers primarily to phosphorus, nitrogen and sediment but may also include salts, heavy metals or pesticides. Some of these pollutants are contributed directly to a lake, but, more commonly, these pollutants are derived from diffuse 'non-point sources.' Non-point source pollution is a term which relates to the contribution of sediments, phosphorus and nitrogen to waterways through land and stream bank erosion, stormwater and septic.

The watersheds of the Kettle Lakes were historically dominated by forest and wetland. With development came the clearing of forests and modification of wetlands, either through infilling, draining or flow alteration. The current land use of the Little York Lake watershed is comprised of a mixture of these forests and wetlands but also the human dominated land uses of residential housing, agriculture and transportation infrastructure. The anthropogenic land use changes reduced vegetative cover, exposed soils, increased impervious areas and introduced pollutants through fertilizers, road salts and byproducts of human materials. These changes ultimately lead to a marked change in the hydrology of the watershed in such a way that infiltration and groundwater recharge was likely reduced while the volume and rate of stormwater based surface discharge increased. Ultimately, this change in stormwater leads to stream channel downcutting, widening and bank instability leading to instream erosion. This geomorphic change results in a disconnect between streams and their floodplains and results in increased sediment and nutrient loading to lakes.

To mitigate non-point source pollution, we look to implement watershed best management practices. Watershed best management practices focus on structures, retrofits and even behaviors that may help reduce pollution to a waterway. Princeton Hydro focuses primarily on the selection and utilization of best management practices which fit in with Green Infrastructure. Green Infrastructure is a water management approach that seeks to mimic the natural environment and associated natural processes. These processes include sedimentation, filtration / flow resistance, bio-uptake, recharge, decomposition and bioretainment. Many of the structures or techniques listed below aim to utilize soils and vegetation to mimic these processes found in nature. In doing so, these techniques may serve to not only reduce nutrients to a lake but also serve as habitat for aquatic and terrestrial organisms in an ever increasing fragmented landscape.

The following section details the results of a watershed walk conducted over a half-day in May 2017 by Princeton Hydro and various stakeholders including members of Syracuse University, C-OFOKLA, local residents and members of Cortland County Soil and Water Conservation District. This walk aimed to photo-document areas of non-point source pollution which may benefit from the inclusion of best management practices. This summary is not an exhaustive survey of watershed conditions or BMP recommendations but provides specific examples of areas that can be improved. Furthermore, prior to the implementation of any BMP there will likely be additional, site specific, information needed such as: Utility, topographic and/or transportation surveys, stormwater engineering calculations, property ownership assessment, geologic or soil assessments, local, state and/or federal permits, etc.

Recommendation of BMP types are included along with rough estimates for costs and pollutant removal. Costs are based on similar projects conducted by Princeton Hydro but are very site specific upon a myriad of factors. Pollutant removal was computed based on removal estimates provided by various BMP manuals including those issued by the States of New York and Pennsylvania. A summary of the types of maintenance associated with each BMP is also listed. Finally, recommendations on the priority of each BMP are listed as 'low', 'medium', and 'high.' These priorities are based on several factors including overall cost, ease of installation, permitting requirements, the need for cooperation from various government entities and pollutant removal. In general, those projects which may be easily implemented with minimal permitting and cost while providing ecological and pollutant removal benefits are rated as 'High.' This is particularly the case for those sites which occur on public property. Sites of high cost, extensive permitting or those on private property may be more difficult to implement and are therefore given a lower rating.

A summary of recommended BMPs is presented first (table 5.1) followed by a breakdown of each site. A figure showing the location of each recommended BMP is provided in Appendix I.

Table 5.1: Watershed BMP Summary

Site	BMP	Estimated Cost ($)	Pollutants Removed (kg/yr)			Priority
			TSS	TP	TN	
1	Step – Pool Conveyance	$50,000 - $100,000	2,590	2.6	65	High
2	Riparian Buffer (600 ft.) / Floodplain bench	Riparian Buffer - $1,750 / acre, Floodplain - $50,000	720	1.2	5.4	High
3	Riparian Buffer (9,500 ft.)	$1,750 / ac	11,400	19	86	High
4	Rain Garden	$2,000 - $5,000	14	0.01	0.06	Medium
5	Lakeshore Buffer	$10,000 - $20,000	400	0.3	1	Medium
6	Catch Basin Insert Filter	$1,000 - $2,000	210	0.13	0.5	High
7	Bioswale	$15,000 - $20,000	28	0.02	0.12	High
8	Bioswale	$10,000 - $15,000	28	0.02	0.12	Medium
9	Bioswale	$10,000 - $15,000	55	0.04	0.24	Low
10	Bioswale / Bioinfiltration trench	$75,000 - $125,000	83	0.06	0.36	Medium

Site 1: Route 11 Stormwater Ditch – Erosion

Site Location and Description: *N42.75204° W76.12100°* – Roadside stormwater ditch

Issues: Stormwater conveyance through dirt ditch leading to erosion.

BMP Recommendation: Encourage vegetative growth in ditch. Utilize check dams where necessary to slow flow or convert to step-pool conveyance system.

Cost: Variable based on site specific conditions. Engineering, permitting and construction. Estimate $50,000 – $100,000

Maintenance: Monitor vegetation and remove invasives. Check for silt build up and remove.

Pollutant Removal: TSS 2,590 kg/yr, TP 2.6 kg/yr, TN 65 kg/yr

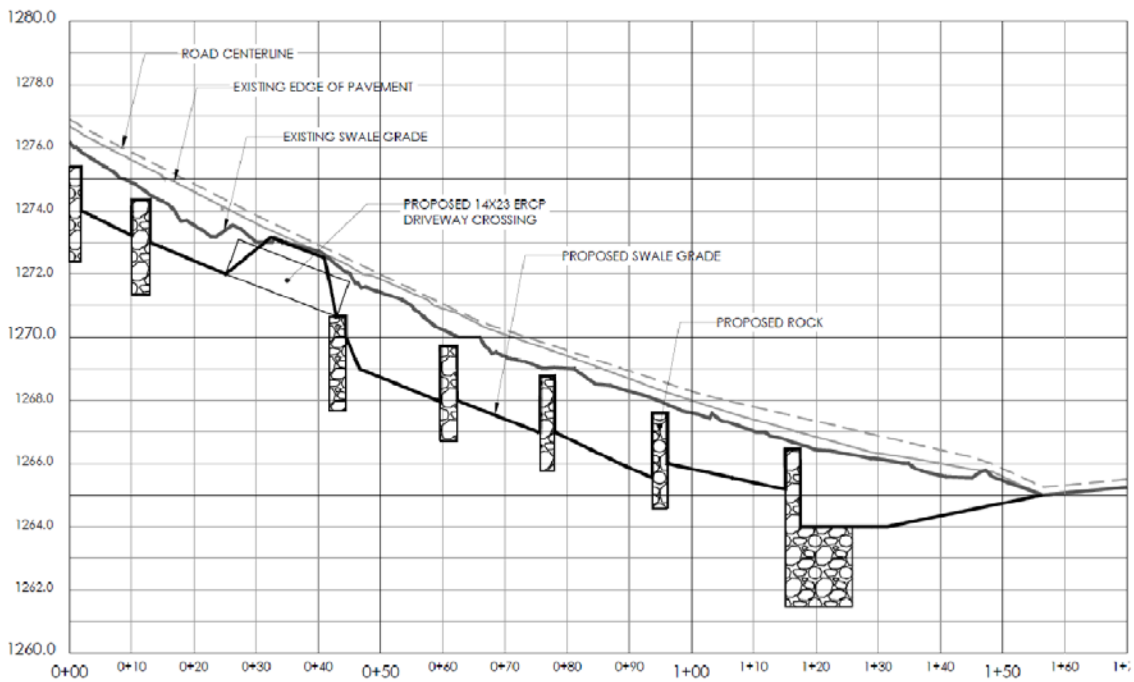
Priority: High

Additional Locations: *N42.69832° W76.16334° & N42.70510° W76.15742° (Route 281)*

Examples of the recommended BMPs are provided below.

Figure 5.1: Route 11 Stormwater Ditch

Figure 5.2: Step-Pool Conveyance Engineering Diagram



Source: Princeton Hydro – Harvey's Lake Step Pool Conveyance / Infiltration

Figure 5.3: Regenerative Step-Pool Conveyance – Before and After

Source: Maryland DEP – Mary Travaglini, Planning Specialist

Site 2: Stream through Agricultural and Residential Area

Site Location and Description: *N42.73680° W76.12472°* – Stream through agricultural and residential land including road crossing.

Issues: Lack of riparian buffer. Stream erosion due to disconnect from floodplain. Possibly undersized culvert

BMP Recommendation: Install 600 linear feet of riparian buffer along stream – Ideally the riparian buffer should be 200’ in width with a minimum width of 50-100’. Conduct geomorphic analysis and install floodplain bench to reconnect stream to floodplain.

Cost: *Riparian buffer* - approximately $1,750 per acre for plants, materials and labor. *Floodplain Bench* - $50,000 not including engineering and permitting.

Maintenance: Monitor vegetation for invasive species or die off. Remove invasives and replant natives that have died.

Pollutant Removal: *Riparian Corridor (500 linear feet) TSS 720 kg/yr, TP 1.2 kg/yr, TN 5.4 kg/yr.*

Priority: High

Additional Locations: Southern portion of the West Branch Tioughnioga River

Figure 5.4: Stream Through Residential and Agricultural Field

Site 3: Stream through Agricultural Area

Site Location and Description: N *42.726611°, W 76.131325°* - West Branch Tioughnioga River through agricultural land

Issues: Lack of riparian buffer between stream and agricultural land and route 11.

BMP Recommendation: Approximately 9,500 linear feet of shoreline is without proper riparian buffer. Install riparian buffer along stream – Ideally the riparian buffer should be 200’ in width with a minimum width of 50-100’.

Cost: *Riparian buffer* - approximately $1,750 per acre for plants, materials and labor.

Maintenance: Monitor vegetation for invasive species or die off. Remove invasives and replant natives that have died.

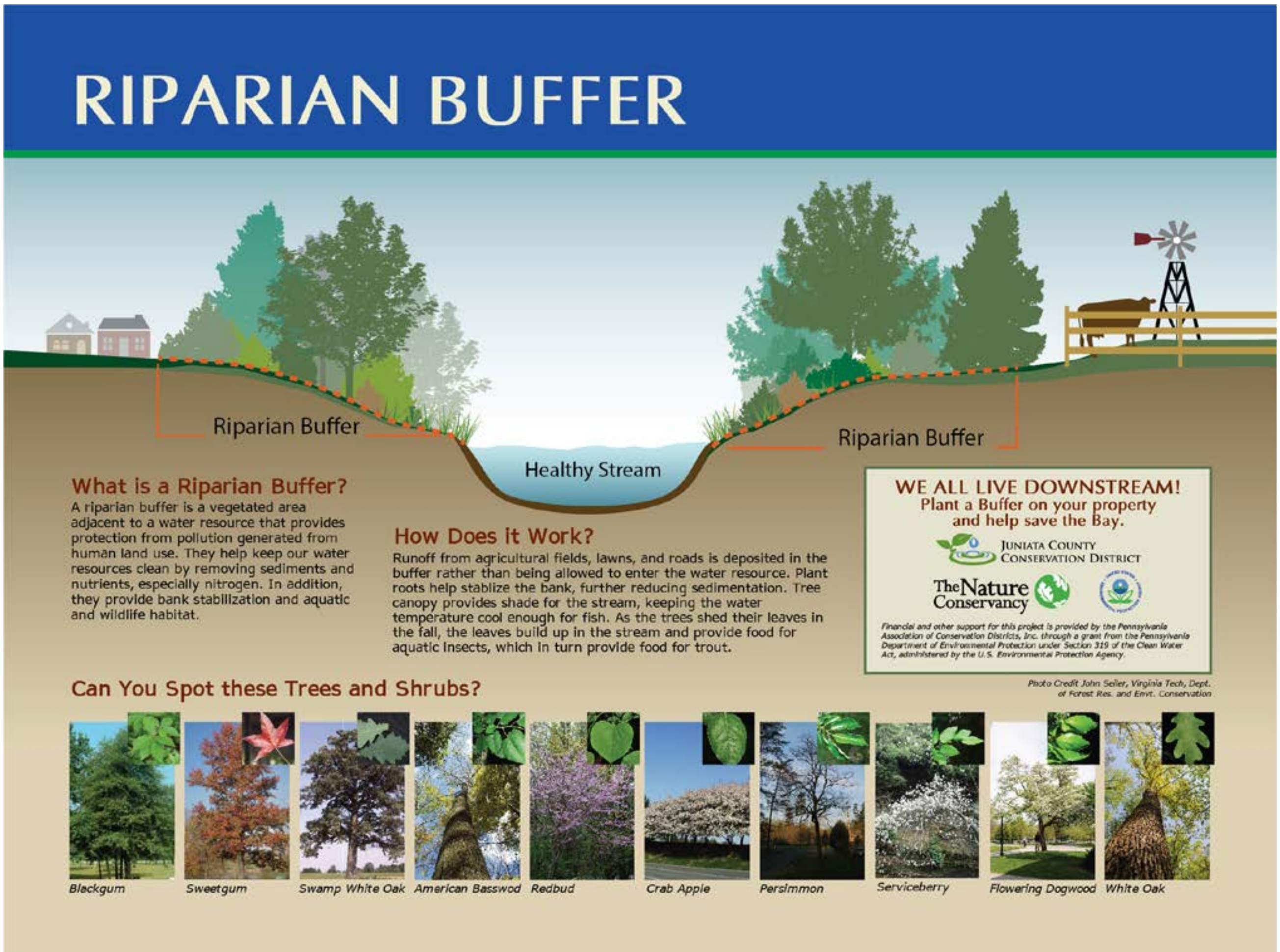
Pollutant Removal: *Riparian Corridor (9,500 linear feet) TSS 11,400 kg/yr, TP 19 kg/yr, TN 86 kg/yr*

Priority: High

Examples of the recommended BMPs for Sites 2 & 3 are provided below.

Figure 5.5: Stream Through Residential and Agricultural Field

Figure 5.6: Riparian Buffer Infographic



Source: PACD.org

Figure 5.7: Riparian Buffer Example

Source: Mr. Josue Cruz

Site 4: Colonial Herb Garden

Site Location and Description: *N42.71275° W76.14859° - Colonial Herb Garden*

Issues: Opportunity for rain garden demonstration project

BMP Recommendation: Establish rain garden and educational signage

Cost: Approximately $2,000 - $5,000 depending on need for soil amendment.

Maintenance: Check and remove any invasive species annually. Monitor functionality in terms of infiltration

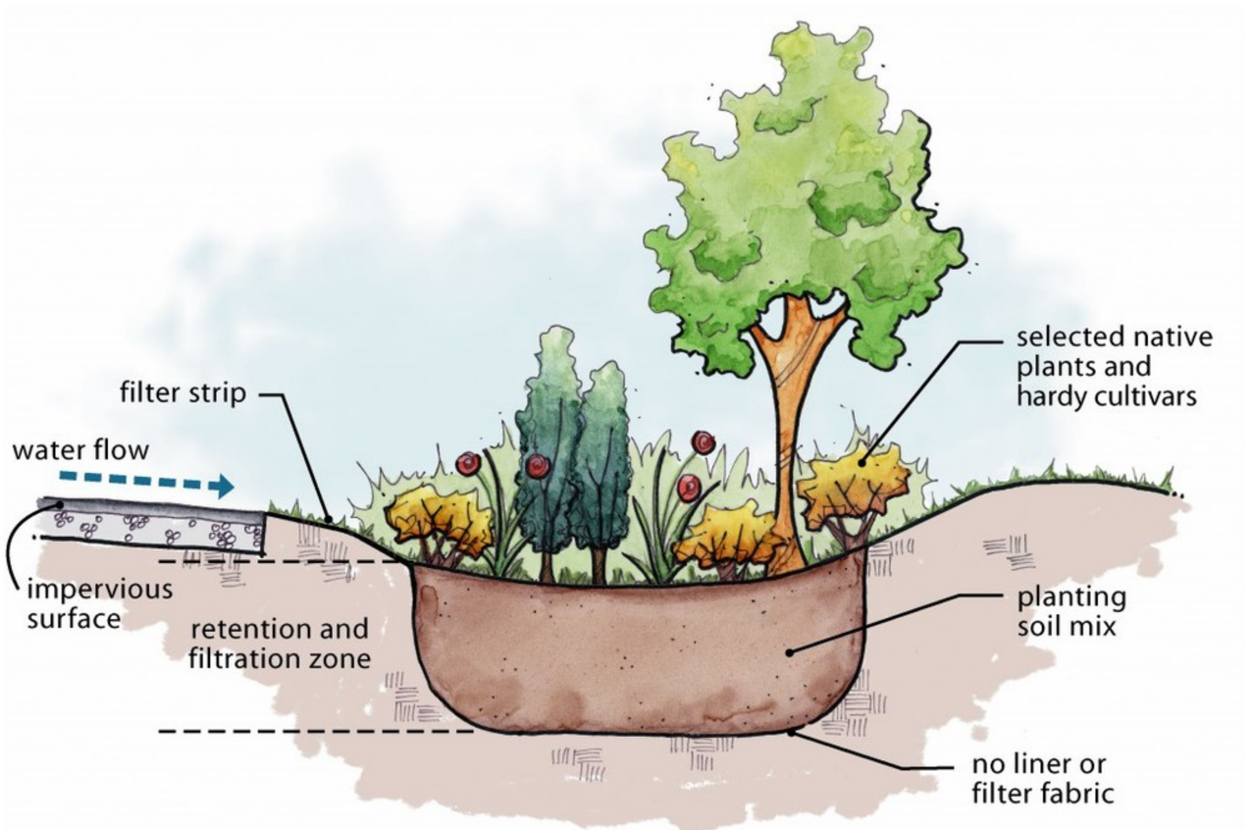
Pollutant Removal: TSS 14 kg/yr, TP 0.01 kg/yr, TN 0.06 kg/yr

Priority: Medium

Examples of the recommended BMPs are provided below.

Figure 5.8: Colonial Herb Garden

Figure 5.9: Raingarden Example



Source: Shohomish Conservation District

Site 5: Lakeside Lot – Northwest Shoreline

Site Location and Description: *N42.71426° W76.14907°* – Turf grass shoreline

Issues: No lakeshore buffer

BMP Recommendation: Establish lakeshore buffer and meadow / pollinator garden. May need to utilize coir fiber logs for erosion control. Utilize low and medium height native vegetation to maintain viewscape. Offers pollutant filtering and critical near-shore habitat.

Cost: Estimated cost approximately $10,000 - $20,000

Maintenance: Check and remove any invasive species annually.

Pollutant Removal: TSS 400 kg/yr, TP 0.3 kg/yr, TN 1 kg/yr

Priority: Medium

Additional Locations: *Majority of lakefront lots exhibit turf grass to water edge and can benefit from shoreline restoration.*

Examples of the recommended BMPs are provided below.

Figure 5.10: South shore of Little York Lake

Figure 5.11: Example of Lakeshore Buffer Conversion

Source: Mr. Josue Cruz

Site 6: East Shore – Residential / Agricultural Stormwater

Site Location and Description: *N42.70057° W76.15711°*– Agriculture / Residential land adjacent to lake and stormwater catch basin

Issues: Erosion and stormwater leading to sediment transport through catch basin

BMP Recommendation: Create vegetated or similar buffer at depressions which capture stormwater. Utilize catch basin retrofit, such as Aqua-Guardian to capture sediments and nutrients

Cost: Vegetation or erosion barrier at agricultural area stormwater catch basin - $200. Aqua-Guardian or similar – Approximately $1,500 - $2,000 each

Maintenance: Check and remove sediment from catch basin with vacuum truck or similar routinely.

Pollutant Removal: *Residential insert – TSS 210 kg/yr, TP 0.13 kg/yr, TN 0.5 kg/yr*

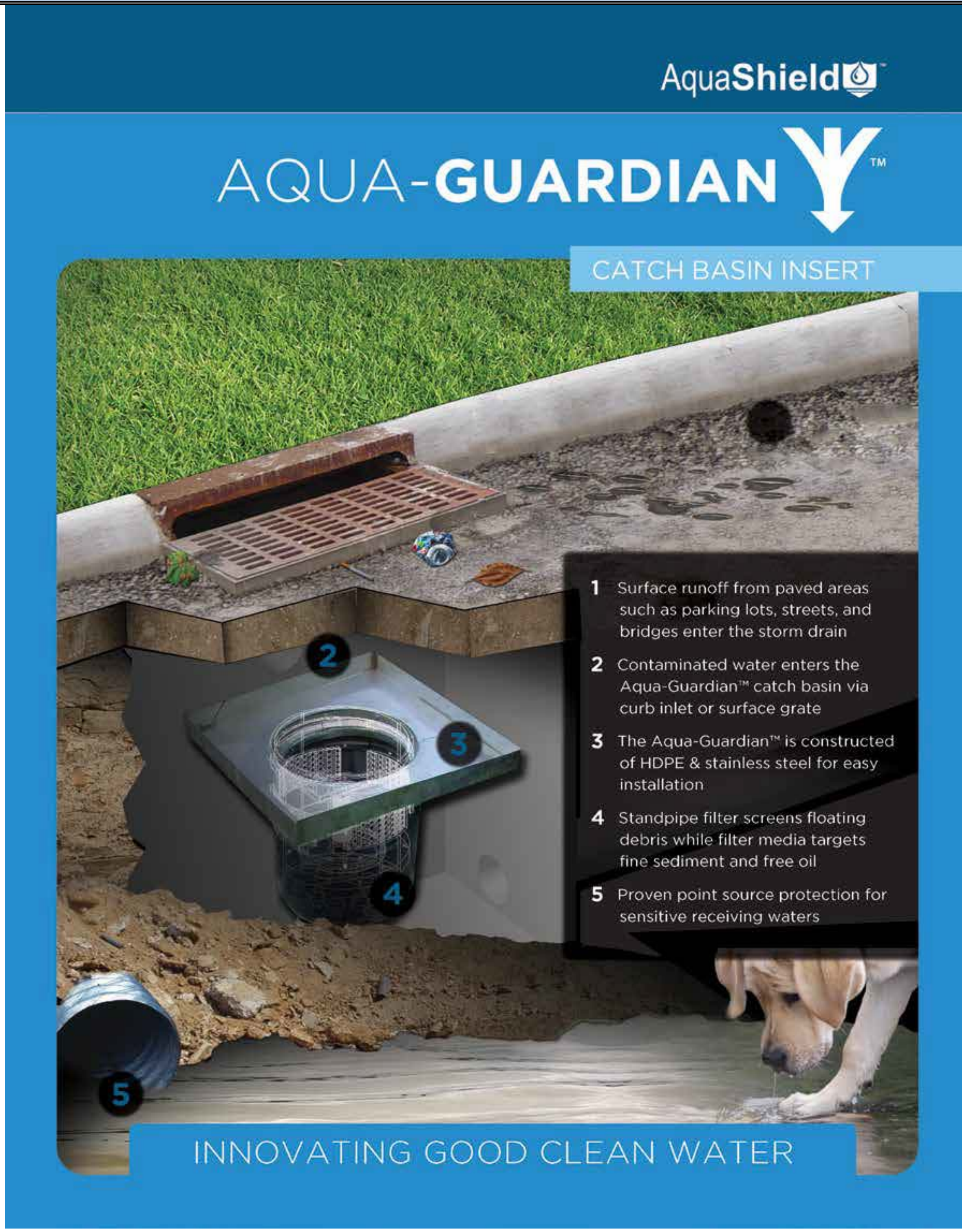
Priority: High

Additional Location: *Catch basin inserts can also be utilized at N42.70061° W76.15502° (E. Spur Road) & N42.70908° W76.15480° (Little York Lake Road)*

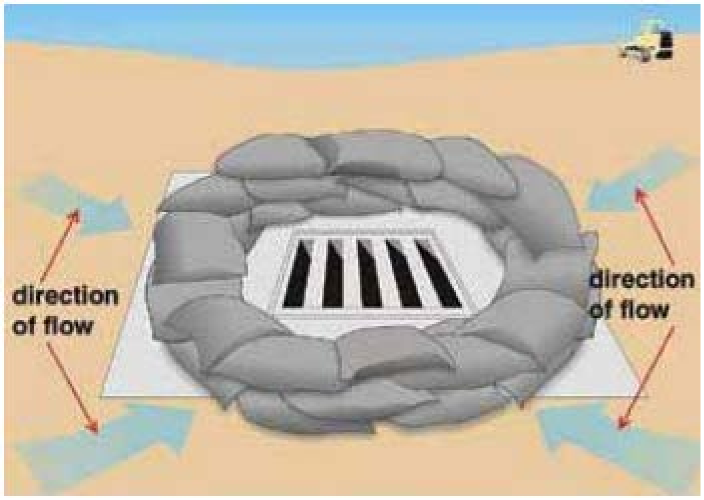
Examples of the recommended BMPs are provided below.

Figure 5.12: South shore of Little York Lake

Figure 5.13: Example of Catch Basin Insert



Source: Aquashieldinc.com

Figure 5.14: Example of Inlet Protection

Source: Stormwater.pca.state.mn.us

Site 7: Dwyer Memorial Park Area – Little Park Road Pavilion

Site Location and Description: *N42.71283° W76.15000°* - Gravel parking lot and swale near basketball courts

Issues: Erosion from gravel parking lot

BMP Recommendation: Stabilize parking lot gullies and direct stormwater to rehabilitated bioswale.

Cost: Estimated cost materials and implementation is approximately $15,000 - $20,000 which does not include engineering or permitting.

Maintenance: Check and remove any invasive species annually.

Pollutant Removal: TSS 28 kg/yr, TP 0.02 kg/yr, TN 0.12 kg/yr

Priority: High

Examples of the recommended BMPs are provided below.

Figure 5.15: Parking Lot and Swale

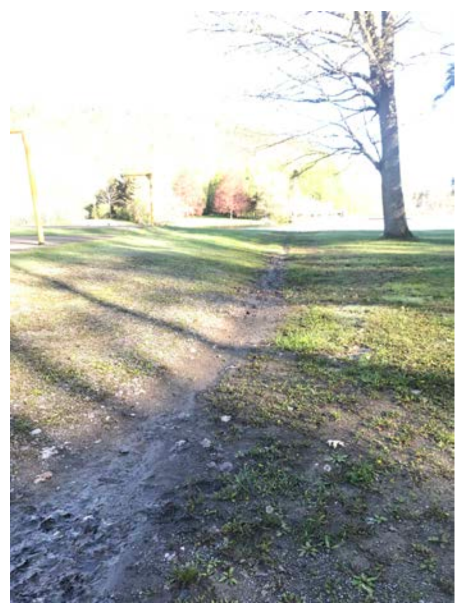


Figure 5.16: Bioswale Infographic

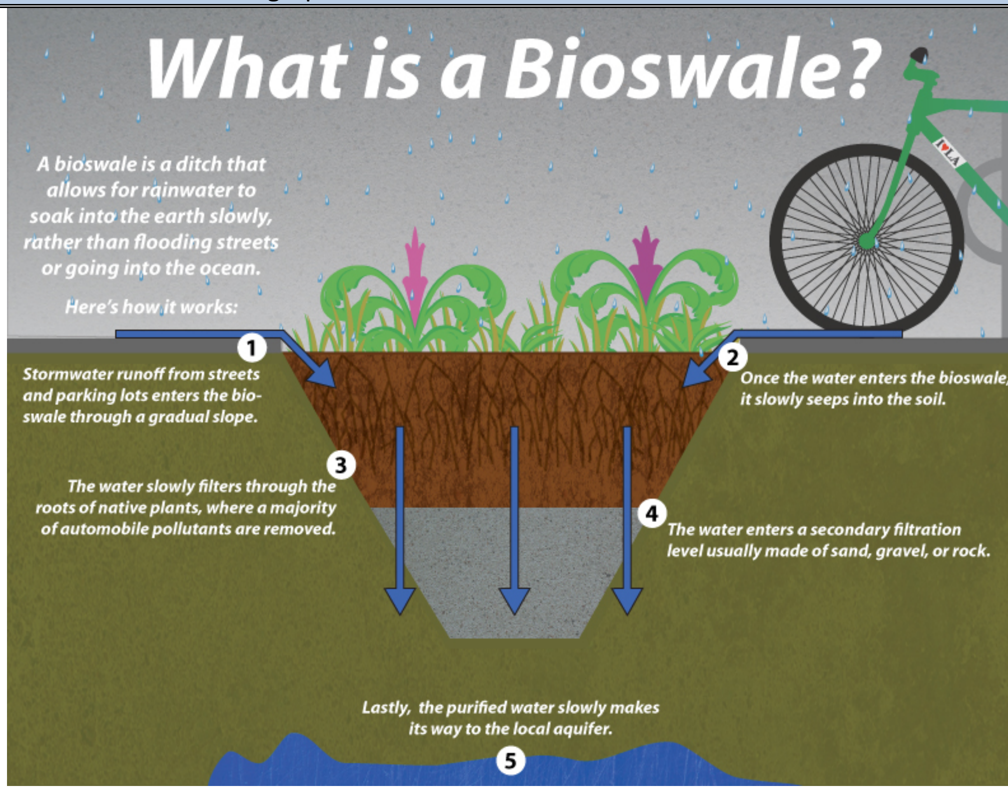


Figure 5.17: Bioswale Site Illustration

Source: Mr. Josue Cruz

Site 8: Dwyer Memorial Park Area – Gravel Boat Launch Area

Site Location and Description: *N42.71283° W76.15000°* - Gravel parking lot / launch and turf grass hillside

Issues: Turf hillside to gravel parking lot – runoff. Use this area to implement bioswale. Additional signage and washdown station for aquatic invasive species.

BMP Recommendation: Stabilize parking lot gullies and direct stormwater to rehabilitated bioswale to intercept and treat runoff from turf hillside – Use this project as educational piece for visitors. Increase signage for aquatic invasive species – provide washdown station.

Cost: *Bioswale* - $10,000 - $15,000. *Washdown Station and Signage* - $20,000

Maintenance: Check bioswale routinely for functionality (i.e. presence of ponding), sediment accumulation and invasive species. Check functionality of washdown station and check / remove discarded AIS

Pollutant Removal: *Bioswale* – TSS 28 kg/yr, TP 0.02 kg/yr, TN 0.12 kg/yr

Priority (Bioswale): Medium

Examples of the recommended BMPs are provided below.

Figure 5.18: Parking Lot and Swale

Figure 5.19: AIS Cleaning Station Example

Site 9: Dwyer Memorial Park Area – Gravel Boat Launch Area

Site Location and Description: *N42.70943° W76.15060°* - Large turf grass area

Issues: Turf hillside and field leading to ponding water at roadside.

BMP Recommendation: Ample space for implementation of bioswales

Cost: *Bioswale* - $10,000 - $15,000 not including engineering or permitting

Maintenance: Check bioswale routinely for functionality (i.e. presence of ponding), sediment accumulation and invasive species.

Pollutant Removal: TSS 55 kg/yr, TP 0.04 kg/yr, TN 0.24 kg/yr

Priority: Low

Figure 5.20: Turf field and gravel road

Site 10: Dwyer Memorial Park Area – Parking Area

Site Location and Description: *N42.70943° W76.15060°* - Large impervious parking area

Issues: Extensive impervious area limiting infiltration and promoting sheetflow

BMP Recommendation: Divert runoff from parking lot to bioswale / bioinfiltration trench

Cost: *$75,000 - $125,000* not including engineering or permitting

Maintenance: Check bioswale / trench routinely for functionality (i.e. presence of ponding), sediment accumulation and invasive species.

Pollutant Removal: *Variable dependent on system & drainage area – low estimate* - TSS 83 kg/yr, TP 0.06 kg/yr, TN 0.36 kg/yr

Priority: Medium

Figure 5.21: Turf field and gravel road

Septic Management

Much of the residential land surrounding Little York Lake utilizes septic systems for treatment of human wastes. The soils, slopes and water table surrounding the lake make on-site wastewater treatment a critical issue for the health of the lake relative to phosphorus loading. Review of the Septic Tank Absorption Field ratings derived from the National Resources Conservation Service show the soils surrounding the lake to range from 'somewhat limited' to 'very limited' in their ability to adequately treat wastes. The estimated total phosphorus load derived from septic systems is 1% of the total load. While a small percentage, the proximity of the systems to the lake impart a higher importance on septic maintenance.

At a minimum, septic tanks should be pumped out every three years. Maintaining this pumpout schedule may reduce phosphorus loading from this source by 20 - 30% (Day, 2001). In addition, water conservation measures should be implemented at each residence. Lowering the burden on the septic system will allow for reduced nutrient transport to shallow groundwater, and ultimately, Little York Lake.

Incentivizing the maintenance of septic systems through providing monetary benefits for completing pumpout or maintenance, or through providing reduced costs for these services, has been implemented successfully locally through the Song Lake Property Owners Association. Similar programs should be implemented on a municipal level to encourage all residents to keep their systems up to date and in good working order.

Finally, the type and age of septic systems may play a significant role in their functionality and contribution of nutrients to the watershed. This study merely looked at the presence of such systems without conducting a detailed assessment of whether systems need upgraded or replaced. Princeton Hydro recommends implementing such a study with backing by the local municipality and C-OFOKLA.

Lawn Fertilizers

Lawn fertilizers are often an acute source of nutrient pollution to lakes. Often, these products are applied in spring or fall and are quickly washed away during precipitation events directly into the lake where they fuel algal blooms. Currently, New York bans phosphorus fertilizers under ECL § 17-2101 et seq. This law, applicable to all persons, states the use of phosphorus fertilizers on lawns or non-agricultural turf is restricted. Only fertilizers with less than 0.67 %/w phosphate may be applied legally. Furthermore, applications between December 1 and April 1 are prohibited. An application buffer of 20 feet from a waterway or paved surface was also implemented as part of this rule.

Prior to application of any fertilizers, homeowners should have their soil tested by the local agricultural district or similar entity. This testing will provide empirical data on the amount of nutrients in the soil and need for any additional nutrients. Often times, phosphorus is present in abundance in soils and does not need additional application. Many times, the pH of the soil needs adjusted with lime thereby raising pH to a level where the phosphorus that is present in the soil becomes biologically available for turf grass. If fertilizers are needed, homeowners should look for and use phosphorus free fertilizers. Fertilizers are typically labeled with three vales (N-P-K) representing the proportion of nitrogen – phosphorus – potassium in the product. As such, look for fertilizers with a middle number of zero (e.g. 24-0-12) or a bag with 'lake friendly' on the front.

Educational campaigns about the 2012 State rule banning phosphorus fertilizer should be conducted routinely for watershed residents.

Deicers

There is considerable concern in the kettle lakes region of the impact of salts on the water quality of the lakes. Road salts (chloride) are commonly applied not only to driveways but also on state roads and interstate 81. The latter of which is likely a major source of chloride pollution during the winter months. The major issue with the application of road salts is that chloride is a conservative ion that is not readily sorbed onto mineral sources or involved in many significant biochemical reactions. As such, this ion persists in soils and ground and surface water. Ultimately, increases in chloride levels follow increases in watershed development and impervious area. These increases may alter the composition of the lake food web through changes in the invertebrate, plankton and fishery structures.

Management of road salts is a complex subject due to the human safety aspect. When possible, those who apply road salts should look into alternative deicers such as calcium magnesium acetate. Additives, such as natural beet sugars, lower the temperature of brine used to pretreat roads and has been documented in reducing overall salt use. such as Furthermore, where possible, setbacks should be established so that deicing compounds are not applied near surface water sources.

6.0 In-lake Phosphorus Management

In Little York Lake, 1% of the annual phosphorus load is estimated to be derived from internal sediment release. This load is extremely small relative to other sources but may provide an acute source of nutrients during the peak of the growing season. While watershed management should be the primary focus for Little York Lake, the following provides options for controlling internal loading.

There are several ways to manage internal loading of phosphorus in lake systems. These techniques focus on the maintenance of oxygen in the hypolimnion of the lake or the 'sealing' of lake sediments through the application of chemical flocculant or inactivation products. In addition, floating wetland islands may be utilized to assimilate phosphorus from the epilimnion. While floating wetlands islands will not control internal loading they serve as a chemical free in-lake measure to reduce the overall phosphorus load in the lake.

Aeration

Aeration for internal phosphorus control focuses on the maintenance of dissolved oxygen in the hypolimnion thereby serving to keep the redox potential at such a level as to mitigate large scale internal release of phosphorus and metals. Aeration systems for lake management typically fall under the categories of systems which disrupt thermal stratification, such as submerged diffuser systems, or systems which keep stratification in place, such as hypolimnetic aeration systems. Typically, the latter is utilized when there is the desire to maintain cold-water fishery habitat while destratification systems are commonly utilized in relatively shallow lakes.

For Little York Lake, efforts should be placed primarily on controlling the external P load and continued study of the impacts of internal loading. Modeling has shown the internal load to be small overall and discrete data collected over several years showed, with the exception of some events, minor variation between surface and deep TP concentrations. As such, the expenditures of an aeration system do not seem warranted at this time.

Nutrient Inactivation

Nutrient inactivation in lakes occurs through the application of a chemical, typically an aluminum or lanthanum/clay based product. Typically, phosphorus is bound to iron in the sediments through a relatively weak molecular bond which is broken under anoxic conditions. In contrast, the bond between phosphorus and nutrient inactivation products is stronger and therefore is not broken, or is broken more slowly, under anoxic conditions.

The products commonly utilized in lake management for nutrient inactivation includes aluminum sulfate (alum) or alum surrogates such as polyaluminum chloride. More recently, the utilization of lanthanum modified bentonite clay based products, such as the proprietary Phoslock©, have been utilized when there are concerns about alum toxicity or regulatory restraints on the use of such products. The latter is currently the case in New York State which has placed an indefinite moratorium on the utilization of alum for lake management purposes. While Phoslock is utilized with efficacy for phosphorus 'stripping' in lakes, where P is removed from the water column, the efficacy of control of sediment released P under anoxic conditions is relatively low while costs are much higher than aluminum based products. As such, this management measure is not currently recommended for Little York Lake.

Floating Wetland Islands

Floating wetland islands (FWIs) are a relatively new technique in lake management that uses biomimicry to assimilate and process nutrients that would otherwise stimulate algal growth. FWIs are structures composed of woven, recycled plastic material. Vegetation is planted directly in the plastic matrix of the islands with peat and then these structures are deployed in the lake. Once positioned, these units are anchored, typically with rope and cinder blocks. The vegetation grows on the FWIs with their roots growing down through the plastic matrix into the lake. The combination of the root structure and plastic matrix relates to a very high surface area which subsequently serves as habitat for bacteria and biofilm. It is estimated that one 250 ft^2 island has a surface area equal to approximately one acre of natural wetland. Once installed, the FWI serves as a nutrient sink whereby the plants and microbial community associated with the root mass and plastic matrix assimilate phosphorus. In turn, a portion of this phosphorus may be incorporated up the food chain and transported out of the lake system. Diverting this phosphorus reduces the amount of phosphorus which may be assimilated by harmful algae. Studies by Princeton Hydro have shown that one (1) 250 ft^2 island has the potential to sequester up to 10 lbs of phosphorus per year. Given that each pound of phosphorus has the potential to produce up to 1,100 lbs of algae per year, each island has the potential to mitigate 11,000 lbs of wet algae biomass annually.

Floating wetland islands are less costly than the measures mentioned above but do not directly address internal loading. Instead, they remove phosphorus from the epilimnion during the growing season. The cost for a single 250 ft^2 island, including plants and installation, is roughly $10,000. Approximately five (5) islands would be recommended for Little York Lake to be placed in shallow areas that are known to receive storm inflow. These units would be installed in conjunction with a holistic watershed / in-lake management plan and as such are viewed as a piece of an overall management approach.

Boat Motor / Sediment suspension

Significant study has been conducted on the impacts boat motors have on sediment suspension and the effects of this on reductions in water transparency and phosphorus mobilization. The degree of impact is generally related to motor size, water depth and sediment type (Buetow, 2000). There is some evidence that, depending on lake, boat motors may increase phosphorus loading which may lead to increases in algal growth. This is particularly the case in shallow areas comprised of fine, nutrient rich sediments. Impacts are less pronounced or absent in deep areas or areas of coarse sediments. Care should be taken to operate a motorized boat in a mindful manner in shallow areas and no-wake zones. Motor sizes and correlated mixing depths are as follows (Nedohin, 1996 & Yousef, 1978):

- 10 hp – 6 feet
- 28 hp – 10 feet
- 50 hp – 15 feet
- 100 hp – 18 feet

Princeton Hydro recommends abiding by the above guidelines. If necessary, local municipalities may consider adopting ordinances or similar to enforce safe, mindful boating practices.

Harvesting

Macrophyte harvesting is currently conducted on Tully Lake and Little York Lake. In addition to removing nuisance densities of aquatic plants, harvesting has the added benefit of removing the nutrients contained within the plant biomass. For example, Princeton Hydro quantified the phosphorus concentration in SAV at Lake Hopatcong in New Jersey. The mean P concentration in this wet SAV biomass was 2,216 mg/kg. Plant removal from Tully and Little York Lake was estimated at approximately 100 tons wet weight thereby resulting in a removal of approximately 200 kg of P per year. This removal accounts for approximately 2.4% of the annual P load to the lake. Princeton Hydro recommends the continuation of this management measure for maintenance of acceptable macrophyte densities and phosphorus removal.

7.0 Summary

Princeton Hydro, along with project partners, conducted a miniature watershed implementation plan for Little York Lake. This plan aimed to characterize the water quality and pollutant load to the lake and to identify areas in the watershed that may be contributing nutrients to the waterbody that could benefit from best management practices. Ultimately, this plan may be integrated into a full-scale watershed implementation plan or lake management plan to contribute towards the restoration of the lake. In addition, this plan may serve as a jump-off point for securing funding for the projects identified herein.

Phosphorus loading to Little York Lake was estimated to occur primarily between CAFOs and watershed sources, each of which accounted for close to half the annual P load. Internal loading, septic systems and atmospheric deposition were all a very minor component of the load. Constructive partnerships between local farmers, the conservation district(s) and C-OFOKLA should continue to be fostered to stress the importance of conservation and nutrient management. Watershed based BMPs, as highlight in section 5, may serve to reduce external P loading to the lake. Internal loading of P may be investigated further as there does appear to be instances of heightened loading under certain conditions.

Princeton Hydro recommends the adoption of this plan by the town of Preble. The successful implementation of this, and any, watershed plan is contingent on the cooperation of multiple stakeholders of varied interests. Finally, Princeton Hydro would like to thank the local residents, C-OFOKLA, Syracuse University and the Cortland County Soil and Water Conservation District for all of their input, help and support during this project.

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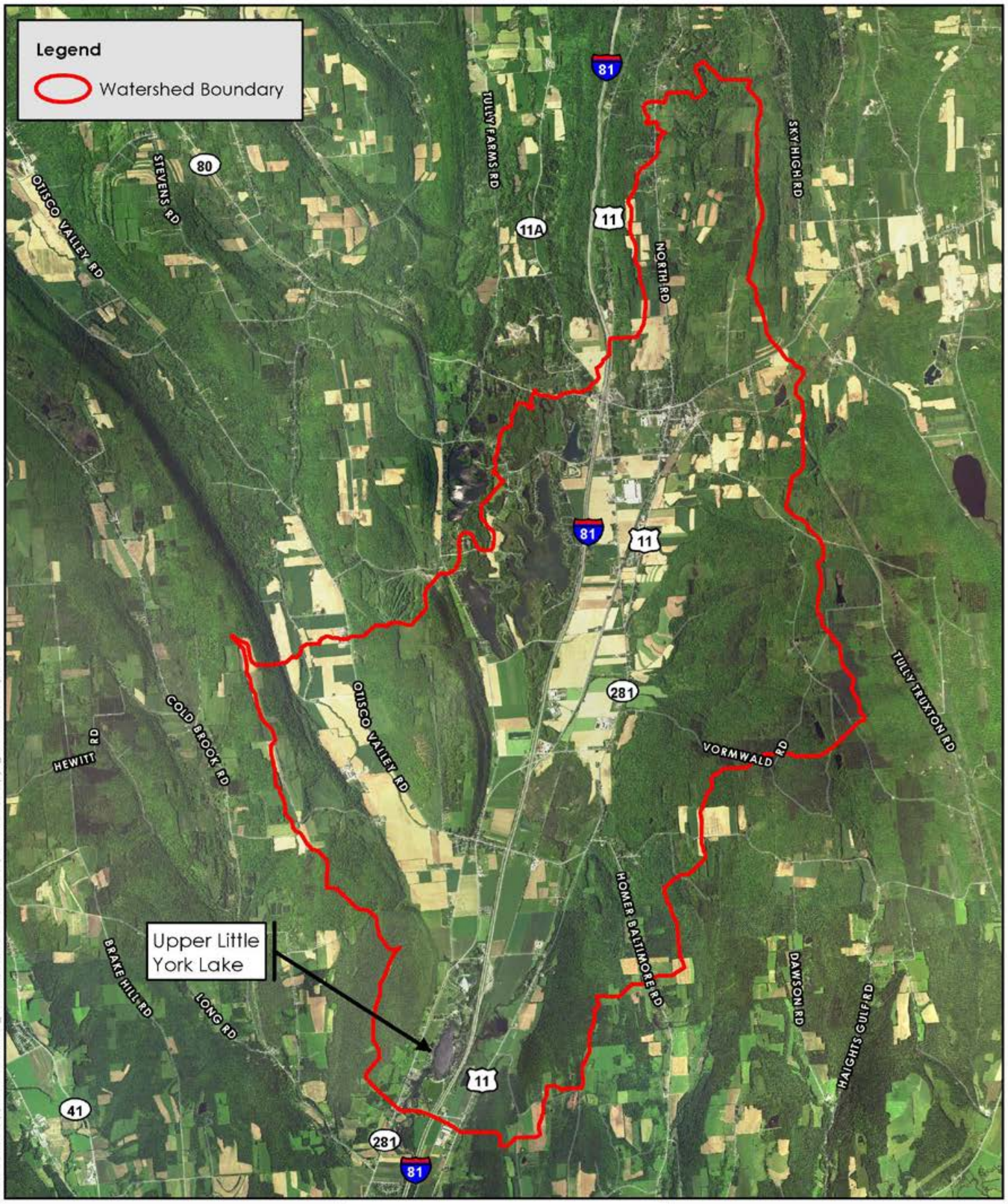
Appendix I



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UPPER LITTLE YORK LAKE WATERSHED

UPPER LITTLE YORK LAKE
WATERSHED IMPLEMENTATION PLAN
TOWNS OF HOMER & PREBLE
ONONDAGA & CORTLAND COUNTIES, NEW YORK

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. 2015 Cortland county orthophotography obtained from the National Agriculture Imagery Program (NAIP).

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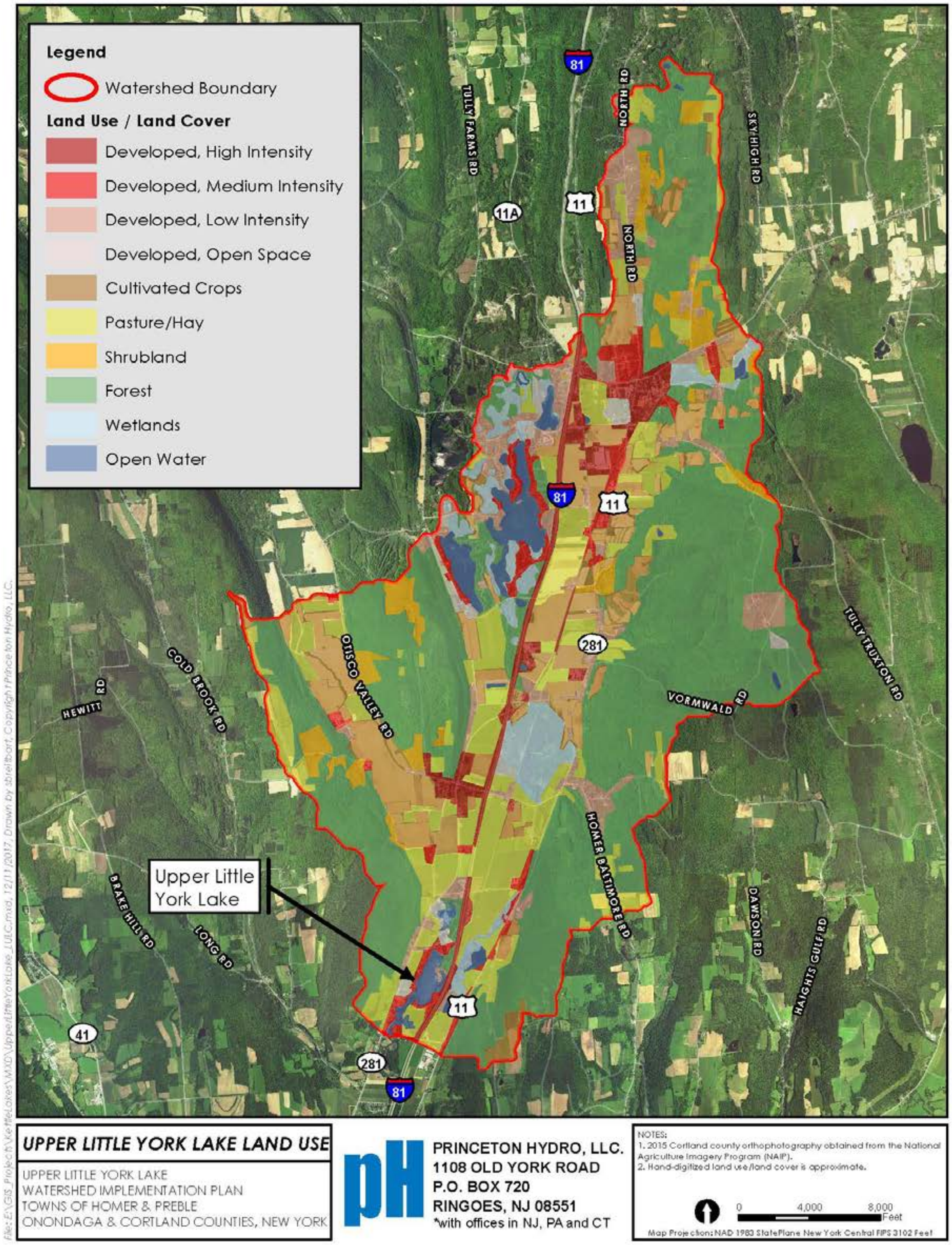
Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet


Legend
Watershed Boundary
Land Use / Land Cover
Developed, High Intensity
Developed, Medium Intensity
Developed, Low Intensity
Developed, Open Space
Cultivated Crops
Pasture/Hay
Shrubland
Forest
Wetlands
Open Water
Upper Little York Lake
TULLY FARMS RD
NORTH RD
SKY HIGH RD
OTISCO VALLEY RD
COLD BROOK RD
HEWITT RD
VORMWALD RD
TULLY TRUXTON RD
HOMER BALTIMORE RD
DAWSON RD
HAIGHTS GULF RD
BRAKE HILL RD
LONG RD
81
11
11A
281
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UPPER LITTLE YORK LAKE LAND USE
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2. Hand-digitized land use/land cover is approximate.
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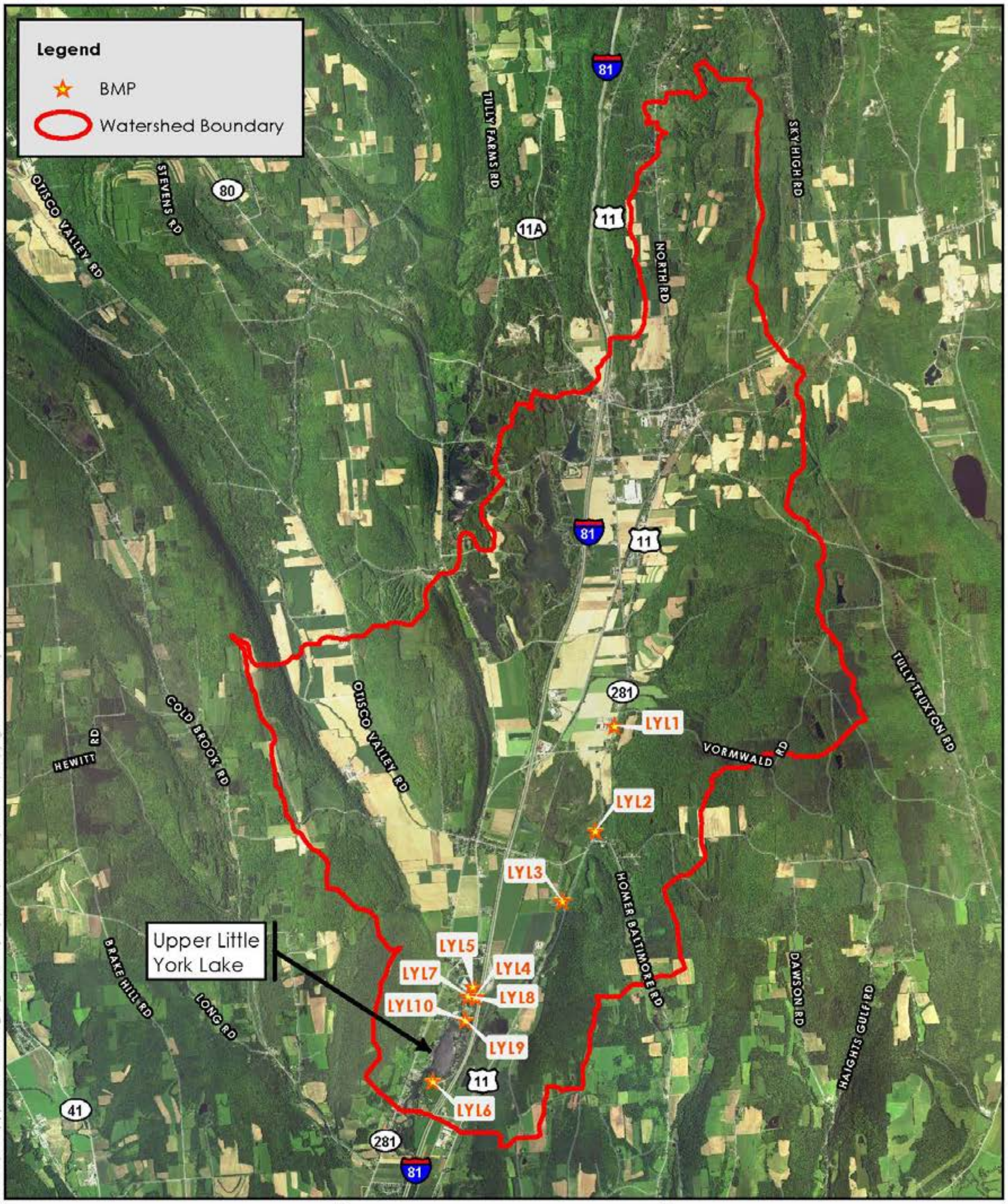
Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet



UPPER LITTLE YORK LAKE BMPS

UPPER LITTLE YORK LAKE
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Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet

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Song Lake
Watershed Implementation Plan
Town of Preble, Cortland County, New York

Prepared for:

Cortland-Onondaga Federation of Kettle Lake Associations
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Contents

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1.0 Introduction

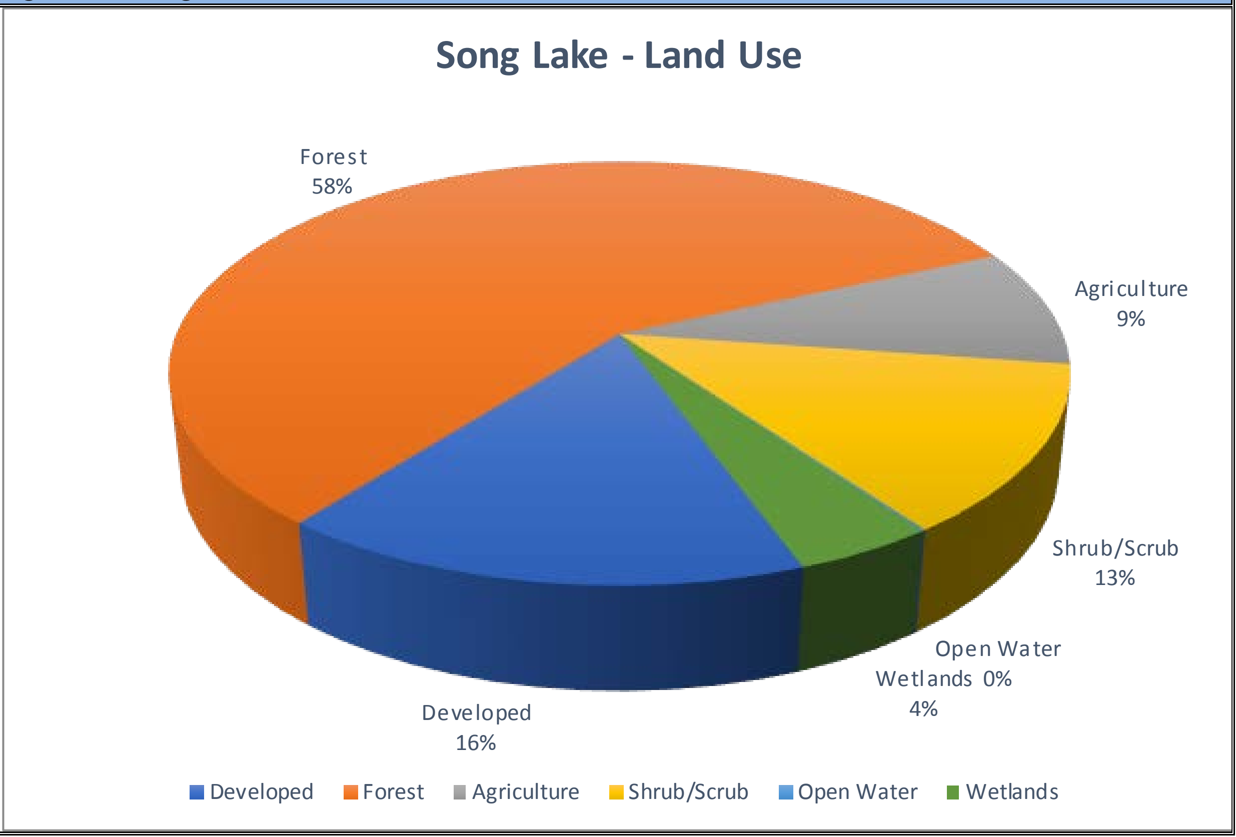
Song Lake, located in the town of Preble, Cortland County, New York, is part of a kettle lake system. Historically, this lake has suffered from symptoms of eutrophication such as elevated phosphorus concentrations, lack of oxygen (anoxia), and harmful algal blooms. In addition, Song Lake has suffered from inundation of invasive macrophyte species and a newly discovered population of zebra mussel (*Dreissena polymorpha*). While the water quality and hydrology of Song Lake has been studied in the past there has not been a concerted effort to conduct a watershed plan for this waterbody. As part of this project, Princeton Hydro, in concert with the Cortland-Onondaga Federation of Kettle Lake Associations (C-OFKLA), Cortland County Soil and Water Conservation District and the Syracuse University Environmental Finance Center, has prepared small-scale Watershed Implementation Plans for Song Lake, Tully Lake, Crooked Lake and Little York Lake. Each plan is comprised of several inter-related components aimed to characterize the water quality of the lake, assess the external and internal phosphorus load, characterize the land use of the watershed and areas where best management practices (BMPs) may be implemented, and to correlate reductions in nutrient loading from each BMP into the nutrient budget for each lake. This plan is considered 'small-scale' given that only a single water quality sampling event was conducted and only ½ day was available to survey the watershed for areas which may benefit from BMPs. As such, this plan does not constitute an extensive lake and watershed management plan. Ultimately, this document may be utilized to seek funding sources to implement the projects contained herein and may be utilized in a larger context for lake management.

2.0 Lake and Watershed Characteristics

Song Lake is a 42 ha (105 ac) kettle lake located in Cortland county, New York. The watershed of Song Lake (Appendix I, Figure 1) encompasses 319 ha (788 ac) resulting in a watershed to lake ratio of 8:1. Typically, watershed to lake ratio values greater than 6 are indicative of a lake which is susceptible to higher levels of nutrient and sediment loading from the watershed. The shoreline development index (SDI), which relates the length of the shoreline to the circumference of a circle of equal area, is 1.46. The SDI is typically utilized to assess the amount of littoral area in a lake and increasing numbers relate to the increased possibility of higher shoreline development and nutrient loading. For comparison, the SDI for Little York Lake is similar at 1.44 while values at Tully and Crooked Lakes are higher with values of 2.66 and 2.06, respectively.

Watershed land use categories are displayed graphically in Appendix I, Figure 2 and broken down by category in figure 2.1.

Figure 2.1: Song Lake – Land Use



Forest represents the dominant land use in the watershed with a coverage of 184 ha (454 ac) located predominantly along the western ridge, and secondarily along the east shore, of the watershed. Developed lands, including low and medium density residential and developed open space, represent 51 ha (127 ac). Medium density residential land is located along the west shoreline of the lake while small patches of low intensity residential are located along the northwestern shore. Developed open space, associated with the Girl Scout camp, is located along the east shore. Scrub / shrub land use is the third most dominant land use comprising 13% of total area and is located along the top of the west ridge.

The hydrology of Song Lake, located in the Susquehanna River basin, is unique in that there are no tributary inflow or outflows (USGS, 2011). Water comes into the lake through groundwater, precipitation and diffuse, stormwater sheetflow and leaves the lake through evaporation and groundwater seepage. Ultimately the catchment of Song Lake, in conjunction with Tully Lake, flow into Little York Lake.

3.0 Water Quality Monitoring

3.1 Introduction and Methodology

Princeton Hydro conducted limited water quality monitoring of Song Lake to characterize the extent of thermal stratification, dissolved oxygen depletion and internal loading of phosphorus. This monitoring was conducted during a single event on July 11, 2017. During this event, Princeton Hydro established a monitoring station at a deep portion of the lake. Maximum depth was recorded and water transparency was measured with a Secchi disc. *In-situ* data collection consisted of measuring temperature, specific conductance, dissolved oxygen, dissolved oxygen percent saturation and pH, at 1 m intervals, throughout the water column. All *in-situ* measures were made utilizing a calibrated Hach MS5 water quality meter tethered to a Hydrolab surveyor. Discrete samples were also collected approximately 0.5 m below the surface and 1 m above the sediments for the analysis of total phosphorus (TP) and soluble reactive phosphorus (SRP). Upon collection, samples were placed on ice to 4°C and forwarded under chain-of-custody procedures to Environmental Compliance Monitoring of Hillsborough, NJ for analysis. Finally, assessment of the plankton (phytoplankton and zooplankton) was conducted through the deployment of a plankton tow net throughout the water column. Upon collection, this sample was preserved with Lugol's solution and analyzed for relative abundance and community composition by Princeton Hydro. The results of this single sampling event are presented below.

3.2 Results

Song Lake was thermally stratified at the time of sampling with temperatures ranging from 14.17°C at 8 m to 24.53°C at the surface (Z_{max} = 8.7 m). Dissolved oxygen concentrations were variable throughout the water column. Anoxic (no oxygen) conditions were measured from 7 m to the lake bottom while concentrations in the upper 2 m were supersaturated. pH values were also variable, ranging from 7.07 at 7 m to 8.46 at the surface. Variation in pH and DO throughout the water column was due to varying rates of primary productivity versus respiration. Secchi disc transparency was excellent with a measure of 3.7 m (Table 3.1 and Figure 3.1).

Discrete measures for phosphorus in the surface waters showed surface TP as 0.01 mg/L while SRP concentrations were 0.003 mg/L. Deep measures for TP were considerably higher than those in the surface with a measure of 0.05 mg/L while deep SRP measures were non-detectable (ND < 0.002 mg/L). Typically, threshold values for TP are 0.03 mg/L while those for SRP are 0.005 mg/L. Concentrations greater than these thresholds may relate to elevated levels of algal and macrophyte growth. The disparity between surface and deep-water TP concentrations, in conjunction with internal anoxia, points to internal loading of P from the sediments.

Phytoplankton samples (Table 3.2) collected at the deep station showed the community to be comprised primarily of cyanobacteria with *Anabaena* exerting dominance over the community. Other cyanobacteria identified during this event included *Coelosphaerium, Microcystis,* and *Lyngbya.* Low densities of a single genus of chlorophyte, diatom, chrysophyte and dinoflagellate were also identified. The zooplankton community was dominated by the herbivorous cladoceran *Daphnia* followed by the copepods then rotifers.

The plankton community at the beach stations showed lower densities of cyanobacteria and greater densities of chlorophytes. *Anabaena* was still present at this station but in much lower densities than the deep station. The zooplankton at the beach were comprised of a single rotifer (*Asplanchna*).

Table 3.1: Song Lake – *In-situ* Data

Kettle Lakes *in-situ* 7/11/17								
Station	Max (m)	Secchi (m)	Depth (m)	Temp (C)	SpC (mS/cm)	DO mg/L	DO % (%)	pH (units)
Song	8.7	3.7	0.1	24.53	0.228	8.92	107.1	8.46
			1.0	24.33	0.228	8.87	106.1	8.45
			2.0	24.05	0.228	8.51	101.3	8.36
			3.0	23.65	0.227	7.89	93.2	8.17
			4.0	22.89	0.230	5.43	63.3	7.64
			5.0	21.14	0.232	1.24	13.9	7.22
			6.0	18.16	0.239	1.49	15.8	7.15
			7.0	15.54	0.241	0.00	0.0	7.07
			8.0	14.17	0.275	0.00	0.0	7.25

Figure 3.1: Song Lake – Temperature and Dissolved Oxygen Profile

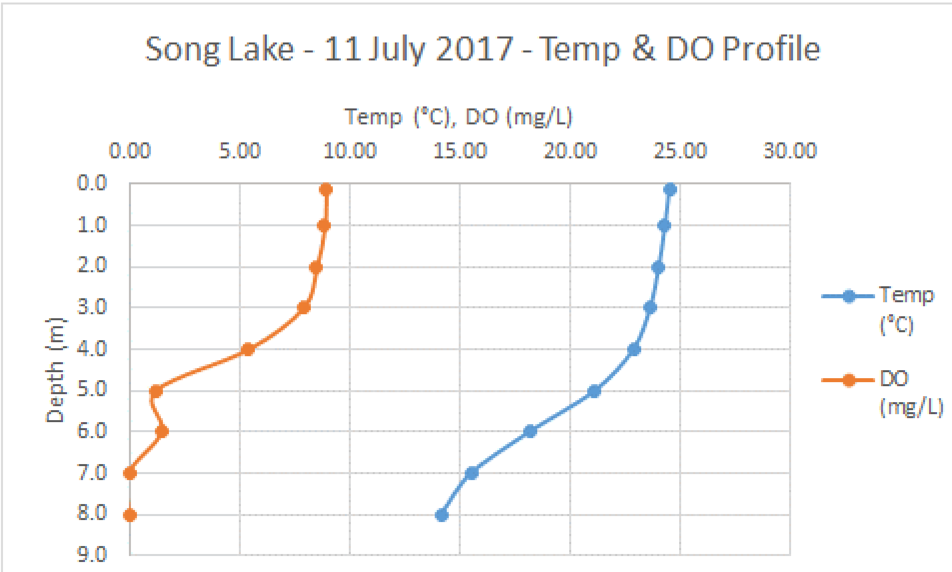


Table 3.2: Song Lake – Plankton Data

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Kettle Lakes			**Sampling Date: 7/11/2017**			**Examination Date: 7/17/2017**		
Site 1: Song Deep			**Site 2: Song Beach**					
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophya (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Synedra	C	P	*Pediastrum*	P		*Anabaena*	A	P
			Sphaerocystis		R	*Coelosphaerium*	P	
			Pediastrum		R	*Microcystis*	P	R
			Mougeotia		C	*Lygnbya*	C	P
			Spirogyra		C			
Chrysophyta (Golden Algae)						**Pyrrhophyta (Dinoflagellates)**		
Dinobryon	P					*Ceratium*	A	
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Daphnia	A		*Cyclops sp.*	C		*Keratella*	P	
			D Nauplius	C		*Kellicottia*	P	
			Diaptomus	R		*Polyarthra*	R	
						Asplanchna		P
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton Genera	8	8						
Total Zooplankton Genera	7	1						
Sample Volume (mL)			**Phytoplankton Key: Bloom (B), Abundant (A) Common (C), Present (P), and Rare (R)**					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R);					

4.0 Pollutant Loading Budget

In order to properly analyze the trophic state of Song Lake and decide on appropriate watershed and in-lake management techniques a comprehensive nutrient budget must first be developed. In this sense all pollutant inputs must be identified and quantified in order to assess those areas which contribute a disproportional amount of that load and their relative influence on lake productivity. The pollutants of concern are total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS). Phosphorus and nitrogen are those two nutrients most critical to plant and algal growth and as such, increases in these nutrients generally lead to increased lake productivity. While both nutrients are modeled the nutrient of primary concern is phosphorus. In most temperate freshwater ecosystems this is the limiting nutrient, that is, the nutrient that is least available in relation to biological demand, and as such, small increases in phosphorus loading may result in exponential increases in algal and weed growth. There are several sources, both external and internal, of phosphorus loading to freshwater systems and each of these potential sources must be evaluated to develop a proper loading estimate. Total suspended solids represent the total amount of inorganic and organic particles within the water column and are the prime determinant of water clarity. High TSS concentrations may be associated with "muddy" water clarity and are generally the result of excessive sediment loading and suspensions of algal particles. Primary sources of sediment loading to the lake are generally derived through erosion of watershed soils and stream banks. Sediment loading generally results in the formation of sediment deltas and infilling of near shore areas thereby increasing aquatic weed habitat and providing the fertile substrate for benthic, filamentous algae. In addition, as phosphorus is often tightly bound to soil particles, increases in sediment loading are commonly correlated with increases in total phosphorus loading.

To address the issues of nutrient loading to trophic response Princeton Hydro conducted a comprehensive pollutant model which served to quantify both external and internal sources of nutrient loading. Those sources of nutrients which were quantified in this study include the following:

External

- Watershed as based on land use and land cover
- Atmospheric deposition
- Septic systems

Internal

- Sediment phosphorus release under oxic and anoxic conditions

Watershed Loading

Watershed based nutrient loading is often times the largest contributor of nutrients and sediments to the receiving waterbody. The watershed area and land uses in conjunction with the soils and slopes which comprise the watershed are all prime determinants of the magnitude of nutrient loading to a lake system. For the purpose of calculating the watershed based nutrient load Princeton Hydro utilized the Unit Areal Loading (UAL) approach. The UAL approach is the recommended pollutant modeling technique as per 40 CFR Part 35, Appendix A, the USEPA's "Guidance for Diagnostic-Feasibility Studies." This modeling approach is widely used by both USEPA and NYSDEC, and Princeton Hydro has applied it to compute the nutrient and sediment loads for well over 200 lakes and reservoirs located throughout the mid-Atlantic and New England states. The unit areal loading modeling approach is based on the premise that land use activities throughout a watershed have a direct impact on nutrient release and transport to a receiving waterbody. Essentially, those land uses which are disturbed (i.e. urban, commercial, and agricultural lands) serve to transport more pollutants to a receiving waterbody than those which are undisturbed (i.e. forest and wetlands). For the application of this model Princeton Hydro first utilized topography data provided by the New York State GIS Clearinghouse to delineate the watershed boundary of Song Lake. Following this delineation land use / land cover data was clipped to this boundary. This data was subsequently reviewed for accuracy utilizing recent aerial photography and reclassified. This information was then utilized as the basis for the selection of pollutant export coefficients, in the units of (Kilogram of pollutant / Hectare / Year), which were most suitable for the watershed given prevailing soils, slopes, geology, and climatic conditions. Sources of export coefficients chosen for the Song Lake watershed were derived primarily from the scientific literature which included but was not limited to those published by Reckhow, 1980 and Uttomark et al, 1974.

Septic

Septic systems serve as the primary method for treating wastes in the Song Lake watershed. Even when the systems are fully operational in their primary function they may contribute phosphorus to the nearby lake. Loading may be attributable to many factors including poor siting as a result of low depth to bedrock, poor soil infiltration or high seasonal water table. In addition, many lakeside houses and septic systems that were originally designed for seasonal use transition into full-time residences and are not properly sized and maintained for this increase in use. For the determination of septic system loads to the lake Princeton Hydro first calculated the number of residences within the zone of influence of the lake or other waterways. For this study, the zone of influence represents those systems within 100 m (330 ft.) of the lake or other waterways per recommendations from the USEPA. Following this determination, Princeton Hydro utilized census data to determine the population served by these systems. Upon this determination, Princeton Hydro applied the phosphorus export coefficient of 0.165 kg/capita/yr to these systems. This export coefficient was developed by Princeton Hydro utilizing empirical septic leachate data on Greenwood Lake (NY/NJ). Nitrogen loading from septic systems was not modeled for this study.

Atmospheric Deposition

The final modeled external input of nutrients and sediments to the lake was that of the atmosphere. Sediments and their bound nutrients may be precipitated as dryfall (dust) or through stripping during rainfall or snow events. While generally recognized as a small source of loading to many waterbodies atmospheric loading may play a critical role in large lakes or in those waterbodies with small watersheds.

This load was calculated using empirically derived loading coefficients (Schueler, 1992, Uttormark, et al. 1974, USEPA 1980 and Owe, et al. 1982) of phosphorus, nitrogen and sediment sources during dryfall and wetfall (rain / snow).

Internal Loading Assessment

A critical component in the development of this WIP was the assessment of the internal phosphorus load for Song Lake. Kettle lakes in this region, formed by glacial retreat, are categorized by relatively deep depths and small watershed areas. These morphometric characteristics, combined with eutrophication resultant from developed watersheds, may lead to deep water anoxia (no oxygen). When this occurs, phosphorus, which is typically chemically bound to iron in the lake sediments, becomes released to the overlying water whereby it becomes accessible to algae for growth.

Internal loading assessment for Song Lake was determined through an evaluation of historical data collected through the CSLAP program including temperature and dissolved oxygen stratification patterns and surface and deep-water total phosphorus concentrations. This data was supplemented through sampling conducted by Princeton Hydro in July 2017. During a single event, Princeton Hydro collected *in-situ* temperature, specific conductance, pH and dissolved oxygen data in profile throughout the water column at the deepest portion of the lake. In addition, samples were collected for total phosphorus and soluble reactive phosphorus in the surface and deep waters of the lake (Section 3). This data was utilized in concert with bathymetric data provided by the NYSDEC to determine the temporal and spatial extent of internal loading in Song Lake. Finally, this information was utilized to help determine export coefficients from the scientific literature for internal phosphorus loading rates under oxic (with oxygen) and anoxic (no oxygen) conditions. The internal loading period was estimated at a total of 120 days per year, 45 of these days were under anoxic conditions while the remainder were under oxic loading. These rates were then applied to Song Lake to determine the annual internal phosphorus load.

Results

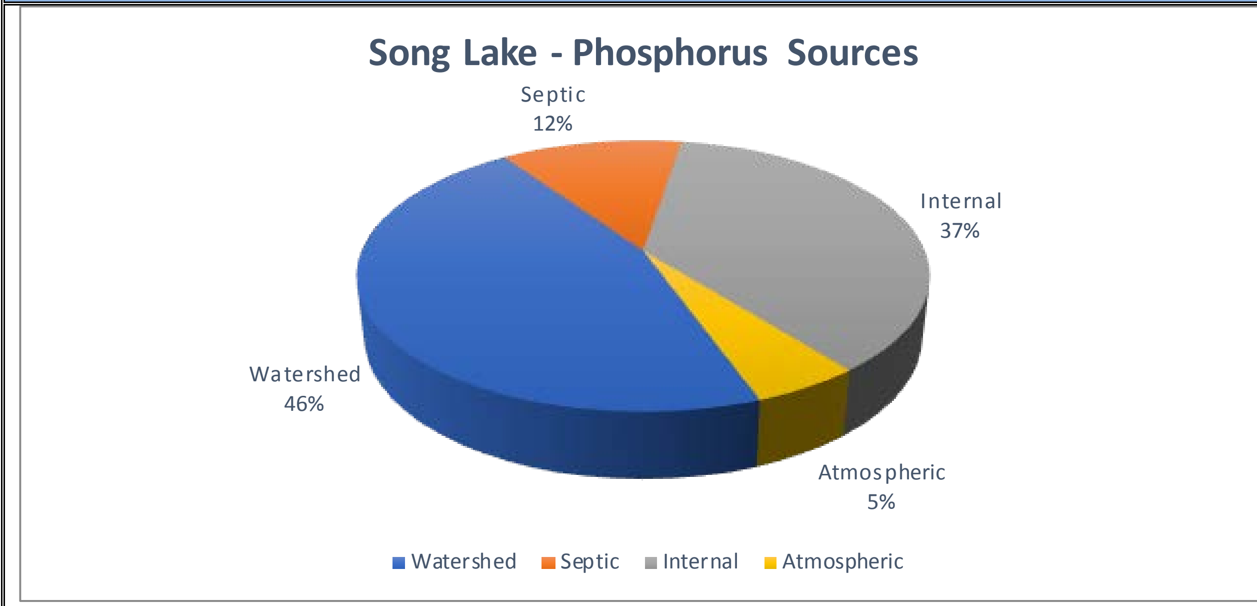
Summary results for nutrient loading to the lake are presented in table 4.1.

Table 4.1: Song Lake Pollutant Loading Summary

Song Lake - Nutrient Loading Summary					
	Watershed	Septic	Internal	Atmospheric	Sum
TN (kg/yr)	1,647	n/a	n/a	425	2,072
TP (kg/yr)	94	25	75	11	205
TSS (kg/yr)	136,548	n/a	n/a	297	136,845

On an annual basis, 2,072 kg (4,568 lbs) of nitrogen, 205 kg (452 lbs) of phosphorus and 136,845 kg (301,692 lbs) of sediments are transported to Song lake. A breakdown of the sources of phosphorus to Song Lake are hereby presented in figures 4.1 and 4.2.

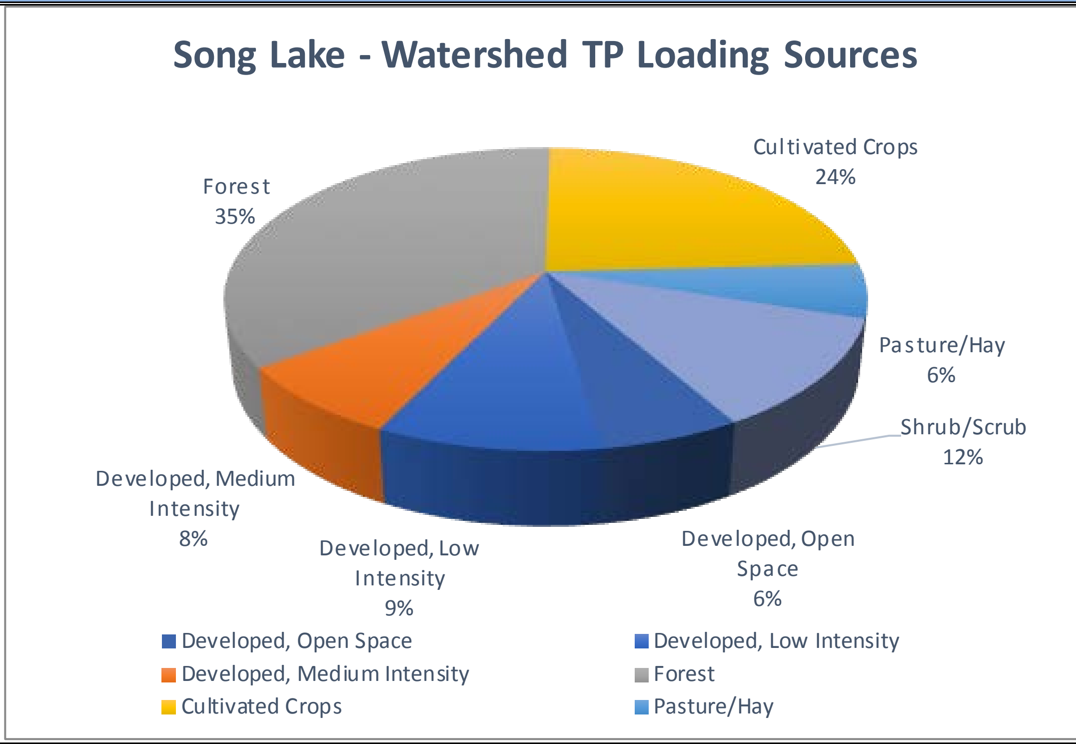
Figure 4.1: Song Lake TP Loading Summary



The primary source of phosphorus loading to Song Lake is derived by external, watershed based sources which contribute 46% to the annual phosphorus budget. Internal loading comprises the second greatest nutrient source at 37% of the annual budget while septic systems comprise 12% of the annual load. It is important to note, that while internal loading is the second greatest contributor of phosphorus to the lake, this contribution only occurs over the short growing period of approximately 120 days. As such, the impact of this load is likely more pronounced relative to its effect on algal growth. Also, the Internal phosphorus load is the largest relative load compared to the internal portions at the other three lakes included in this study. Finally, septic sources, the third greatest contributor overall, are in close spatial proximity to the lake and as such should be actively managed.

Watershed sources of total phosphorus are broken down according to land use area in figure 4.2. Forest represents the largest contributor on an absolute basis, contributing 35% of the annual phosphorus load. Since this is a natural phosphorus load, and proportionally related to the predominance of forest in the watershed, this load is not targeted for management. Instead, agriculture and developed lands, which both account for 30% and 23% of the load, respectively, should be targeted for management.

Figure 4.2: Song Lake – Watershed TP Loading



Watershed based BMPs will need to focus on phosphorus derived from both agriculture and residential land use. Residential (and associated septic systems) based phosphorus loading is the closest in proximity to the lake proper and may have pronounced, acute impacts on lake water quality. The following section will detail the results of a watershed walk conducted by Princeton Hydro in May 2017. Please note, this section is not an exhaustive survey of the watershed. Specifically, many areas, such as agricultural lands, that are on private land or are otherwise inaccessible are excluded from this report but will very likely need managed to reach nutrient reduction goals. This section will provide examples of watershed issues which could benefit from better management and provide information on approximate costs, nutrient reduction and maintenance opportunities for each section.

5.0 Watershed Disturbance and Best Management Practices

In anthropogenically altered watersheds, land use practices have been changed in ways that consequently alter the hydrologic cycle and increase pollutant loading to a lake. For this document, the term 'pollutant,' refers primarily to phosphorus, nitrogen and sediment but may also include salts, heavy metals or pesticides. Some of these pollutants are contributed directly to a lake, but, more commonly, these pollutants are derived from diffuse 'non-point sources.' Non-point source pollution is a term which relates to the contribution of sediments, phosphorus and nitrogen to waterways through land and stream bank erosion, stormwater and septic.

The watersheds of the Kettle Lakes were historically dominated by forest and wetland. With development came the clearing of forests and modification of wetlands, either through infilling, draining or flow alteration. The current land use of the Song Lake watershed is comprised of a mixture of these forests and wetlands but also the human dominated land uses of residential housing, agriculture and transportation infrastructure. The anthropogenic land use changes reduced vegetative cover, exposed soils, increased impervious areas and introduced pollutants through fertilizers, road salts and byproducts of human materials. These changes ultimately lead to a marked change in the hydrology of the watershed in such a way that infiltration and groundwater recharge was likely reduced while the volume and rate of stormwater based surface discharge increased. Ultimately, this change in stormwater leads to increased sediment and nutrient loading to lakes.

To mitigate non-point source pollution, we look to implement watershed best management practices. Watershed best management practices focus on structures, retrofits and even behaviors that may help reduce pollution to a waterway. Princeton Hydro focuses primarily on the selection and utilization of best management practices which fit in with Green Infrastructure. Green Infrastructure is a water management approach that seeks to mimic the natural environment and associated natural processes. These processes include sedimentation, filtration / flow resistance, bio-uptake, recharge, decomposition and bioretainment. Many of the structures or techniques listed below aim to utilize soils and vegetation to mimic these processes found in nature. In doing so, these techniques may serve to not only reduce nutrients to a lake but also serve as habitat for aquatic and terrestrial organisms in an ever increasing fragmented landscape.

The following section details the results of a watershed walk conducted over a half-day in May 2017 by Princeton Hydro and various stakeholders including members of Syracuse University, C-OFOKLA, local residents and members of Cortland County Soil and Water Conservation District. This walk aimed to photo-document areas of non-point source pollution which may benefit from the inclusion of best management practices. This summary is not an exhaustive survey of watershed conditions or BMP recommendations but provides specific examples of areas that can be improved. Furthermore, prior to the implementation of any BMP there will likely be additional, site specific, information needed such as: Utility, topographic and/or transportation surveys, stormwater engineering calculations, property ownership assessment, geologic or soil assessments, local, state and/or federal permits, etc.

Recommendation of BMP types are included along with rough estimates for costs and pollutant removal. Costs are based on similar projects conducted by Princeton Hydro but are very site specific based upon a myriad of factors and do not include associated permitting or engineering. Pollutant removal was computed based on removal estimates provided by various BMP manuals including those issued by the States of New York and Pennsylvania. A summary of the types of maintenance associated with each BMP is also listed. Finally, recommendations on the priority of each BMP are listed as 'low', 'medium', and 'high.' These priorities are based on several factors including overall cost, ease of installation, permitting requirements, the need for cooperation from various government entities and pollutant removal. In general, those projects which may be easily implemented with minimal permitting and cost while providing ecological and pollutant removal benefits are rated as 'High.' This is particularly the case for those sites which occur on public property. Sites of high cost, extensive permitting or those on private property may be more difficult to implement and are therefore given a lower rating.

A summary of recommended BMPs is presented first (table 5.1) followed by a breakdown of each site.

Table 5.1: Song Lake - Watershed BMP Summary

Site	BMP	Estimated Cost ($)	Pollutants Removed (kg/yr)			Priority
			TSS	TP	TN	
1	Shoreline Buffer	$5,000 - $10,000 / lot	400	0.3	1.0	High
2	Reforestation	$10,000	400	0.3	1.0	High

Site 1: Shoreline Buffer

Site Location and Description: *N42.77417° W76.15160° and various* – Lake Shoreline

Issues: Turf grass to edge of lake does not filter nutrients from watershed, is prone to erosion from wind and wave action and lacks ecological benefits of a healthy, vegetated littoral zone.

BMP Recommendation: Vegetate shoreline with native, water loving plants.

Cost: Approximately $5,000 - $10,000 per lot

Pollutant Removal: TSS 400 kg/yr, TP 0.3 kg/yr, TN 1.0 kg/yr

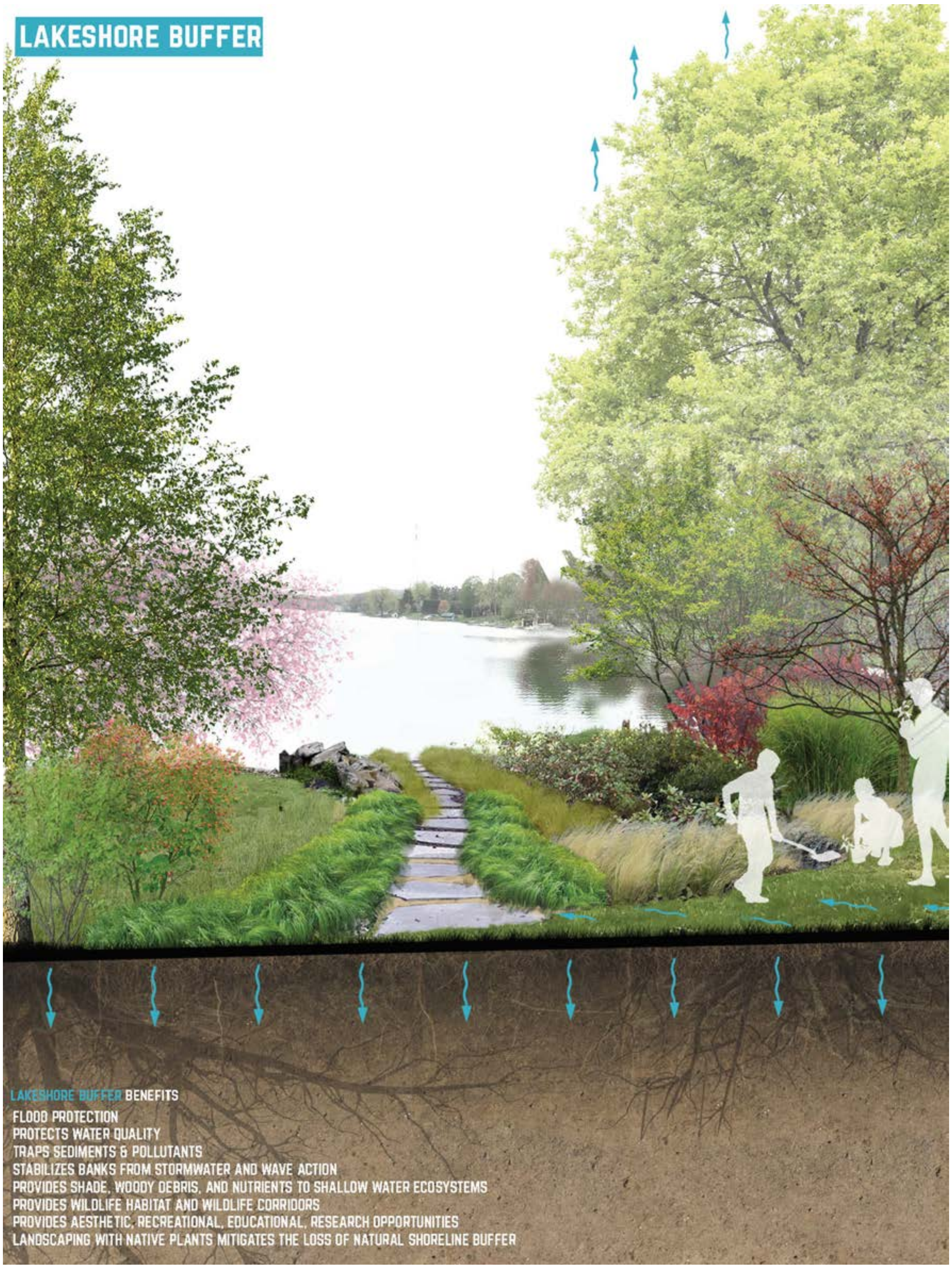
Maintenance: Check site several times throughout the year to manually remove invasives.

Priority: High

Examples of the recommended BMPs are provided below.

Figure 5.1: Song Lake – Typical Shoreline

Figure 5.2: Schematic of Naturalized Shoreline



Source: Mr. Josue Cruz

Site 2: South Shore - Reforestation

Site Location and Description: *N42.76149° W76.14262°* – South shoreline bordering agriculture

Issues: Agricultural land use and road abutting south shore which lacks buffer

BMP Recommendation: Increase vegetated buffer around to road side. If possible, vegetate portion of agricultural land adjacent to road to provide buffer / setback. Cover cropping is in place and should be continued along with conservation minded agricultural practices.

Cost: Approximately $10,000

Pollutant Removal: TSS 400 kg/yr, TP 0.3 kg/yr, TN 1.0 kg/yr

Maintenance: Check site several times throughout the year to manually remove invasives.

Priority: High

Figure 5.3: Song Lake – South Shoreline

Song Mountain Ski Area

A portion of Song Mountain Ski Area drains to Song Lake while the bulk of this area drains to Crooked Lake. BMPs for this area were described in the Crooked Lake WIP and may benefit nutrient reduction to Song Lake. Recommendations for this area included containment and silt fencing for a gravel storage area, riparian buffers, streambank stabilization, creation of a forebay at the mountain's retention basin and utilization of bioswales. Numerous improvements to the maintenance area(s) of this mountain will directly benefit the water quality of both Crooked and Song Lakes.

Septic Management

Much of the residential land surrounding Song Lake utilizes septic systems for treatment of human wastes. The soils, slopes and water table surrounding the lake make on-site wastewater treatment a critical issue for the health of the lake relative to phosphorus loading. Review of the Septic Tank Absorption Field ratings derived from the National Resources Conservation Service show the soils surrounding the lake to range from 'somewhat limited' to 'very limited' in their ability to adequately treat wastes. The estimated total phosphorus load derived from septic systems is 12% of the total load. While a small percentage, the proximity of the systems to the lake impart a higher importance on septic maintenance.

At a minimum, septic tanks should be pumped out every three years. Maintaining this pump-out schedule may reduce phosphorus loading from this source by 20 - 30% (Day, 2001). The Song Lake Property Owners Association has, in the past, incentivized maintenance, inspection and pumping of residential septic systems through a $25 credit. Princeton Hydro commends this incentive and recommends the continuation of this program. In addition, water conservation measures should be implemented at each residence. Lowering the burden on the septic system will allow for reduced nutrient transport to shallow groundwater, and ultimately, Song Lake. Finally, the type and age of septic systems may play a significant role in their functionality and contribution of nutrients to the watershed. This study merely looked at the presence of such systems without conducting a detailed assessment of whether systems need upgraded or replaced. Princeton Hydro recommends implementing such a study with backing by the local municipality and C-OFOKLA.

Lawn Fertilizers

Lawn fertilizers are often an acute source of nutrient pollution to lakes. Often, these products are applied in spring or fall and are quickly washed away during precipitation events directly into the lake where they fuel algal blooms. Currently, New York bans phosphorus fertilizers under ECL § 17-2101 et seq. This law, applicable to all persons, states the use of phosphorus fertilizers on lawns or non-agricultural turf is restricted. Only fertilizers with less than 0.67 %/w phosphate may be applied legally. Furthermore, applications between December 1 and April 1 are prohibited. An application buffer of 20 feet from a waterway or paved surface was also implemented as part of this rule.

Prior to application of any fertilizers, homeowners should have their soil tested by the local agricultural district or similar entity. This testing will provide empirical data on the amount of nutrients in the soil and need for any additional nutrients. Often times, phosphorus is present in abundance in soils and does not need additional application. Many times, the pH of the soil needs adjusted with lime thereby raising pH to a level where the phosphorus that is present in the soil becomes biologically available for turf grass. If fertilizers are needed, homeowners should look for and use phosphorus free fertilizers. Fertilizers are typically labeled with three vales (N-P-K) representing the proportion of nitrogen – phosphorus – potassium in the product. As such, look for fertilizers with a middle number of zero (e.g. 24-0-12) or a bag with 'lake friendly' on the front.

Educational campaigns about the 2012 State rule banning phosphorus fertilizer should be conducted routinely for watershed residents.

Deicers

There is considerable concern in the kettle lakes region of the impact of salts on the water quality of the lakes. Road salts (chloride) are commonly applied not only to driveways but also on state roads and interstate 81. The major issue with the application of road salts is that chloride is a conservative ion that is not readily sorbed onto mineral sources or involved in many significant biochemical reactions. As such, this ion persists in soils and ground and surface water. Ultimately, increases in chloride levels follow increases in watershed development and impervious area. These increases may alter the composition of the lake food web through changes in the invertebrate, plankton and fishery structures.

Management of road salts is a complex subject due to the human safety aspect. When possible, those who apply road salts should look into alternative deicers such as calcium magnesium acetate. Additives, such as natural beet sugars, lower the temperature of brine used to pretreat roads and has been documented in reducing overall salt use. such as Furthermore, where possible, setbacks should be established so that deicing compounds are not applied near surface water sources.

6.0 In-lake Phosphorus Management

In Song Lake, 37% of the annual phosphorus load is estimated to be derived from internal sediment release. As previously mentioned, this load is pronounced related to the other loading sources (watershed, atmospheric and septic) and also in regard to the duration and the timing of the load. Specifically, the internal load represents a pulse of phosphorus during the growing season where it may be readily assimilated by algae for explosive growth. As such, in Song Lake, in-lake management of phosphorus is recommended.

There are several ways to manage internal loading of phosphorus in lake systems. These techniques focus on the maintenance of oxygen in the hypolimnion of the lake or the 'sealing' of lake sediments through the application of chemical flocculant or inactivation products. In addition, floating wetland islands may be utilized to assimilate phosphorus from the epilimnion. While floating wetlands islands will not control internal loading, they serve as a chemical free in-lake measure to reduce the overall phosphorus load in the lake.

Aeration

Aeration for internal phosphorus control focuses on the maintenance of dissolved oxygen in the hypolimnion thereby serving to keep the redox potential at such a level as to mitigate large scale internal release of phosphorus and metals. Aeration systems for lake management typically fall under the categories of systems which disrupt thermal stratification, such as submerged diffuser systems, or systems which keep stratification in place, such as hypolimnetic aeration systems. Typically, the latter is utilized when there is the desire to maintain cold-water fishery habitat while destratification systems are commonly utilized in relatively shallow lakes.

For Song Lake, a hypolimnetic aeration unit, or similar, would likely be the desired type of unit. An additional, full year of monitoring would be necessary to accurately characterize the stratification patterns, carbon demand and phosphorus loading rates to size and spec a system. Estimated costs for monitoring, sizing, material and installation are significant and would be upwards of $150,000 not including annual operating costs.

Nutrient Inactivation

Nutrient inactivation in lakes occurs through the application of a chemical, typically an aluminum or lanthanum/clay based product. Typically, phosphorus is bound to iron in the sediments through a relatively weak molecular bond which is broken under anoxic conditions. In contrast, the bond between phosphorus and nutrient inactivation products is stronger and therefore is not broken, or is broken more slowly, under anoxic conditions.

The products commonly utilized in lake management for nutrient inactivation includes aluminum sulfate (alum) or alum surrogates such as polyaluminum chloride. More recently, the utilization of lanthanum modified bentonite clay based products, such as the proprietary Phoslock©, have been utilized when there are concerns about alum toxicity or regulatory restraints on the use of such products. The latter is currently the case in New York State which has placed an indefinite moratorium on the utilization of alum for lake management purposes. While Phoslock is utilized with efficacy for phosphorus 'stripping' in lakes, where P is removed from the water column, the efficacy of control of sediment released P under anoxic conditions is relatively low while costs are much higher than aluminum based products. As such, this management measure is not currently possible for Song Lake. Alum, if permitted in the future by NYSDEC, could be a feasible and relatively inexpensive product for sealing the profundal sediments thereby preventing phosphorus release. The cost for such an application, including monitoring, bench testing, permitting, application and follow up monitoring would likely range between $75,000 to $125,000. Alum applications which seal the sediments typically provide 5 to 7 years of internal load control.

Floating Wetland Islands

Floating wetland islands (FWIs) are a relatively new technique in lake management that uses biomimicry to assimilate and process nutrients that would otherwise stimulate algal growth. FWIs are structures composed of woven, recycled plastic material. Vegetation is planted directly in the plastic matrix of the islands with peat and then these structures are deployed in the lake. Once positioned, these units are anchored, typically with rope and cinder blocks. The vegetation grows on the FWIs with their roots growing down through the plastic matrix into the lake. The combination of the root structure and plastic matrix relates to a very high surface area which subsequently serves as habitat for bacteria and biofilm. It is estimated that one 250 ft^2 island has a surface area equal to approximately one acre of natural wetland. Once installed, the FWI serves as a nutrient sink whereby the plants and microbial community associated with the root mass and plastic matrix assimilate phosphorus. In turn, a portion of this phosphorus may be incorporated up the food chain and transported out of the lake system. Diverting this phosphorus reduces the amount of phosphorus which may be assimilated by harmful algae. Studies by Princeton Hydro have shown that one (1) 250 ft^2 island has the potential to sequester up to 10 lbs of phosphorus per year. Given that each pound of phosphorus has the potential to produce up to 1,100 lbs of algae per year, each island has the potential to mitigate 11,000 lbs of wet algae biomass annually.

Floating wetland islands are less costly than the measures mentioned above but do not directly address internal loading. Instead, they remove phosphorus from the epilimnion during the growing season. The cost for a single 250 ft^2 island, including plants and installation, is roughly $10,000. Each island has a lifespan of approximately 15 years. Approximately five (5) islands would be recommended for Song Lake to be placed in shallow areas that are known to receive storm inflow. These units would be installed in conjunction with a holistic watershed / in-lake management plan and as such are viewed as a piece of an overall management approach.

Harvesting

Macrophyte harvesting is currently conducted on Tully Lake and Little York Lake. In addition to removing nuisance densities of aquatic plants, harvesting has the added benefit of removing the nutrients contained within the plant biomass. For example, Princeton Hydro quantified the phosphorus concentration in SAV at Lake Hopatcong in New Jersey. The mean P concentration in this wet SAV biomass was 2,216 mg/kg. Plant removal from Tully and Little York Lake was estimated at approximately 100 tons wet weight thereby resulting in a removal of approximately 200 kg of P per year. If plant densities warrant, harvesting may play an effective role in a larger nutrient reduction plan for Song Lake.

Boating Impacts

Significant study has been conducted on the impacts boat motors have on sediment suspension and the effects of this on reductions in water transparency and phosphorus mobilization. The degree of impact is generally related to motor size, water depth and sediment type (Buetow, 2000). There is some evidence that, depending on the lake, boat motors may increase phosphorus loading which may lead to increases in algal growth. This is particularly the case in shallow areas comprised of fine, nutrient rich sediments. Impacts are less pronounced or absent in deep areas or areas of coarse sediments. Care should be taken to operate a motorized boat in a mindful manner in shallow areas and no-wake zones. Motor sizes and correlated mixing depths are as follows (Nedohin, 1996 & Yousef, 1978):

- 10 hp – 6 feet
- 28 hp – 10 feet
- 50 hp – 15 feet
- 100 hp – 18 feet

Princeton Hydro recommends abiding by the above guidelines. If necessary, local municipalities may consider adopting ordinances or similar to enforce safe, mindful boating practices.

7.0 Summary

Princeton Hydro, along with project partners, conducted a miniature watershed implementation plan for Song Lake. This plan aimed to characterize the water quality and pollutant load to the lake and to identify areas in the watershed that may be contributing nutrients to the waterbody that could benefit from best management practices. Ultimately, this plan may be integrated into a full-scale watershed implementation plan or lake management plan to contribute towards the restoration of the lake. In addition, this plan may serve as a jump-off point for securing funding for the projects identified herein.

Phosphorus loading to Song Lake was estimated to occur primarily from the watershed which contributes 46% of the P load followed by internal loading (37%) and septic systems (12%). Of the watershed sources, agriculture contributes approximately 30% of the load while residential contributes 23% of the load. Watershed BMPs will need to focus on controlling nutrient loading from both agriculture and developed land to reduce phosphorus loading to the lake. The internal phosphorus load to the lake is sizeable compared to the external load and would warrant management. Currently, alum and surrogates are banned in the State. If the moratorium is lifted in the future, this may serve as an effective means to neutralize internal P loading for 5 to 7 years. Another solution for internal P control may include the design and installation of a hypolimnetic (or similar) aeration system. This system could provide longer term control but with more capital and operational costs.

Princeton Hydro recommends the adoption of this plan by the town of Preble. The successful implementation of this, and any, watershed plan is contingent on the cooperation of multiple stakeholders of varied interests. Finally, Princeton Hydro would like to thank the local residents, C-OFOKLA, Syracuse University and the Cortland County Soil and Water Conservation District for all of their input, help and support during this project.

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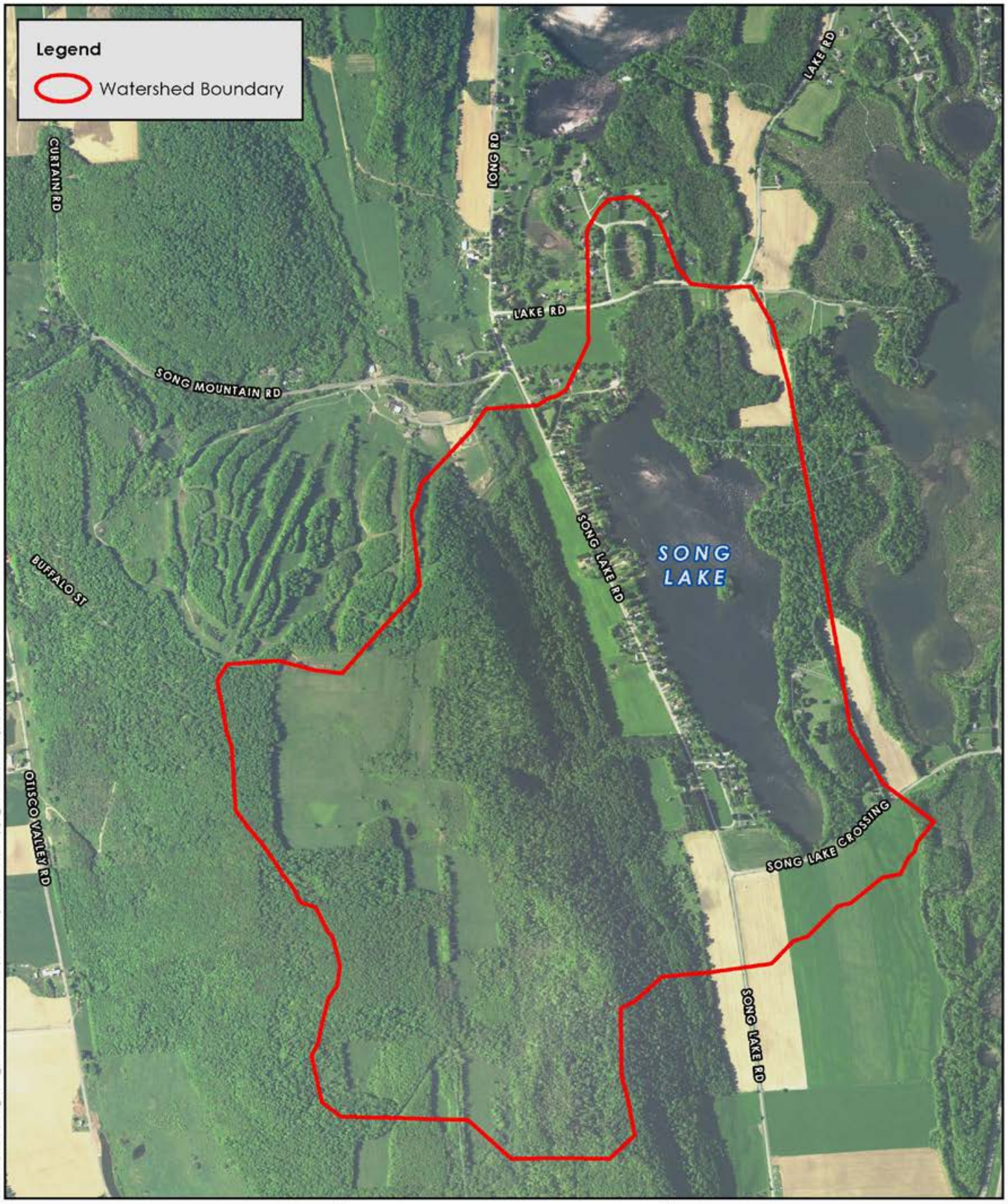
Appendix I



SONG LAKE WATERSHED

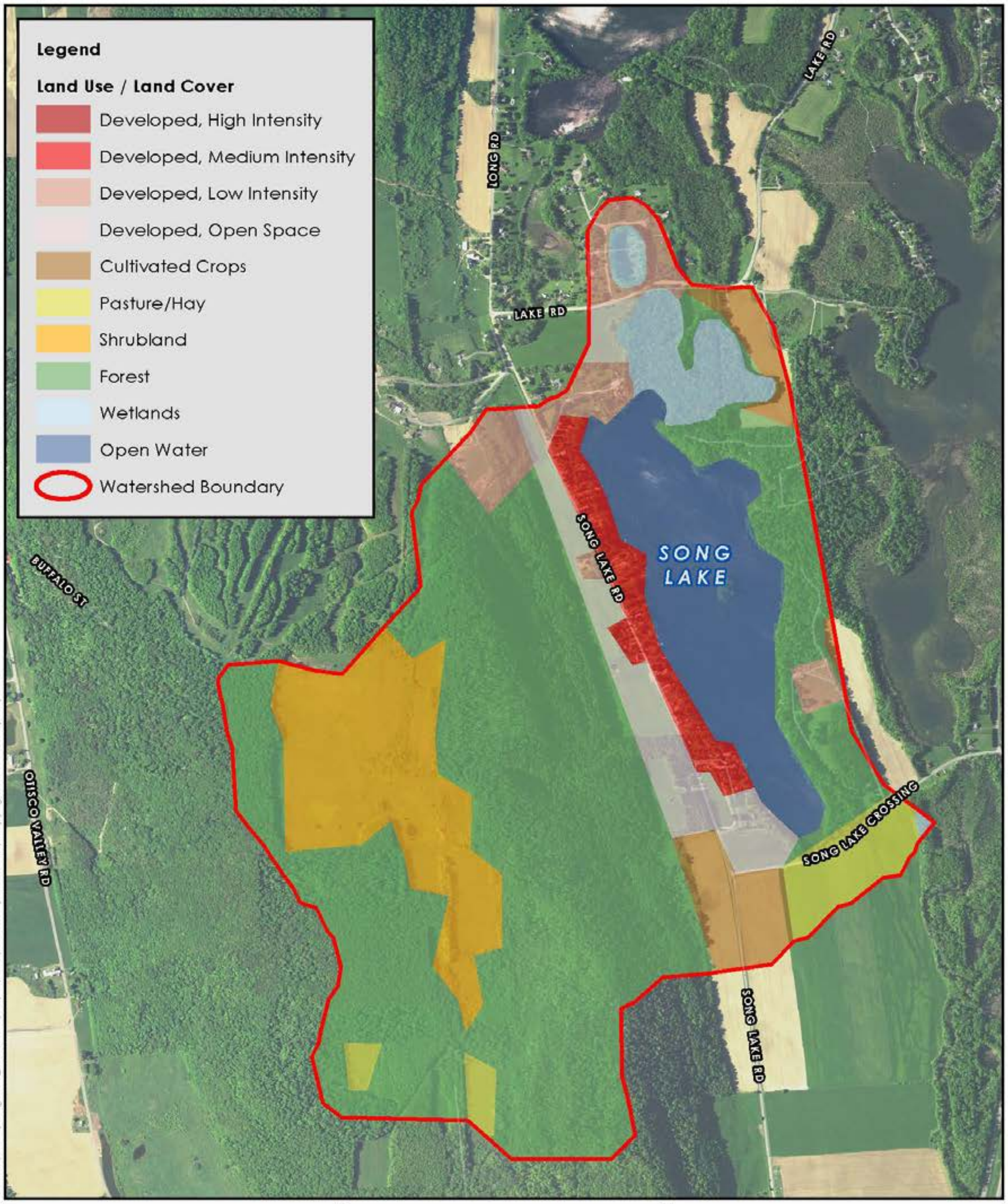
SONG LAKE
WATERSHED IMPLEMENTATION PLAN
TOWN OF PREBLE
CORTLAND COUNTY, NEW YORK

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. 2015 Cortland county orthophotography obtained from the National Agriculture Imagery Program (NAIP).

0 1,000 2,000 Feet

Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet



SONG LAKE LAND USE

SONG LAKE
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TOWN OF PREBLE
CORTLAND COUNTY, NEW YORK

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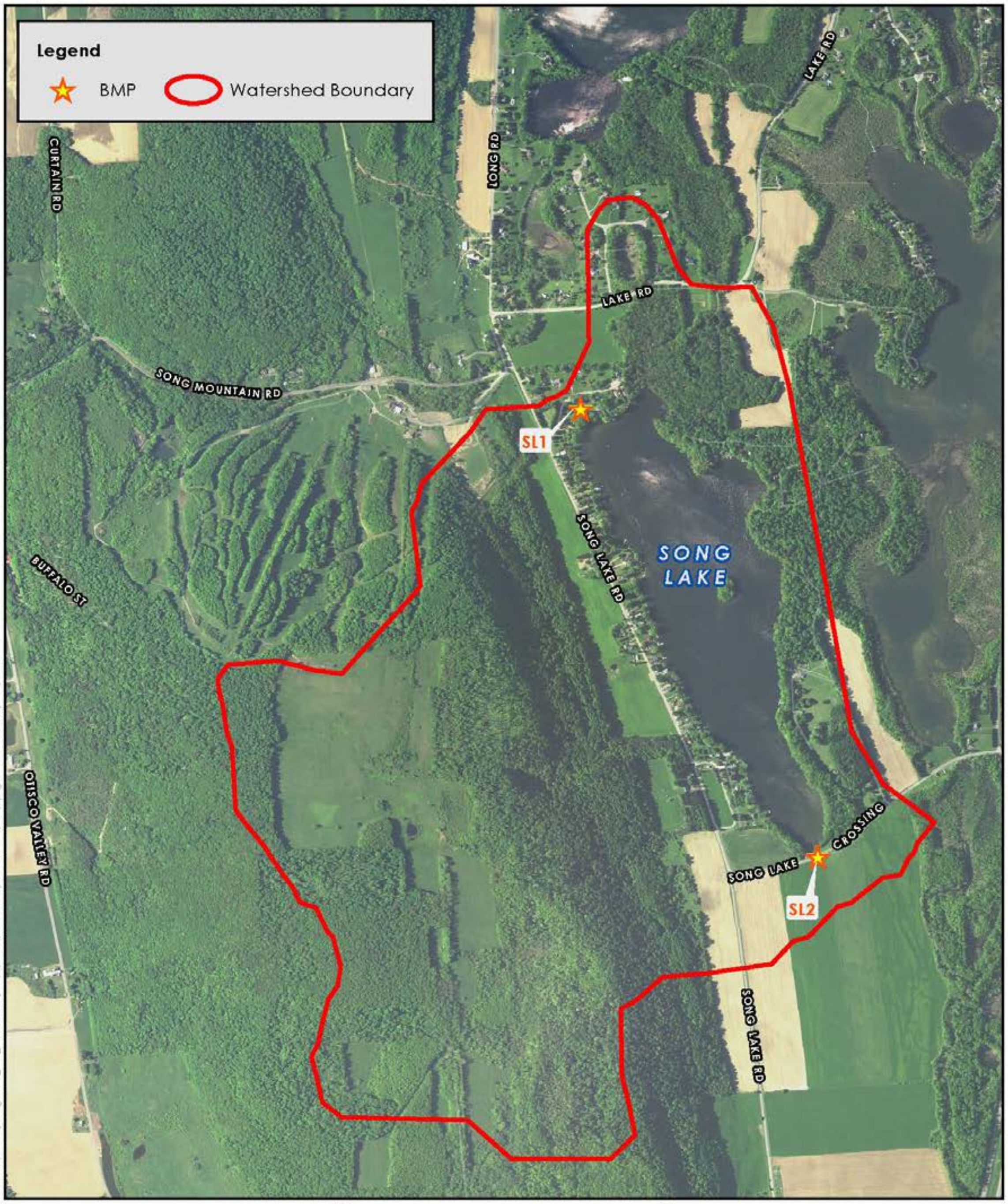
NOTES:
1. 2015 Cortland county orthophotography obtained from the National Agriculture Imagery Program (NAIP).
2. Hand-digitized land use/land cover is approximate.

0 1,000 2,000 Feet

Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet



SONG LAKE BMPS

SONG LAKE
WATERSHED IMPLEMENTATION PLAN
TOWN OF PREBLE
CORTLAND COUNTY, NEW YORK

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. 2015 Cortland county orthophotography obtained from the National Agriculture Imagery Program (NAIP).

0 1,000 2,000 Feet

Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet

File: E:\GIS_Projects\KettleLakes\MXD\SongLake_WS_BMPs.mxd, 11/9/2017. Drawn by sbeltbart. Copyright Princeton Hydro, LLC.

Tully Lake
Watershed Implementation Plan
Towns of Tully & Preble, Onondaga & Cortland Counties, New York

Prepared for:

Cortland-Onondaga Federation of Kettle Lake Associations
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Contents

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1.0 Introduction

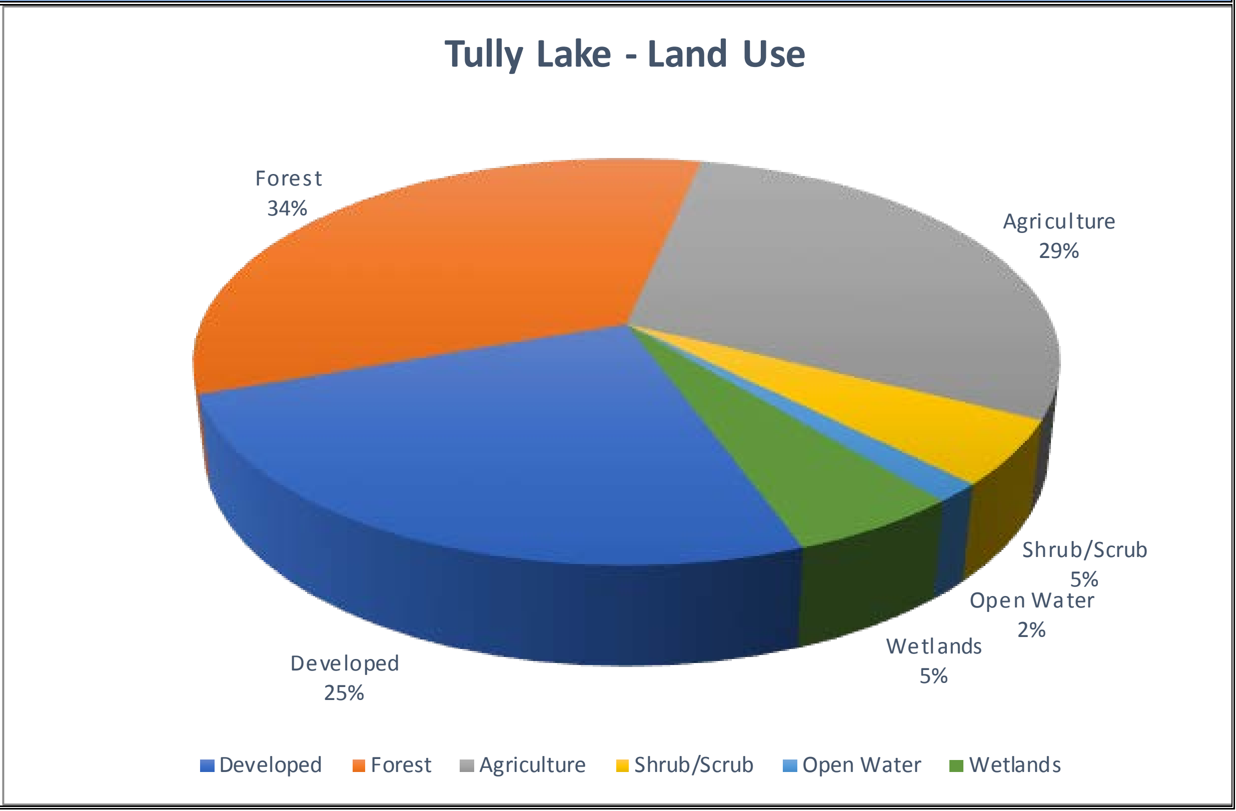
Tully Lake, located in the town of Preble, Onondaga and Cortland Counties, New York, is part of a kettle lake system. Historically, this lake has suffered from symptoms of eutrophication such as dense aquatic vegetation, elevated phosphorus concentrations, lack of oxygen (anoxia), and algal blooms. While the water quality and hydrology of Tully Lake has been studied in the past there has not been a concerted effort to conduct a watershed plan for this waterbody. As part of this project, Princeton Hydro, in concert with the Cortland-Onondaga Federation of Kettle Lake Associations (C-OFKLA), Cortland County Soil and Water Conservation District and the Syracuse University Environmental Finance Center, has prepared small-scale Watershed Implementation Plans for Tully Lake, Crooked Lake, Song Lake and Little York Lake. Each plan is comprised of several inter-related components aimed to characterize the water quality of the lake, assess the external and internal phosphorus load, characterize the land use of the watershed and areas where best management practices (BMPs) may be implemented, and to correlate reductions in nutrient loading from each BMP into the nutrient budget for each lake. This plan is considered 'small-scale' given that only a single water quality sampling event was conducted and only ½ day was available to survey the watershed for areas which may benefit from BMPs. As such, this plan does not constitute an extensive lake and watershed management plan. Ultimately, this document may be utilized to seek funding sources to implement the projects contained herein and may be utilized in a larger context for lake management.

2.0 Lake and Watershed Characteristics

Tully lake is a 91 ha (226 ac) kettle lake located in Cortland and Onondaga counties, New York. The lake has a mean depth of 2.8 m (9.2 ft) and a moderate maximum depth of approximately 11 m (36 ft) located in the southern portion of the lake. The shape of Tully lake is irregular leading to a shoreline of 9.8 km (6.1 mi) resulting in a shoreline development index (SDI) of 2.66. The shoreline development index is a unitless figure which relates the length of shoreline to the circumference of a perfectly circular lake of the same area. Many kettle and volcanic cirque lakes have smaller indices while larger index values are associated with the potential for higher development pressure and nutrient loading to a lake. For comparison, the SDI of Song and Little York Lakes are 1.46 and 1.44, respectively. The watershed of Tully Lake (Appendix I, Figure 1) encompasses 2,621 ha (6,476 ac) resulting in a watershed to lake ratio of 29:1. Typically, watershed to lake ratio values greater than 6 are indicative of a lake which is susceptible to higher levels of nutrient and sediment loading from the watershed.

Watershed land use categories are displayed graphically in Appendix I, Figure 2 and broken down by category in figure 2.1.

Figure 2.1: Tully Lake – Watershed Land Use



Forest represents the dominant land use in the watershed with a coverage of 886 ha (2,190 ac) located predominantly the northern and eastern portions of the watershed. Agriculture represents the second most prevalent land use category, comprising 762 ha (1,884 ac) of the watershed while developed lands comprise the third most prevalent land use category, comprising 657 ha (1,624 ac).

The inflow of Tully lake is derived from the outflow of Green Lake and also through the west branch of the Tioughnioga River and shallow groundwater derived from nearby Crooked Lake (at times) and also from the eastern ridge. Outflow from Tully Lake continues the west branch of the Tioughnioga River which subsequently flows in a southern direction into Little York Lake. Point source discharge to the lake includes the Tully STP.

3.0 Water Quality Monitoring

3.1 Introduction and Methodology

Princeton Hydro conducted limited water quality monitoring of Tully Lake to characterize the extent of thermal stratification, dissolved oxygen depletion and internal loading of phosphorus. This monitoring was conducted during a single event on July 11, 2017. During this event, Princeton Hydro established a monitoring station at a deep portion of the lake. Maximum depth was recorded and water transparency was measured with a Secchi disc. *In-situ* data collection consisted of measuring temperature, specific conductance, dissolved oxygen, dissolved oxygen percent saturation and pH, at 1 m intervals, throughout the water column. All *in-situ* measures were made utilizing a calibrated Hach MS5 water quality meter tethered to a Hydrolab surveyor. Discrete samples were also collected approximately 0.5 m below the surface and 1 m above the sediments for the analysis of total phosphorus (TP) and soluble reactive phosphorus (SRP). Upon collection, samples were placed on ice to 4°C and forwarded under chain-of-custody procedures to Environmental Compliance Monitoring of Hillsborough, NJ for analysis. Finally, assessment of the plankton (phytoplankton and zooplankton) was conducted through the deployment of a plankton tow net throughout the water column. Upon collection, this sample was preserved with Lugol's solution and analyzed for relative abundance and community composition by Princeton Hydro. The results of this single sampling event are presented below.

3.2 Results

Tully Lake was thermally stratified at the time of sampling with temperatures ranging from 10.06°C at 9 m to 22.95°C at the surface (Z_{max} = 9.3 m). Dissolved oxygen (DO) concentrations were anoxic from 7 m to the bottom and supersaturated in the upper 2 m with a maximum concentration of 10.75 mg/L (125.3%) at the surface. pH values were variable throughout the water column ranging from 7.30 in the deep water to 8.45 at the surface. Variations in DO and pH were indicative of higher levels of productivity in the upper 1 m of the water column and elevated bacterial respiration in the hypolimnion.

Discrete samples collected in the surface waters showed a relatively low TP concentration of 0.02 mg/L while SRP concentrations were 0.005 mg/L. Deep water TP concentrations were slightly higher than those in the surface with a measure of 0.03 mg/L while SRP concentrations were 0.004 mg/L. Typically, TP values should remain below 0.03 mg/L and SRP values below 0.005 mg/L to preclude excessive primary productivity.

The plankton community at the deep station of Tully lake showed low to moderate species richness with the dinoflagellate *Ceratium* and the chrysophyte *Chrysophaerella* exerting dominance in the community. Cyanobacteria were present with *Anabaena* listed as 'common' and *Microcystis* listed as 'rare.' The zooplankton community showed an abundance of the herbivorous cladoceran *Daphnia* and the copepod *Cyclops*.

Algal densities at the beach station were lower than at mid-lake with *Ceratium* listed as 'present.' The cyanobacteria *Anabaena* and *Microcystis* were also identified but listed as 'rare.' The zooplankton community was sparse at this station with two genera (*Polyarthra* and *Bosmina*) listed as 'rare.'

Table 3.1: Tully Lake – *In-situ* Data

Kettle Lakes *in-situ* 7/11/17								
Station	Max (m)	Secchi (m)	Depth (m)	Temp (C)	SpC (mS/cm)	DO mg/L	DO % (%)	pH (units)
Tully	9.3	3.4	0.1	22.95	0.505	10.75	125.3	8.45
			1.0	22.57	0.491	10.50	121.6	8.41
			2.0	20.62	0.437	8.78	98.0	7.99
			3.0	19.08	0.462	7.44	80.4	7.72
			4.0	17.74	0.487	5.94	62.4	7.51
			5.0	14.88	0.494	4.16	41.3	7.46
			6.0	13.14	0.522	1.69	16.2	7.30
			7.0	11.31	0.536	0.00	0.0	7.30
			8.0	10.45	0.544	0.00	0.0	7.30
			9.0	10.06	0.556	0.00	0.0	7.30

Figure 3.1: Tully Lake – Temperature and Dissolved Oxygen Profile

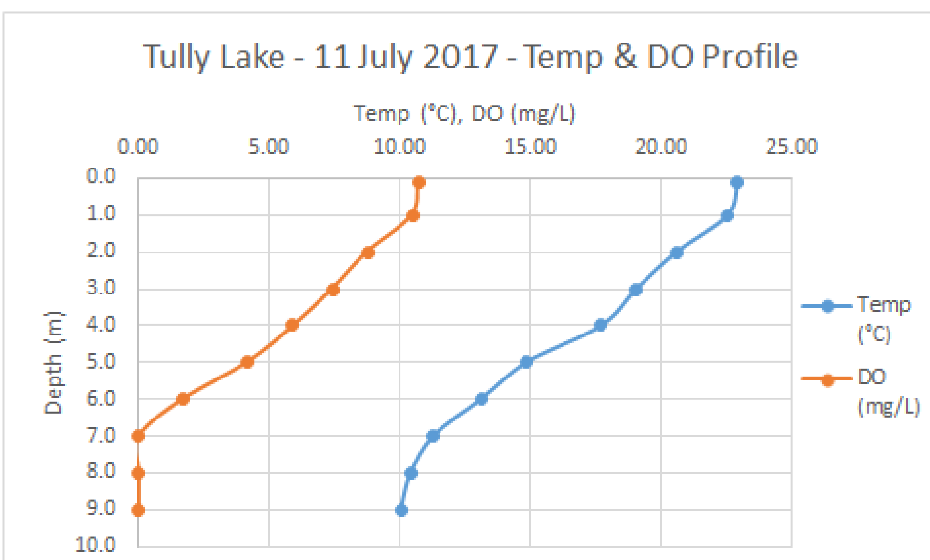


Table 3.2: Tully Lake – Plankton Data

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Kettle Lakes			Sampling Date: 7/11/2017			Examination Date: 7/17/2017		
Site 1: Tully Deep			Site 2: Tully Beach					
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophya (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Fragilaria	P	R	*Sphaerocystis*		P	*Anabaena*	C	R
			Crucigenia		R	*Microcystis*	R	R
Chrysophyta (Golden Algae)						**Pyrrhophyta (Dinoflagellates)**		
Chrysophaerella	A					*Ceratium*	A	P
Dinobryon	C	R						
Mallomonas	R							
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Daphnia	A		*Cyclops sp.*	A		*Keratella*	P	
Diaphanosoma	R		*D Nauplius*	C		*Kellicottia*	R	
Bosmina		R	*Diaptomus*	P		*Polyarthra*	R	R
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton Genera	7	7						
Total Zooplankton Genera	8	2						
Sample Volume (mL)			**Phytoplankton Key: Bloom (B), Abundant (A) Common (C), Present (P), and Rare (R)**					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous					

4.0 Pollutant Loading Budget

4.1 Introduction

In order to properly analyze the trophic state of Tully Lake and decide on appropriate watershed and in-lake management techniques a comprehensive nutrient budget must first be developed. In this sense all pollutant inputs must be identified and quantified in order to assess those areas which contribute a disproportional amount of that load and their relative influence on lake productivity. The pollutants of concern are total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS). Phosphorus and nitrogen are those two nutrients most critical to plant and algal growth and as such, increases in these nutrients generally lead to increased lake productivity. While both nutrients are modeled the nutrient of primary concern is phosphorus. In most temperate freshwater ecosystems this is the limiting nutrient, that is, the nutrient that is least available in relation to biological demand, and as such, small increases in phosphorus loading may result in exponential increases in algal and weed growth. There are several sources, both external and internal, of phosphorus loading to freshwater systems and each of these potential sources must be evaluated to develop a proper loading estimate. Total suspended solids represent the total amount of inorganic and organic particles within the water column and are the prime determinant of water clarity. High TSS concentrations may be associated with “muddy” water clarity and are generally the result of excessive sediment loading and suspensions of algal particles. Primary sources of sediment loading to the lake are generally derived through erosion of watershed soils and stream banks. Sediment loading generally results in the formation of sediment deltas and infilling of near shore areas thereby increasing aquatic weed habitat and providing the fertile substrate for benthic, filamentous algae. In addition, as phosphorus is often tightly bound to soil particles, increases in sediment loading are commonly correlated with increases in total phosphorus loading.

To address the issues of nutrient loading to trophic response Princeton Hydro conducted a comprehensive pollutant model which served to quantify both external and internal sources of nutrient loading. Those sources of nutrients which were quantified in this study include the following:

External

- Watershed as based on land use and land cover
- Atmospheric deposition
- Septic systems
- Point source

Internal

- Sediment phosphorus release under oxic and anoxic conditions

4.2 Methodology

Watershed Loading

Watershed based nutrient loading is often times the largest contributor of nutrients and sediments to the receiving waterbody. The watershed area and land uses in conjunction with the soils and slopes which comprise the watershed are all prime determinants of the magnitude of nutrient loading to a lake system. For the purpose of calculating the watershed based nutrient load Princeton Hydro utilized the Unit Areal Loading (UAL) approach. The UAL approach is the recommended pollutant modeling technique as per 40 CFR Part 35, Appendix A, the USEPA's "Guidance for Diagnostic-Feasibility Studies." This modeling approach is widely used by both USEPA and NYSDEC, and Princeton Hydro has applied it to compute the nutrient and sediment loads for well over 200 lakes and reservoirs located throughout the mid-Atlantic and New England states. The unit areal loading modeling approach is based on the premise that land use activities throughout a watershed have a direct impact on nutrient release and transport to a receiving waterbody. Essentially, those land uses which are disturbed (i.e. urban, commercial, and agricultural lands) serve to transport more pollutants to a receiving waterbody than those which are undisturbed (i.e. forest and wetlands). For the application of this model Princeton Hydro first utilized topography data provided by the New York State GIS Clearinghouse to delineate the watershed boundary of Tully Lake. Following this delineation land use / land cover data was clipped to this boundary. This data was subsequently reviewed for accuracy utilizing recent aerial photography and reclassified. This information was then utilized as the basis for the selection of pollutant export coefficients, in the units of (Kilogram of pollutant / Hectare / Year), which were most suitable for the watershed given prevailing soils, slopes, geology, and climatic conditions. Sources of export coefficients chosen for the Tully Lake watershed were derived primarily from the scientific literature which included but was not limited to those published by Reckhow, 1980 and Uttomark et al, 1974.

Septic

Septic systems serve as the primary method for treating wastes in the Tully Lake watershed. Even when the systems are fully operational in their primary function they may contribute phosphorus to the nearby lake. Loading may be attributable to many factors including poor siting as a result of low depth to bedrock, poor soil infiltration or high seasonal water table. In addition, many lakeside houses and septic systems that were originally designed for seasonal use transition into full-time residences and are not properly sized and maintained for this increase in use. For the determination of septic system loads to the lake Princeton Hydro first calculated the number of residences within the zone of influence of the lake or other waterways. For this study, the zone of influence represents those systems within 100 m (330 ft.) of waterways per recommendations from the USEPA. Following this determination, Princeton Hydro utilized census data to determine the population served by these systems. Upon this determination, Princeton Hydro applied the phosphorus export coefficient of 0.165 kg/capita/yr to these systems. This export coefficient was developed by Princeton Hydro utilizing empirical septic leachate data on Greenwood Lake (NY/NJ). Nitrogen loading from septic systems was not modeled for this study.

Atmospheric Deposition

The final modeled external input of nutrients and sediments to the lake was that of the atmosphere. Sediments and their bound nutrients may be precipitated as dryfall (dust) or through stripping during rainfall or snow events. While generally recognized as a small source of loading to many waterbodies atmospheric loading may play a critical role in large lakes or in those waterbodies with small watersheds.

This load was calculated using empirically derived loading coefficients (Schueler, 1992, Uttormark, et al. 1974, USEPA 1980 and Owe, et al. 1982) of phosphorus, nitrogen and sediment sources during dryfall and wetfall (rain / snow).

Internal Loading Assessment

A critical component in the development of this WIP was the assessment of the internal phosphorus load for Tully Lake. Kettle lakes in this region, formed by glacial retreat, are categorized by relatively deep depths and small watershed areas. These morphological characteristics, combined with eutrophication resultant from developed watersheds, may lead to deep water anoxia (no oxygen). When this occurs, phosphorus, which is typically chemically bound to iron in the lake sediments, becomes released to the overlying water whereby it becomes accessible to algae for growth.

Internal loading assessment for Tully Lake was determined through an evaluation of historical data collected through the CSLAP program including temperature and dissolved oxygen stratification patterns and surface and deep-water total phosphorus concentrations. This data was supplemented through sampling conducted by Princeton Hydro in July 2017. During a single event, Princeton Hydro collected *in-situ* temperature, specific conductance, pH and dissolved oxygen data in profile throughout the water column at the deepest portion of the lake. In addition, samples were collected for total phosphorus and soluble reactive phosphorus in the surface and deep waters of the lake. This data was utilized in concert with bathymetric data provided by the NYSDEC to determine the temporal and spatial extent of internal loading in Tully Lake. Finally, this information was utilized to help determine export coefficients from the scientific literature for internal phosphorus loading rates under oxic (with oxygen) and anoxic (no oxygen) conditions. The internal loading period was estimated at a total of 120 days per year, 45 of these days were under anoxic conditions while the remainder were under oxic loading. These rates were then applied to Tully Lake to determine the annual internal phosphorus load.

Point Sources

There is a single point source discharge with available data located in the Tully watershed. This point source is the Tully STP located at 42.793389°N, -76.106222°W. Pollutant data for this source was collected from the EPA Enforcement and Compliance History Online (ECHO) database. Data for total nitrogen, total phosphorus and total suspended solids was available from 2013 – 2017. For this study, Princeton Hydro utilized the mean load from 2013 – 2016.

Macrophyte Harvesting – Nutrient Removal

The final component in assessing the nutrient budget for Tully Lake was the integration of macrophyte harvesting. This management measure is utilized primarily to control nuisance levels of aquatic vegetation but has the added benefit of removing those nutrients contained within plant biomass from the lake thereby serving as an in-lake bmp. For this study, Princeton Hydro received estimated mass removed per year from the Cortland County Soil and Water Conservation District. This value was estimated to range between 100 to 250 tons per year, wet weight. Princeton Hydro utilized the low estimate (100 tons/year) in conjunction with a phosphorus value of 2,216 mg/kg of P to compute the mass of phosphorus removed from the lake on an annual basis. The plant phosphorus concentration data was obtained from Princeton Hydro's in-house database on macrophyte phosphorus concentrations derived from work conducted on Lake Hopatcong in New Jersey.

4.3 Results

Summary results for nutrient loading to the lake are presented in table 4.1.

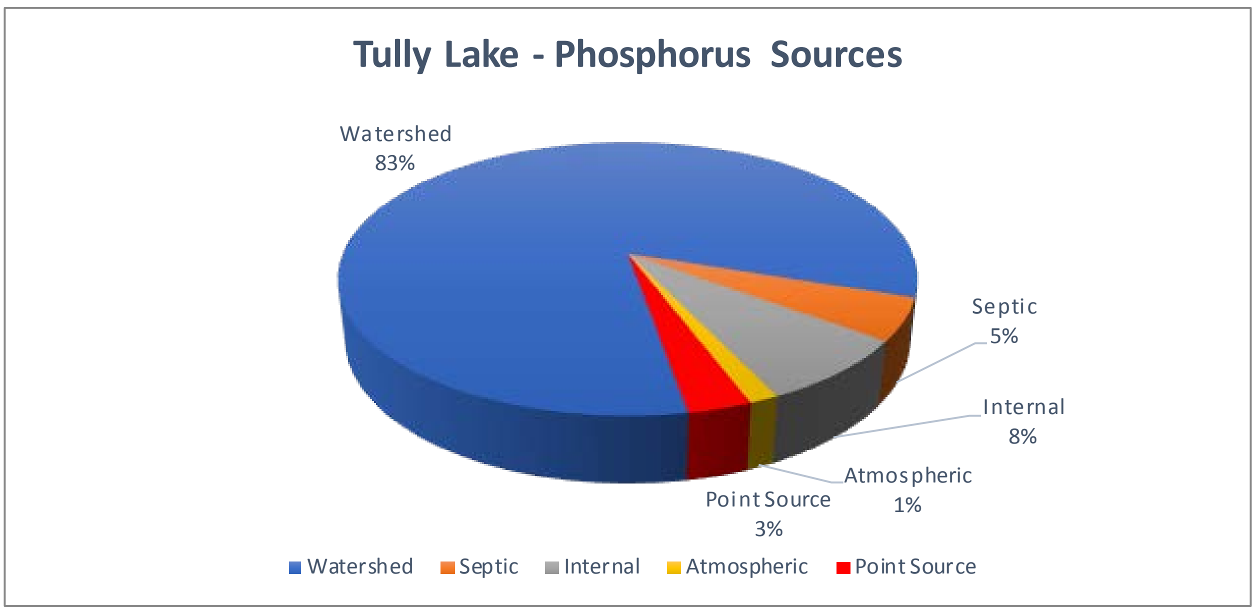
Table 4.1: Tully Lake Pollutant Loading Summary

Tully Lake - Nutrient Loading Summary

	Watershed	Septic	Internal	Atmospheric	Point Source	Harvesting	Sum
TN (kg/yr)	26,048	n/a	n/a	915	3,962	n/a	30,925
TP (kg/yr)	1,370	82	128	23	50	-201	1,452
TSS (kg/yr)	1,832,223	n/a	n/a	640	578	n/a	1,833,441

On an annual basis, 30,925 kg (68,178 lbs) of nitrogen, 1,452 kg (3,201 lbs) of phosphorus and 1,833,441 kg (4,042,045 lbs) of sediments are transported to Tully lake. A breakdown of the sources of phosphorus to Tully Lake are hereby presented in figures 4.1 and 4.2.

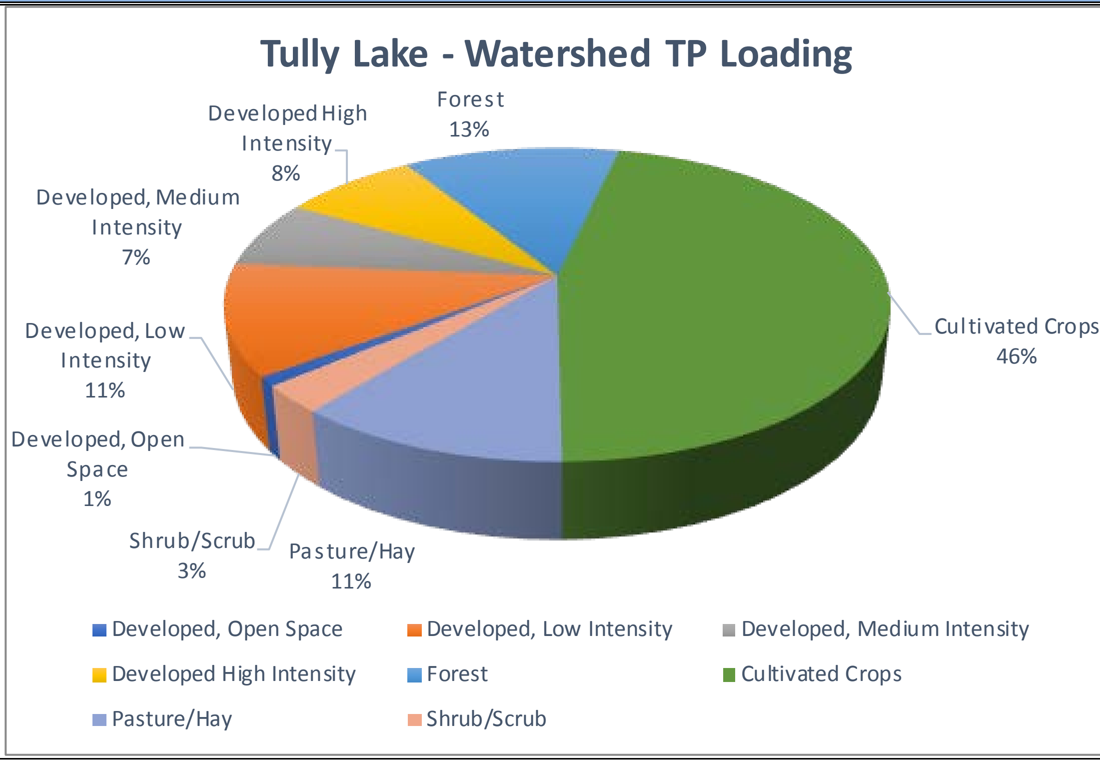
Figure 4.1: Tully Lake TP Loading Summary



The primary source of phosphors loading to Tully Lake is derived from external, watershed based sources which contribute 83% to the annual phosphorus budget. Internal loading accounts for 8% of the total load while septic systems account for 5% of the annual load.

Watershed sources of total phosphorus are broken down according to land use area in figure 4.2. Agriculture represents the primary land derived phosphorus source with cultivated crops and pasture / hay contributing 57% of the watershed based load. Developed land is the second greatest source with 27% of the load while forested land contributes 13% of the watershed based load. Please note, open water and wetlands are also present in the watershed and represent phosphorus attenuation of 45.3 kg/TP/yr.

Figure 4.2: Tully Lake – Watershed TP Loading



Watershed based BMPs will need to focus on phosphorus derived from both agriculture and residential land use. While residential (and associated septic systems) based phosphorus loading is not the primary contributor to the total phosphorus budget, this source is the closest in proximity to the lake proper and may have pronounced, acute impacts on lake water quality. The following section will detail the results of a watershed walk conducted by Princeton Hydro in May 2017. This section will provide examples of watershed issues which could benefit from better management and provide information on approximate costs and maintenance opportunities for each best management practice.

5.0 Watershed Disturbance and Best Management Practices

In anthropogenically altered watersheds, land use practices have been changed in ways that consequently alter the hydrologic cycle and increase pollutant loading to a lake. For this document, the term 'pollutant,' refers primarily to phosphorus, nitrogen and sediment but may also include salts, heavy metals or pesticides. Some of these pollutants are contributed directly to a lake, but, more commonly, these pollutants are derived from diffuse 'non-point sources.' Non-point source pollution is a term which relates to the contribution of sediments, phosphorus and nitrogen to waterways through land and stream bank erosion, stormwater and septic.

The watersheds of the Kettle Lakes were historically dominated by forest and wetland. With development came the clearing of forests and modification of wetlands, either through infilling, draining or flow alteration. The current land use of the Tully Lake watershed is comprised of a mixture of these forests and wetlands but also the human dominated land uses of residential housing, agriculture and transportation infrastructure. The anthropogenic land use changes reduced vegetative cover, exposed soils, increased impervious areas and introduced pollutants through fertilizers, road salts and byproducts of human materials. These changes ultimately lead to a marked change in the hydrology of the watershed in such a way that infiltration and groundwater recharge was likely reduced while the volume and rate of stormwater based surface discharge increased. Ultimately, this change in stormwater leads to stream channel downcutting, widening and bank instability leading to instream erosion. This geomorphic change results in a disconnect between streams and their floodplains and results in increased sediment and nutrient loading to lakes.

To mitigate non-point source pollution, we look to implement watershed best management practices. Watershed best management practices focus on structures, retrofits and even behaviors that may help reduce pollution to a waterway. Princeton Hydro focuses primarily on the selection and utilization of best management practices which fit in with Green Infrastructure. Green Infrastructure is a water management approach that seeks to mimic the natural environment and associated natural processes. These processes include sedimentation, filtration / flow resistance, bio-uptake, recharge, decomposition and bioretainment. Many of the structures or techniques listed below aim to utilize soils and vegetation to mimic these processes found in nature. In doing so, these techniques may serve to not only reduce nutrients to a lake but also serve as habitat for aquatic and terrestrial organisms in an ever increasing fragmented landscape.

The following section details the results of a watershed walk conducted over a half-day in May 2017 by Princeton Hydro and various stakeholders including members of Syracuse University, C-OFOKLA, local residents and members of Cortland County Soil and Water Conservation District. This walk aimed to photo-document areas of non-point source pollution which may benefit from the inclusion of best management practices. This summary is not an exhaustive survey of watershed conditions or BMP recommendations but provides specific examples of areas that can be improved. Furthermore, prior to the implementation of any BMP there will likely be additional, site specific, information needed such as: Utility, topographic and/or transportation surveys, stormwater engineering calculations, property ownership assessment, geologic or soil assessments, local, state and/or federal permits, etc.

Recommendation of BMP types are included along with rough estimates for costs and pollutant removal. Costs are based on similar projects conducted by Princeton Hydro but are very site specific upon a myriad of factors and do not cover engineering calculations or permitting unless otherwise specified. Pollutant removal was computed based on removal estimates provided by various BMP manuals including those issued by the States of New York and Pennsylvania. A summary of the types of maintenance associated with each BMP is also listed. Finally, recommendations on the priority of each BMP are listed as 'low', 'medium', and 'high.' These priorities are based on several factors including overall cost, ease of installation, permitting requirements, the need for cooperation from various government entities and pollutant removal. In general, those projects which may be easily implemented with minimal permitting and cost while providing ecological and pollutant removal benefits are rated as 'High.' This is particularly the case for those sites which occur on public property. Sites of high cost, extensive permitting or those on private property may be more difficult to implement and are therefore given a lower rating.

A summary of recommended BMPs is presented first (table 5.1) followed by a breakdown of each site. A figure depicting the location of these BMPs is provided in Appendix I.

Table 5.1: Watershed BMP Summary

Site	BMP	Estimated Cost ($)	Pollutants Removed (kg/yr)			Priority
			TSS	TP	TN	
1	Bioretention Swale	$20,000	304	0.23	2.3	High
1	Rain barrel	$75	-	-	-	High
2	Riparian buffer	$1,750 / ac	720	1.2	5.4	Medium
3	Bioswale	$20,000 – $25,000	52	0.04	0.14	High
4	Riparian buffer	$1,750 / ac	720	1.2	5.4	High
4	Bioswale	$40,000 - $60,000	70	0.05	0.30	Medium
4	Rain Garden	$1,000 - $2,500	15	0.01	0.06	Medium
5	Lake shore buffer	$10,000 - $20,000	400	0.3	1.0	High
6	Bioinfiltration	$100,000 - $200,000	6,321	4.5	16	Medium
6	Rain garden	$1,000 - $2,500	30	0.02	0.1	Medium
7	Step pool conveyance	$70,000 - $100,000	14,569	12.3	299	Medium

Site 1: Sunfish Bay Circle – Erosion

Site Location and Description: *42.78773°N, 76.13285°W* – Residential gravel road

Issues: Stormwater based erosion creating gullies

BMP Recommendation: Direct sheetflow from road to bioretention swale for slowing stormwater and filtering pollutants. Minimize sheetflow and avoid concentrating flow at residences through implementation of small-scale rain gardens and rain barrels at individual houses.

Cost: Estimated cost for engineering, permit and constructions of bioretention swale is $20,000. Individual rain barrels are approximately $75

Maintenance: Monitor vegetation and remove invasives. Check for silt build up and remove.

Pollutant Removal: TSS 304 kg/yr, TP 0.23 kg/yr, TN 2.3 kg/yr

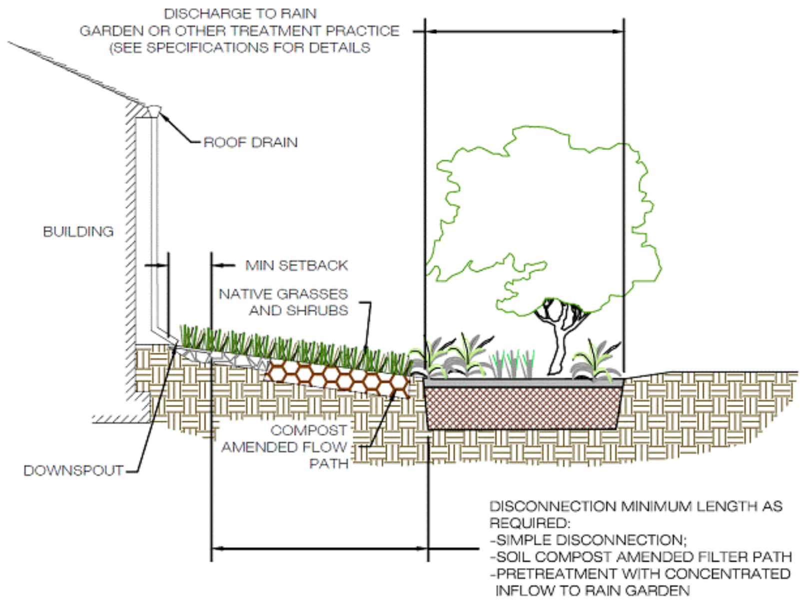
Priority: High

Examples of the recommended BMPs are provided below.

Figure 5.1: Sunfish Bay Circle

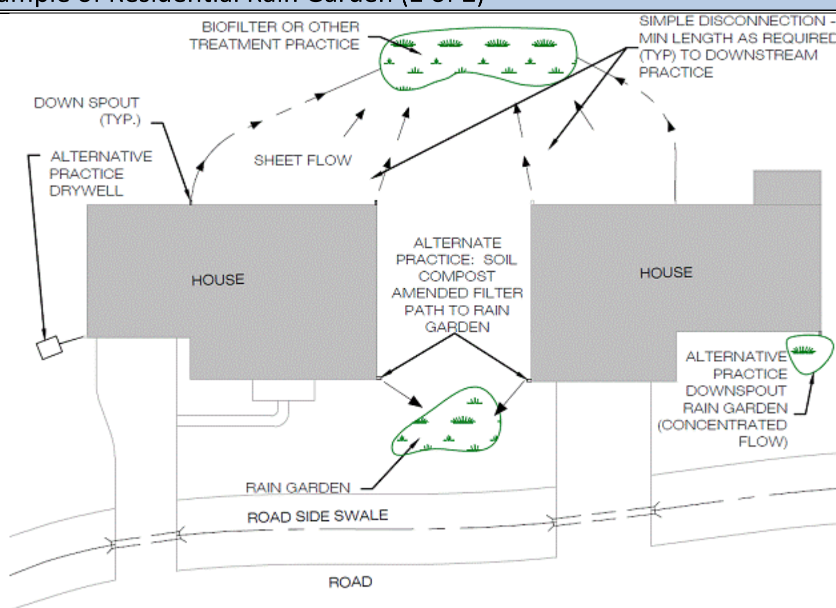
Figure 5.2: Example of Roadside Swale

Figure 5.3: Example of Residential Rain Garden (1 of 2)



Source: Virginia Department of Environmental Quality

Figure 5.4: Example of Residential Rain Garden (2 of 2)



Source: Virginia Department of Environmental Quality

Site 2: Agricultural Field – West Branch of Tioughnioga River

Site Location and Description: *42.77910°N, 76.11510°W* – River through agricultural area

Issues: Lack of riparian buffer

BMP Recommendation: Install 600 linear feet of riparian buffer along stream – Ideally the riparian buffer should be 200' in width with a minimum width of 50-100'.

Cost: *Riparian buffer* - approximately $1,750 per acre for plants, materials and labor.

Maintenance: Monitor vegetation for invasive species or die off. Remove invasives and replant natives that have died.

Pollutant Removal: TSS 720 kg/yr, TP 1.2 kg/yr, TN 5.4 kg/yr

Priority: High

Examples of the recommended BMPs are provided below.

Figure 5.5: W Branch Tioughnioga River Through Agricultural Field

Figure 5.6: Agricultural Riparian Buffer

Site 3: Tully Lake Boat Launch

Site Location and Description: *42.77251°N, 76.13393°W* – Tully Lake boat launch with gravel parking lot

Issues: Erosion from gravel parking lot

BMP Recommendation: Stormwater diversion into vegetated swale. Opportunity for public outreach through signage.

Cost: Estimated cost for engineering, materials and implementation is approximately $20,000 - $25,000

Maintenance: Check and remove any invasive species annually.

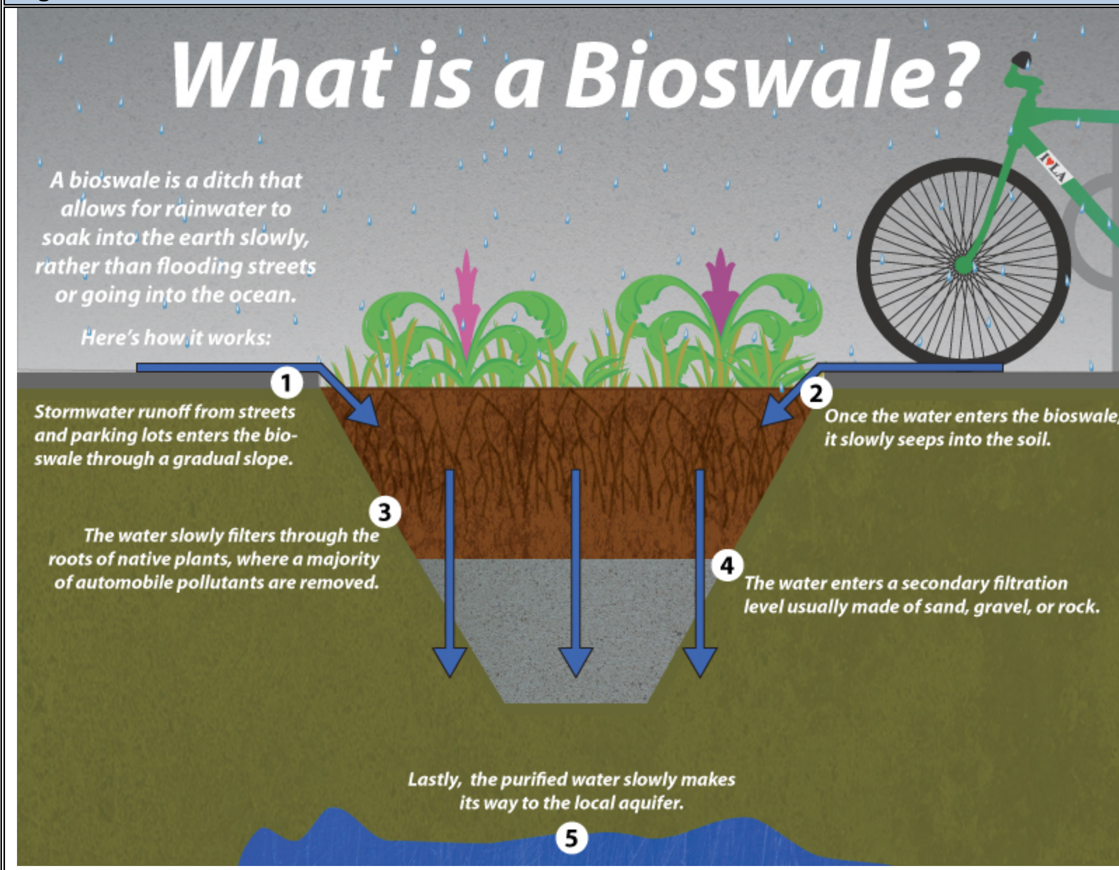
Pollutant Removal: TSS 52 kg/yr, TP 0.04 kg/yr, TN 0.14 kg/yr

Priority: High

Examples of the recommended BMPs are provided below.

Figure 5.7: Tully Lake Boat Launch

Figure 5.8: Bioswale



Site 4: Cummings Park

Site Location and Description: *42.79581°N, 76.10371°W* – Cummings Park

Issues: No riparian buffer, lack of stream connection to floodplain, opportunity for biofiltration at parking lot.

BMP Recommendation: Establish 600' riparian buffer. Opportunities at park for biofiltration at parking lot and rain gardens at pavilion area.

Cost: Riparian buffer approximately $1,750 per acre for plants, material and labor. Larger Biofiltration system cost approximately $40,000 - $60,000 for engineering design and implementation. Small scale rain garden cost approximately $1,000 - $2,500 for materials, labor and signage.

Maintenance: Check and remove any invasive species annually.

Pollutant Removal: Riparian – TSS 720 kg/yr, TP 1.2 kg/yr, TN 5.4 kg/yr. Biofiltration – TSS 70 kg/yr, TP 0.05 kg/yr, TN 0.30 kg/yr. Rain Garden – TSS 14 kg/yr, TP 0.01 kg/yr, TN 0.06 kg/yr

Priority: High

Figure 5.9: Cummings Park

Site 5: Lakeside Lot – South End of Tully Lake

Site Location and Description: *42.76416°N, 76.13760°W* – South End of Tully Lake

Issues: No lakeshore buffer

BMP Recommendation: Establish lakeshore buffer and meadow / pollinator garden

Cost: Estimated cost approximately $10,000 - $20,000

Maintenance: Check and remove any invasive species annually.

Pollutant Removal: TSS 400 kg/yr, TP 0.3 kg/yr, TN 1.0 kg/yr

Priority: High

Additional Info: May need to utilize coir fiber logs for erosion control. Utilize low and medium height native vegetation to maintain viewscape. Offers pollutant filtering and critical near-shore habitat.

Examples of the recommended BMPs are provided below.

Figure 5.10: South shore of Tully Lake

Figure 5.11: Example of Lakeshore Buffer Conversion

Source: Mr. Josue Cruz

Site 6: Tully High School

Site Location and Description: *42.79705°N, 76.11403°W* – Tully High School Turf Fields

Issues: Large expanses of impervious area (rooftops and parking lots) and open turf grass. No stormwater management

BMP Recommendation: Numerous opportunities exist to treat stormwater at this site. The turf grass at the bus circle could be converted to a meadow / pollinator garden, or bioretention / infiltration basin. Numerous, small-scale raingardens could be implemented around the building.

Cost: Biofiltration / infiltration basin approximately $100,000 - $200,000 for design and installation. Small-scale raingardens approximately $1,000 - $2,500

Maintenance: Check and remove any invasive species annually, cut and remove vegetation in infiltration basin annually.

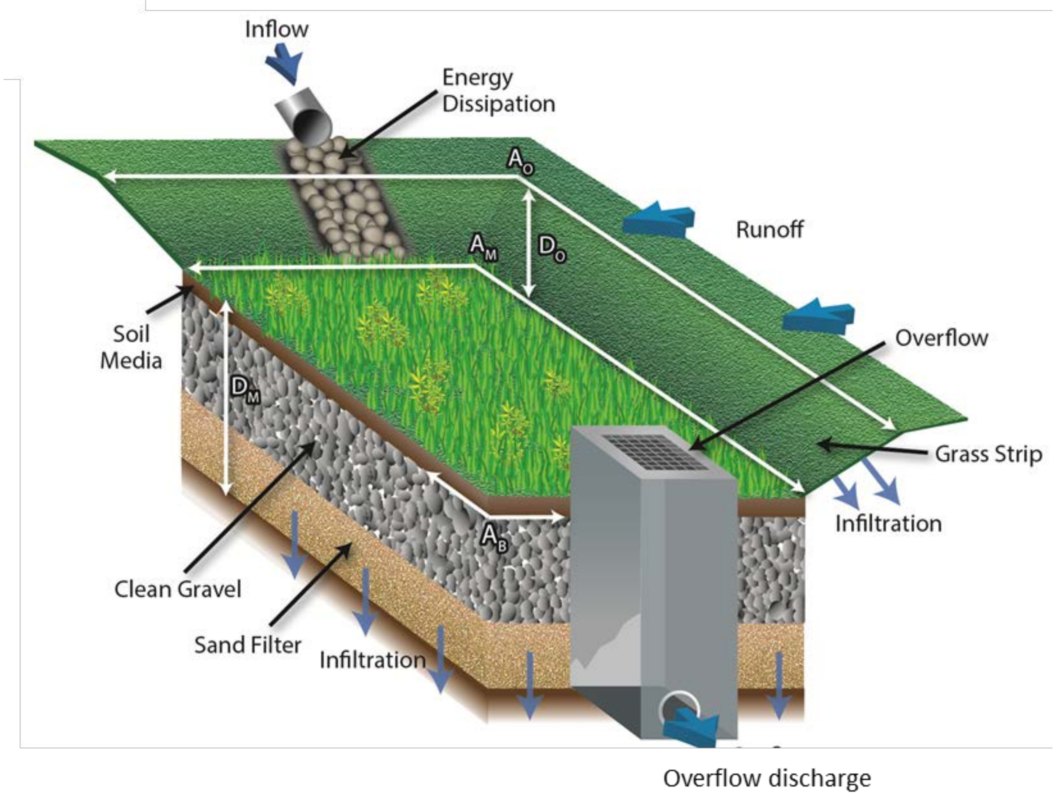
Pollutant Removal: Biofiltration / Infiltration TSS 6,321 kg/yr, TP 4.5 kg/yr, TN 16 kg/yr. Each raingarden TSS 30 kg/yr, TP 0.02 kg/yr, TN 0.1 kg/yr

Priority: Medium

Examples of the recommended BMPs are provided below.

Figure 5.12: Tully High School

Figure 5.13: Example of Infiltration Basin



Source: Minnesota Stormwater Manual

Site 7: Roadside Drainage Ditch / Stream

Site Location and Description: *42.79476°N, 76.10303°W* – Roadside stream / ditch

Issues: Channelized stream / stormwater ditch with no flow attenuation

BMP Recommendation: Integrate Step-Pool Conveyance System to slow flow, settle solids and nutrients and, if possible, infiltrate water.

Cost: Variable based on site specific conditions. Engineering, permitting and construction. Estimate $70,000 – 100,000

Maintenance: Check and remove any invasive species annually, cut and remove vegetation in infiltration basin annually.

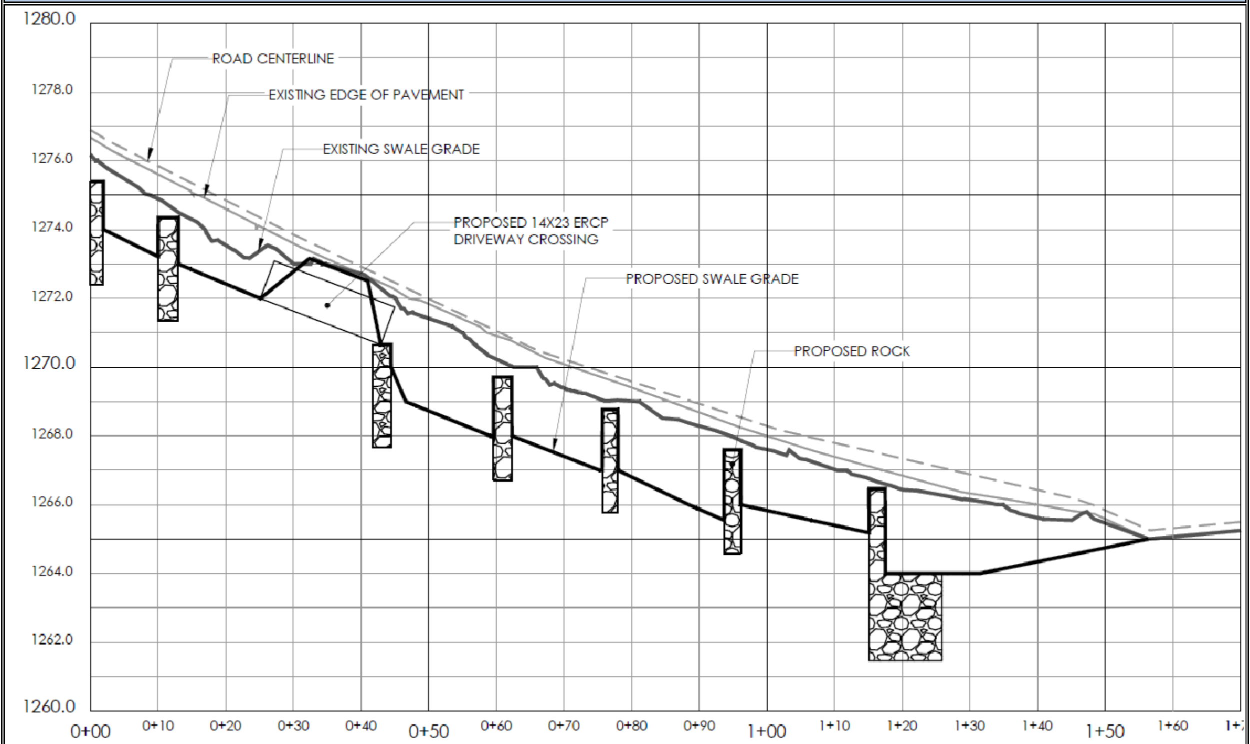
Pollutant Removal: TSS 14,569 kg/yr, TP 12.3 kg/yr, TN 299 kg/yr

Priority: Medium

Examples of the recommended BMPs are provided below.

Figure 5.14: Roadside Drainage Ditch

Figure 5.15: Step-Pool Conveyance Engineering Diagram



Source: Princeton Hydro – Harvey's Lake Step Pool Conveyance / Infiltration

Figure 5.16: Regenerative Step-Pool Conveyance – Before and After

Source: Maryland DEP – Mary Travaglini, Planning Specialist

Septic Management

Much of the residential land surrounding Tully Lake utilizes septic systems for treatment of human wastes while the town of Tully is serviced by public sewer. The soils, slopes and water table surrounding the lake make on-site wastewater treatment a critical issue for the health of the lake relative to phosphorus loading. Review of the Septic Tank Absorption Field ratings derived from the National Resources Conservation Service show the soils surrounding the lake to range from 'somewhat limited' to 'very limited' in their ability to adequately treat wastes. The estimated total phosphorus load derived from septic systems is 5% of the total load. While a small percentage, the proximity of the systems to the lake impart a higher importance on septic maintenance.

At a minimum, septic tanks should be pumped out every three years. Maintaining this pumpout schedule may reduce phosphorus loading from this source by 20 - 30% (Day, 2001). In addition, water conservation measures should be implemented at each residence. Lowering the burden on the septic system will allow for reduced nutrient transport to shallow groundwater, and ultimately, Tully Lake.

Incentivizing the maintenance of septic systems through providing monetary benefits for completing pumpout or maintenance, or through providing reduced costs for these services, has been implemented successfully locally through the Song Lake Property Owners Association. Similar programs should be implemented on a municipal level to encourage all residents to keep their systems up to date and in good working order.

Finally, the type and age of septic systems may play a significant role in their functionality and contribution of nutrients to the watershed. This study merely looked at the presence of such systems without conducting a detailed assessment of whether systems need upgraded or replaced. Princeton Hydro recommends implementing such a study with backing by the local municipality and C-OFOKLA

Lawn Fertilizers

Lawn fertilizers are often an acute source of nutrient pollution to lakes. Often, these products are applied in spring or fall and are quickly washed away during precipitation events directly into the lake where they fuel algal blooms. Currently, New York bans phosphorus fertilizers under ECL § 17-2101 et seq. This law, applicable to all persons, states the use of phosphorus fertilizers on lawns or non-agricultural turf is restricted. Only fertilizers with less than 0.67 %/w phosphate may be applied legally. Furthermore, applications between December 1 and April 1 are prohibited. An application buffer of 20 feet from a waterway or paved surface was also implemented as part of this rule.

Prior to application of any fertilizers, homeowners should have their soil tested by the local agricultural district or similar entity. This testing will provide empirical data on the amount of nutrients in the soil and need for any additional nutrients. Often times, phosphorus is present in abundance in soils and does not need additional application. Many times, the pH of the soil needs adjusted with lime thereby raising pH to a level where the phosphorus that is present in the soil becomes biologically available for turf grass. If fertilizers are needed, homeowners should look for and use phosphorus free fertilizers. Fertilizers are typically labeled with three vales (N-P-K) representing the proportion of nitrogen – phosphorus – potassium in the product. As such, look for fertilizers with a middle number of zero (e.g. 24-0-12) or a bag with 'lake friendly' on the front.

Educational campaigns about the 2012 State rule banning phosphorus fertilizer should be conducted routinely for watershed residents.

Deicers

There is considerable concern in the kettle lakes region of the impact of salts on the water quality of the lakes. Road salts (chloride) are commonly applied not only to driveways but also on state roads and interstate 81. The latter may serve as a substantial source of salts during the winter months as runoff from this large road goes directly into the lake. The major issue with the application of road salts is that chloride is a conservative ion that is not readily sorbed onto mineral sources or involved in many significant biochemical reactions. As such, this ion persists in soils and ground and surface water. Ultimately, increases in chloride levels follow increases in watershed development and impervious area. These increases may alter the composition of the lake food web through changes in the invertebrate, plankton and fishery structures.

Management of road salts is a complex subject due to the human safety aspect. When possible, those who apply road salts should look into alternative deicers such as calcium magnesium acetate. Additives, such as natural beet sugars, lower the temperature of brine used to pretreat roads and has been documented in reducing overall salt use. such as Furthermore, where possible, setbacks should be established so that deicing compounds are not applied near surface water sources.

6.0 In-lake Phosphorus Management

In Tully Lake, 8% of the annual phosphorus load is estimated to be derived from internal sediment release. This load is small relative to other sources but may provide an acute source of nutrients during the peak of the growing season. Watershed management should be the primary focus for Tully Lake. With that said, options for controlling internal loading are presented below.

There are several ways to manage internal loading of phosphorus in lake systems. These techniques focus on the maintenance of oxygen in the hypolimnion of the lake or the 'sealing' of lake sediments through the application of chemical flocculant or inactivation products. In addition, floating wetland islands may be utilized to assimilate phosphorus from the epilimnion. While floating wetlands islands will not control internal loading they serve as a chemical free in-lake measure to reduce the overall phosphorus load in the lake. Finally, macrophyte harvesting, which already occurs in Tully Lake, serves as a means of removing phosphorus in plant tissue. This method does not directly manage internal loading of P from profundal sediments but provides overall P removal.

Aeration

Aeration for internal phosphorus control focuses on the maintenance of dissolved oxygen in the hypolimnion thereby serving to keep the redox potential at such a level as to mitigate large scale internal release of phosphorus and metals. Aeration systems for lake management typically fall under the categories of systems which disrupt thermal stratification, such as submerged diffuser systems, or systems which keep stratification in place, such as hypolimnetic aeration systems. Typically, the latter is utilized when there is the desire to maintain cold-water fishery habitat while destratification systems are commonly utilized in relatively shallow lakes.

For Tully Lake, a submerged aeration / destratification system would likely be the recommended type of unit. An additional full year of monitoring would be necessary to accurately characterize the stratification patterns, carbon demand and phosphorus loading rates to size and spec a system. Estimated costs for monitoring, sizing, material and installation are significant and would be upwards of $75,000 not including annual operating costs. At this time, Princeton Hydro recommends a focus primarily on watershed restoration with evaluation of aeration at a later date.

Nutrient Inactivation

Nutrient inactivation in lakes occurs through the application of a chemical, typically an aluminum or lanthanum/clay based product. Typically, phosphorus is bound to iron in the sediments through a relatively weak molecular bond which is broken under anoxic conditions. In contrast, the bond between phosphorus and nutrient inactivation products is stronger and therefore is not broken, or is broken more slowly, under anoxic conditions.

The products commonly utilized in lake management for nutrient inactivation includes aluminum sulfate (alum) or alum surrogates such as polyaluminum chloride. More recently, the utilization of lanthanum modified bentonite clay based products, such as the proprietary Phoslock©, have been utilized when there are concerns about alum toxicity or regulatory restraints on the use of such products. The latter is currently the case in New York State which has placed an indefinite moratorium on the utilization of alum for lake management purposes. While Phoslock is utilized with efficacy for phosphorus 'stripping' in lakes, where P is removed from the water column, the efficacy of control of sediment released P under anoxic conditions is relatively low while costs are much higher than aluminum based products. As such, this management measure is not currently recommended for Tully Lake. Alum, if permitted in the future by NYSDEC, could be a feasible and relatively inexpensive product for sealing the profundal sediments thereby preventing phosphorus release. The cost for such an application, including monitoring, permitting, application and follow up monitoring would likely range between $75,000 to $125,000.

Floating Wetland Islands

Floating wetland islands (FWIs) are a relatively new technique in lake management that uses biomimicry to assimilate and process nutrients that would otherwise stimulate algal growth. FWIs are structures composed of woven, recycled plastic material. Vegetation is planted directly in the plastic matrix of the islands with peat and then these structures are deployed in the lake. Once positioned, these units are anchored, typically with rope and cinder blocks. The vegetation grows on the FWIs with their roots growing down through the plastic matrix into the lake. The combination of the root structure and plastic matrix relates to a very high surface area which subsequently serves as habitat for bacteria and biofilm. It is estimated that one 250 ft^2 island has a surface area equal to approximately one acre of natural wetland. Once installed, the FWI serves as a nutrient sink whereby the plants and microbial community associated with the root mass and plastic matrix assimilate phosphorus. In turn, a portion of this phosphorus may be incorporated up the food chain and transported out of the lake system. Diverting this phosphorus reduces the amount of phosphorus which may be assimilated by harmful algae. Studies by Princeton Hydro have shown that one (1) 250 ft^2 island has the potential to sequester up to 10 lbs of phosphorus per year. Given that each pound of phosphorus has the potential to produce up to 1,100 lbs of algae per year, each island has the potential to mitigate 11,000 lbs of wet algae biomass annually.

Floating wetland islands are less costly than the measures mentioned above but do not directly address internal loading. Instead, they remove phosphorus from the epilimnion during the growing season. The cost for a single 250 ft^2 island, including plants and installation, is roughly $10,000. Approximately five (5) islands would be recommended for Tully Lake to be placed in shallow areas that are known to receive storm inflow. These units would be installed in conjunction with a holistic watershed / in-lake management plan and as such are viewed as a piece of an overall management approach.

Boat Motor / Sediment suspension

Significant study has been conducted on the impacts boat motors have on sediment suspension and the effects of this on reductions in water transparency and phosphorus mobilization. The degree of impact is generally related to motor size, water depth and sediment type (Buetow, 2000). There is some evidence that, depending on lake, boat motors may increase phosphorus loading which may lead to increases in algal growth. This is particularly the case in shallow areas comprised of fine, nutrient rich sediments. Impacts are less pronounced or absent in deep areas or areas of coarse sediments. Care should be taken to operate a motorized boat in a mindful manner in shallow areas and no-wake zones. Motor sizes and correlated mixing depths are as follows (Nedohin, 1996 & Yousef, 1978):

- 10 hp – 6 feet
- 28 hp – 10 feet
- 50 hp – 15 feet
- 100 hp – 18 feet

Princeton Hydro recommends abiding by the above guidelines. If necessary, local municipalities may consider adopting ordinances or similar to enforce safe, mindful boating practices.

Harvesting

Macrophyte harvesting is currently conducted on Tully Lake and Little York Lake. In addition to removing nuisance densities of aquatic plants, harvesting has the added benefit of removing the nutrients contained within the plant biomass. For example, Princeton Hydro quantified the phosphorus concentration in SAV at Lake Hopatcong in New Jersey. The mean P concentration in this wet SAV biomass was 2,216 mg/kg. Plant removal from Tully and Little York Lake was estimated at approximately 100 tons wet weight thereby resulting in a removal of approximately 200 kg of P per year. Princeton Hydro recommends the continuation of this program for the maintenance of non-nuisance densities of plants and P removal.

7.0 Summary

Princeton Hydro, along with project partners, conducted a miniature watershed implementation plan for Tully Lake. This plan aimed to characterize the water quality and pollutant load to the lake and to identify areas in the watershed that may be contributing nutrients to the waterbody that could benefit from best management practices. Ultimately, this plan may be integrated into a full-scale watershed implementation plan or lake management plan to contribute towards the restoration of the lake. In addition, this plan may serve as a jump-off point for securing funding for the projects identified herein.

Phosphorus loading to Crooked Lake was estimated to occur primarily from the watershed which contributes 83% of the P load followed by internal loading (8%) and septic systems (5%). Agriculture represents the primary land derived phosphorus source with cultivated crops and pasture / hay contributing 57% of the watershed based load. Developed land is the second greatest source with 27% of the load while forested land contributes 13% of the watershed based load. Watershed BMPs will need to focus on controlling nutrient loading from both agriculture and developed land to reduce phosphorus loading to the lake. The internal phosphorus load to the lake is relatively minor compared to that of the watershed load but is pronounced in that it occurs during the growing season. At this time, large scale measures to control internal P, such as alum or an aeration system, should not be conducted until the external nutrient load is brought under control. Smaller scale measures, such as floating wetland islands, may be implemented at any time.

Princeton Hydro recommends the adoption of this plan by the towns of Tully and Preble. The successful implementation of this, and any, watershed plan is contingent on the cooperation of multiple stakeholders of varied interests. Finally, Princeton Hydro would like to thank the local residents, C-OFOKLA, Syracuse University and the Cortland County Soil and Water Conservation District for all of their input, help and support during this project.

8.0 References

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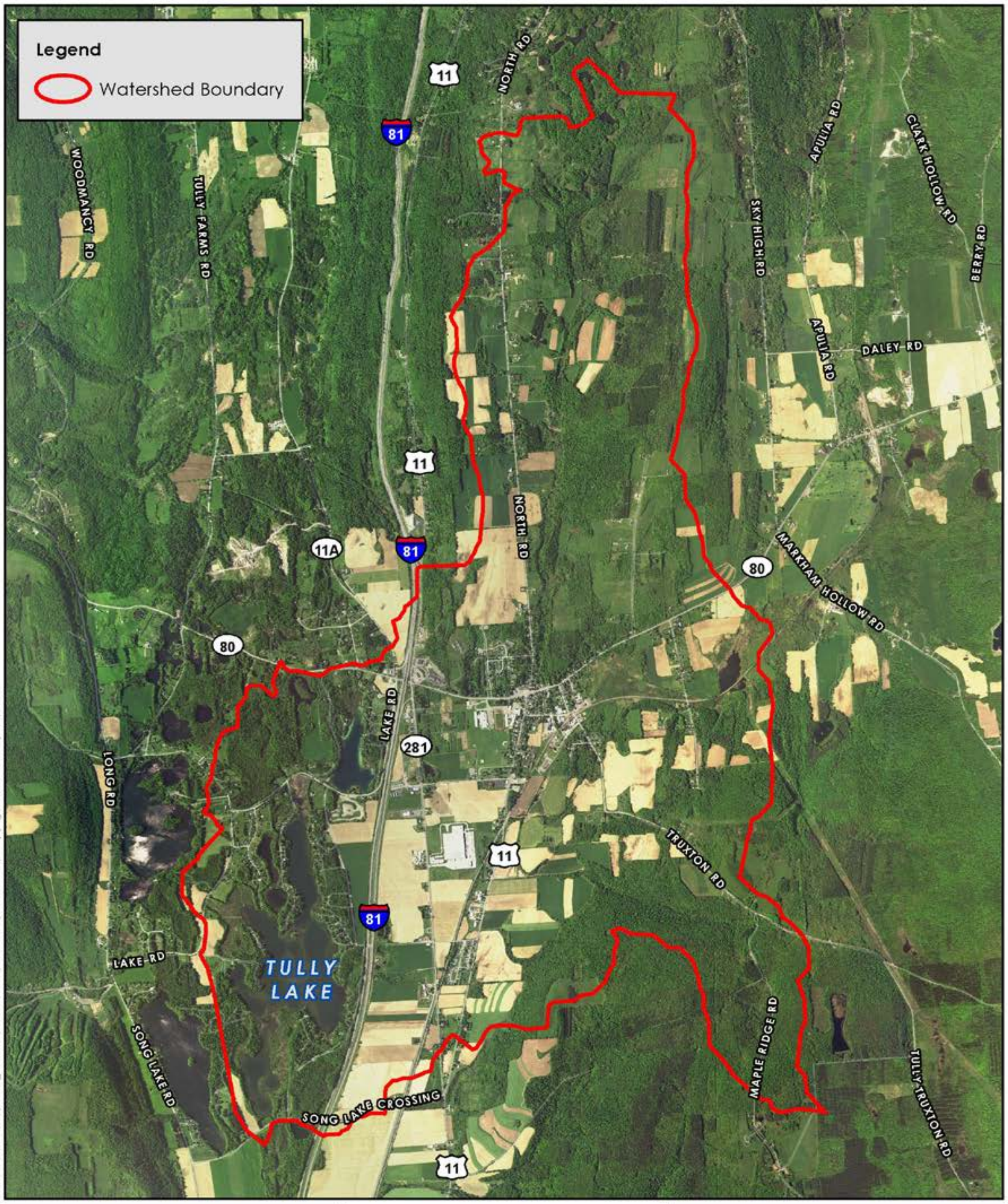
Appendix I



TULLY LAKE WATERSHED

TULLY LAKE
WATERSHED IMPLEMENTATION PLAN
TOWNS OF PREBLE & TULLY
ONONDAGA & CORTLAND COUNTIES, NEW YORK

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
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*with offices in NJ, PA and CT

NOTES:
1. 2015 Onondaga county orthophotography obtained from the National Agriculture Imagery Program (NAIP).

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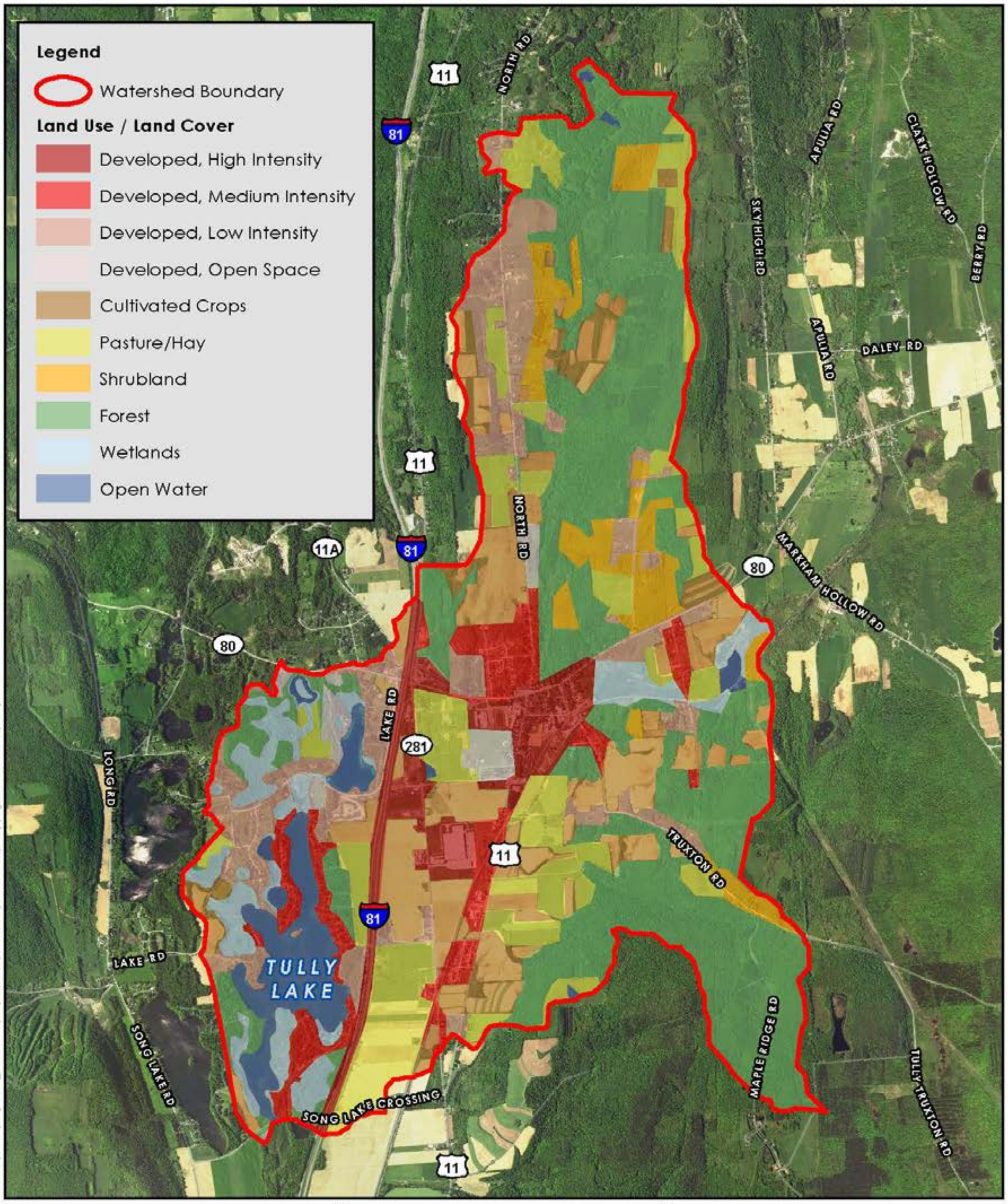
Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet



TULLY LAKE LAND USE

TULLY LAKE
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2. Hand-digitized land use/land cover is approximate.

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Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet

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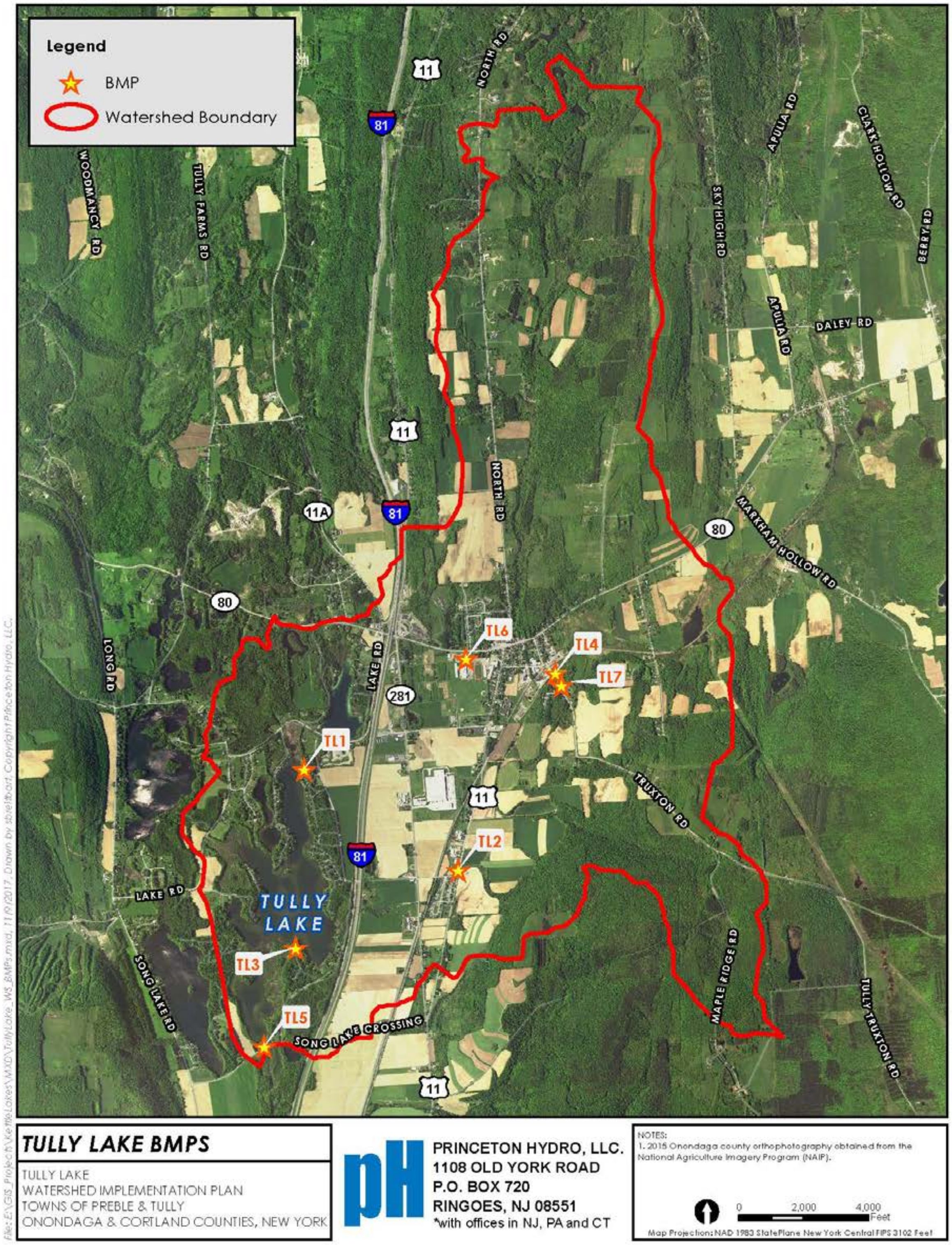
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