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

Prepared for:

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December 2017

Funding: This report was funded by the National Fish and Wildlife Foundation Chesapeake Bay Technical Grants Program for Stormwater Management

Contents

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1.0 Introduction

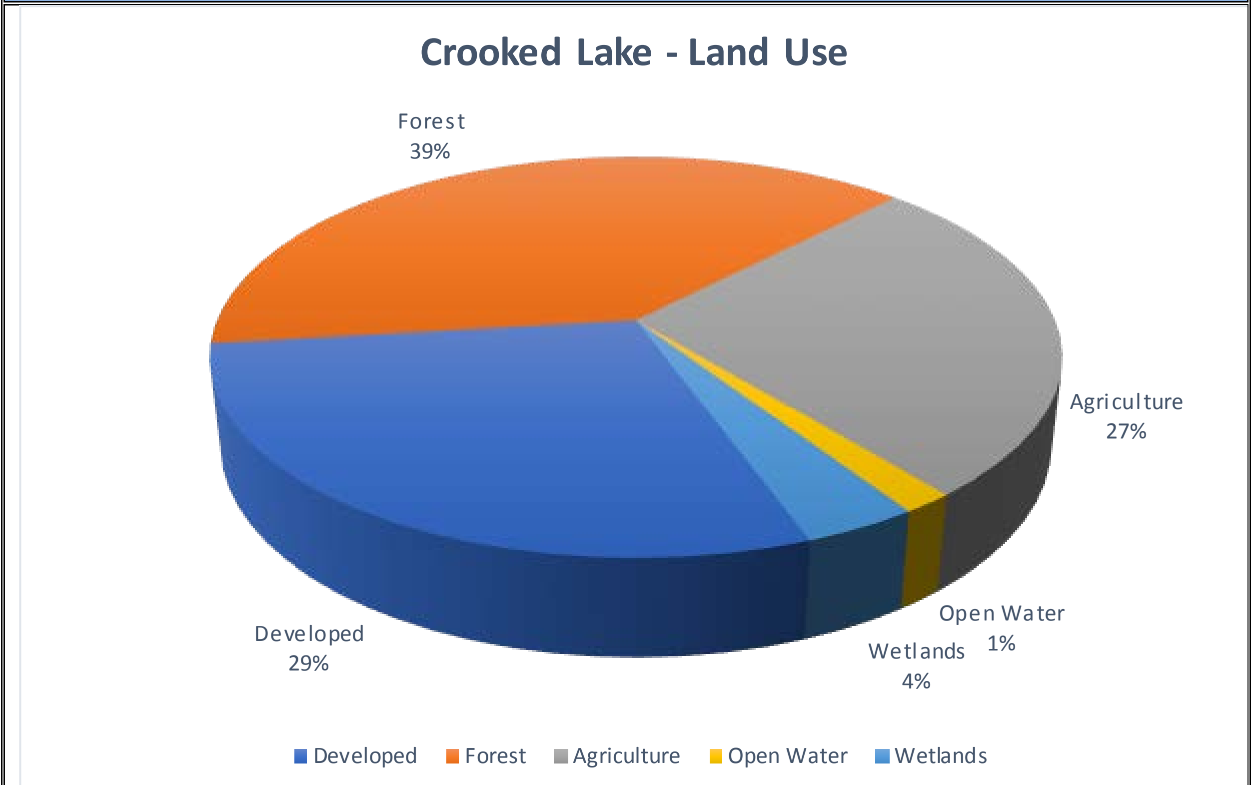
Crooked Lake, located in the town of Tully, Onondaga County, New York, is part of a kettle lake system. Historically, this lake has suffered from symptoms of eutrophication such as elevated phosphorus concentrations, lack of oxygen (anoxia), algal blooms and dense aquatic vegetation. While the water 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

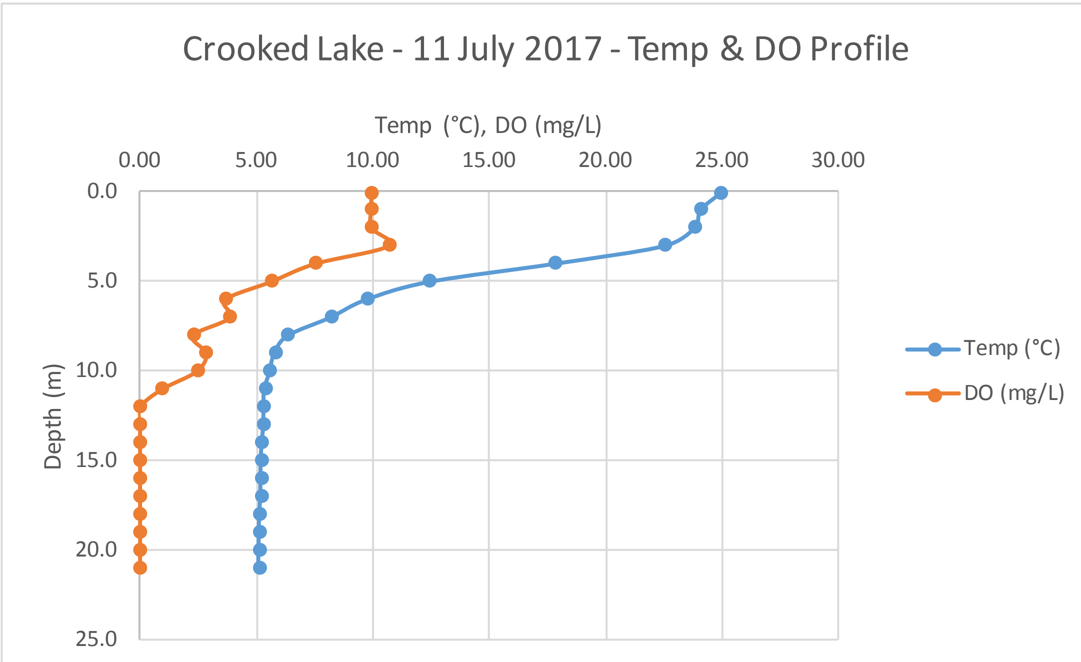


Table 3.2: Crooked Lake – Plankton Data

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

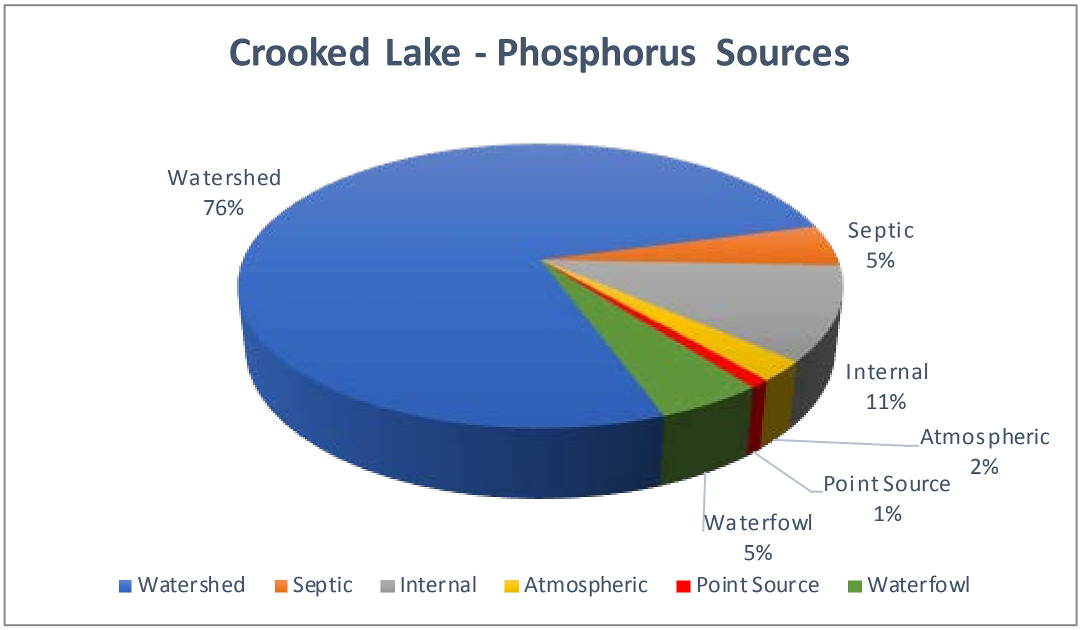
Summary results for nutrient loading to the lake are presented in table 4.1.

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.

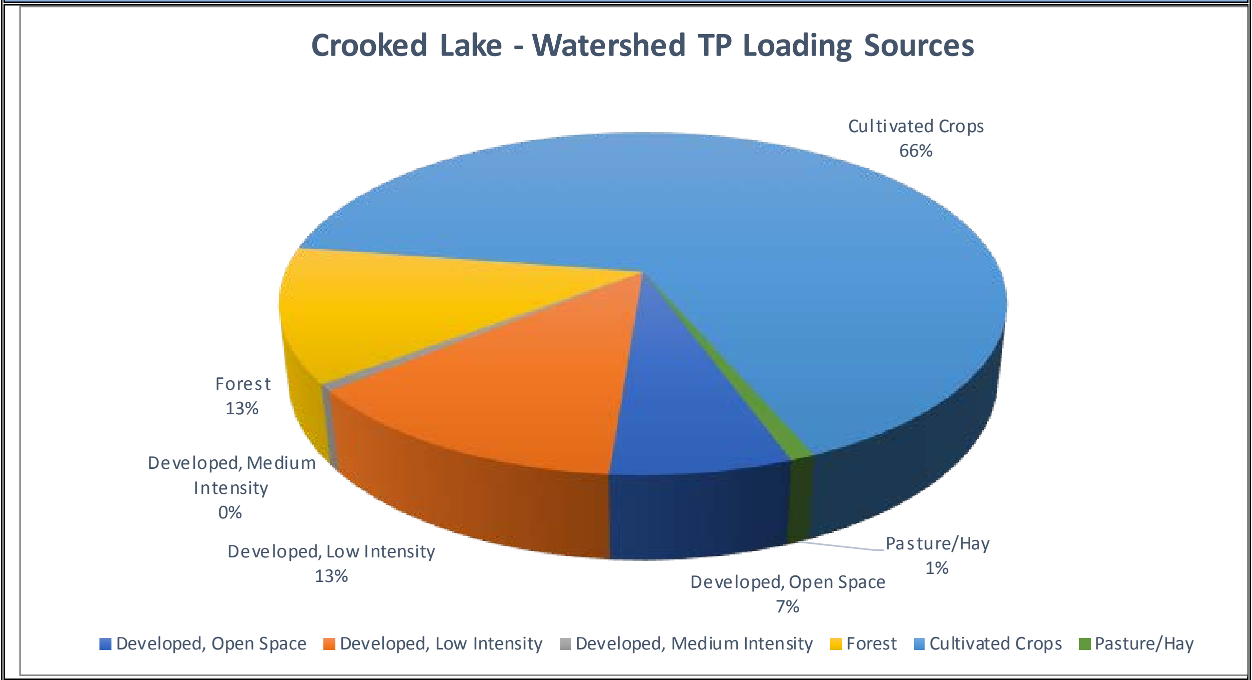
Figure 4.1: Crooked Lake TP Sources



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

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 5.1: Song Mountain Erosion

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)

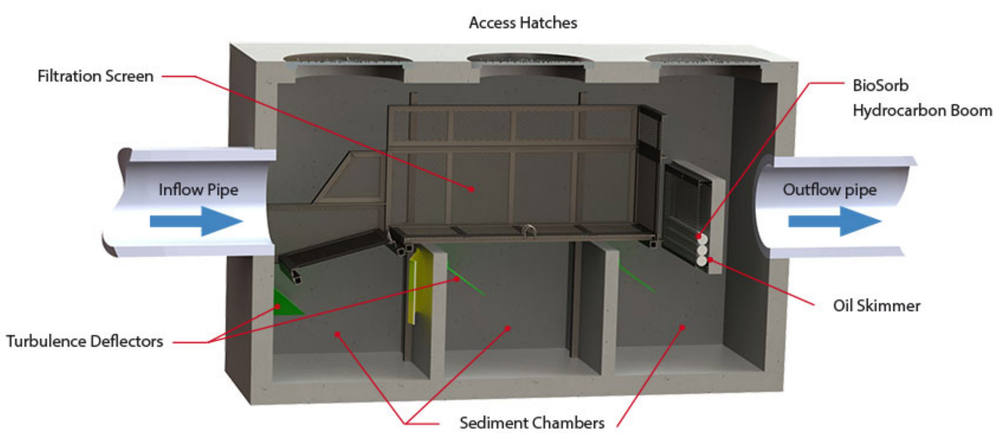
Examples of the recommended BMPs are provided below.

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.

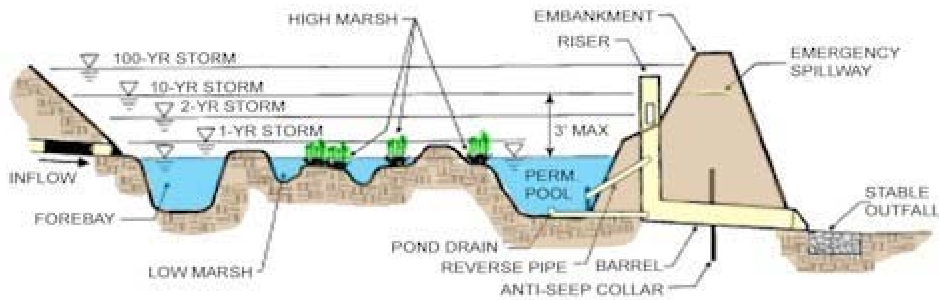
Pollutant Removal: TSS 100,000 kg/yr, TP 75 kg/yr, TN 750 kg/yr. *Pollutant removal estimates based off of wet pond, less 50% due to steep slopes. Actual removals will be highly variable.*

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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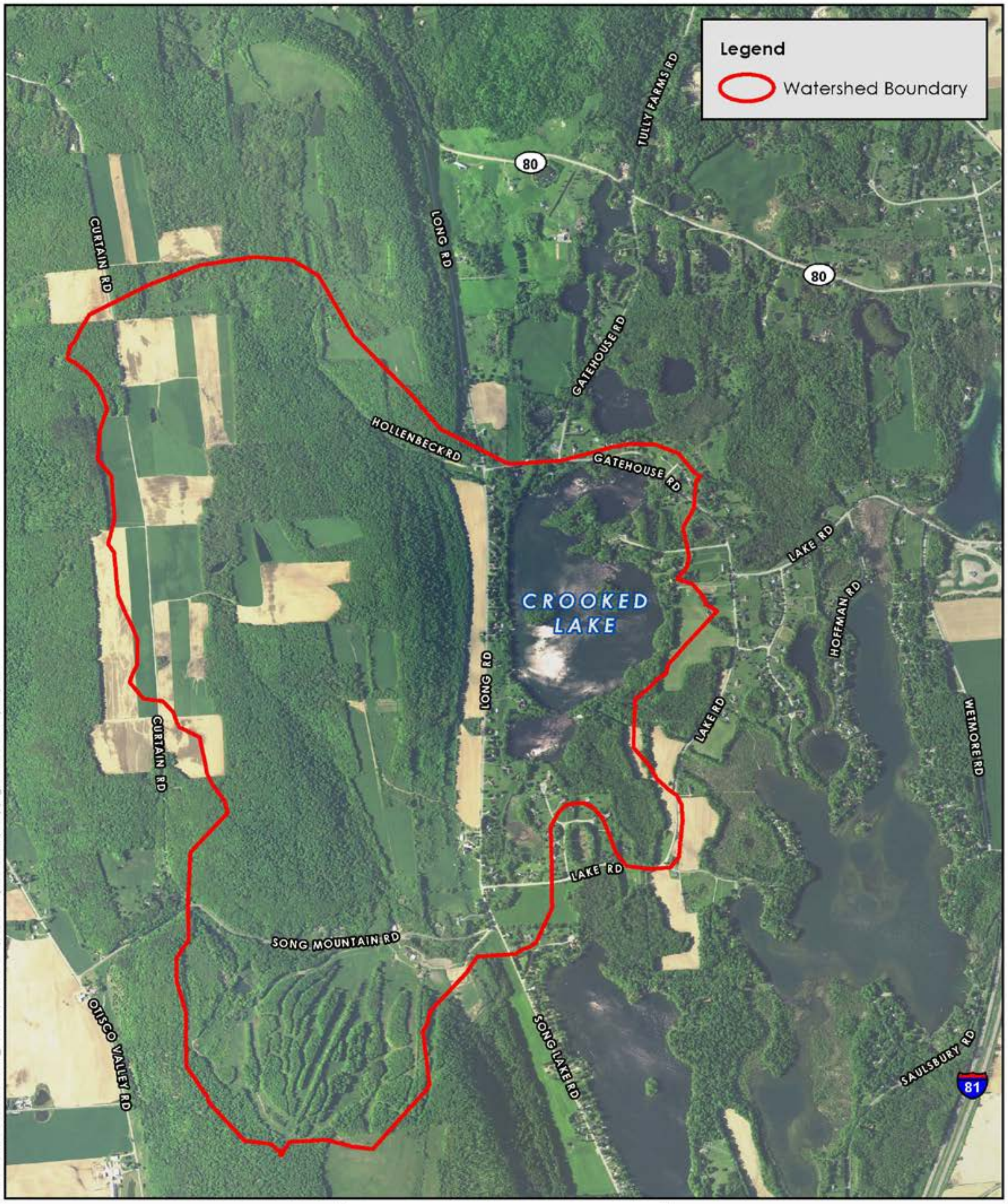
Appendix I



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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
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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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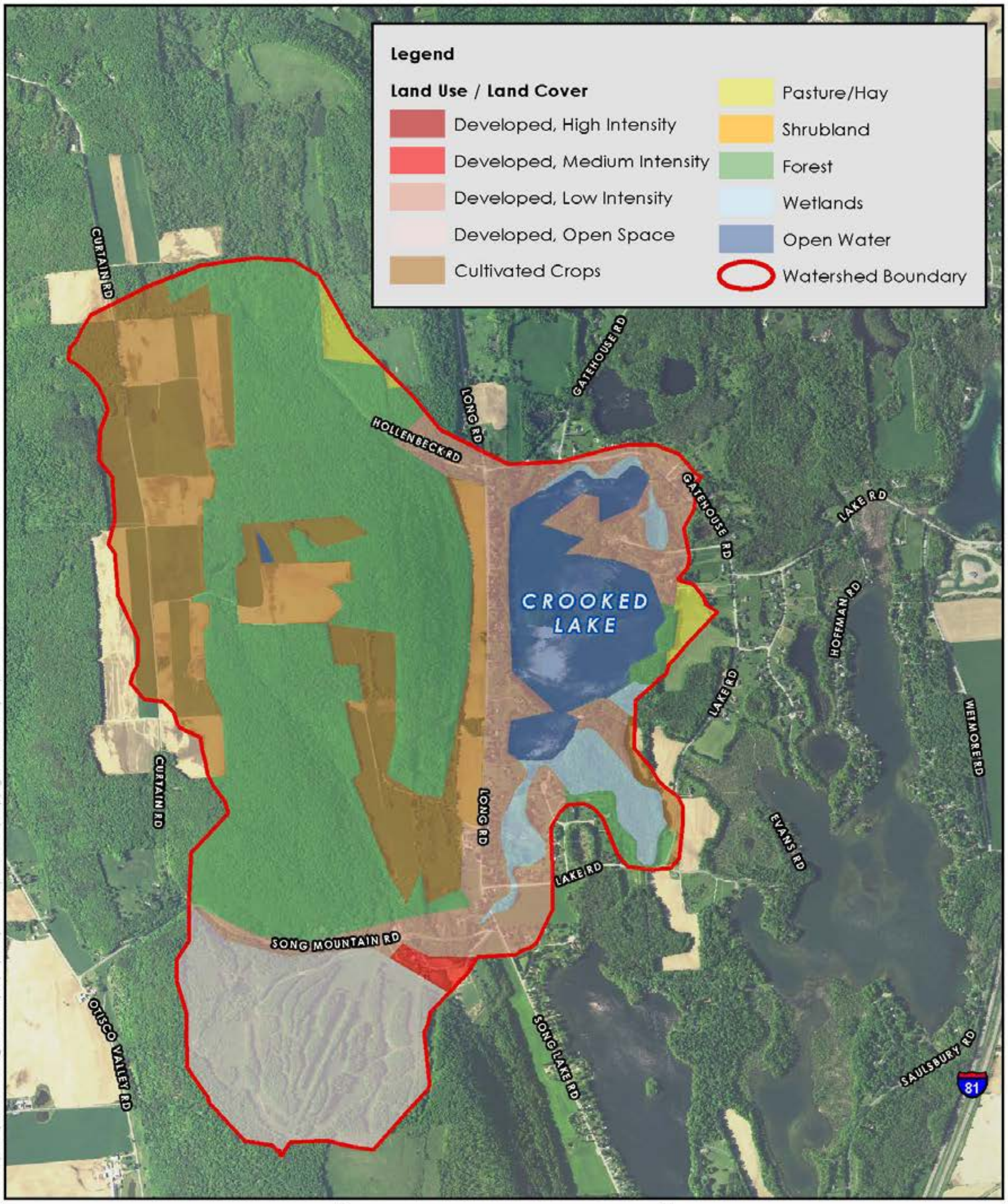

CROOKED LAKE LAND USE

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

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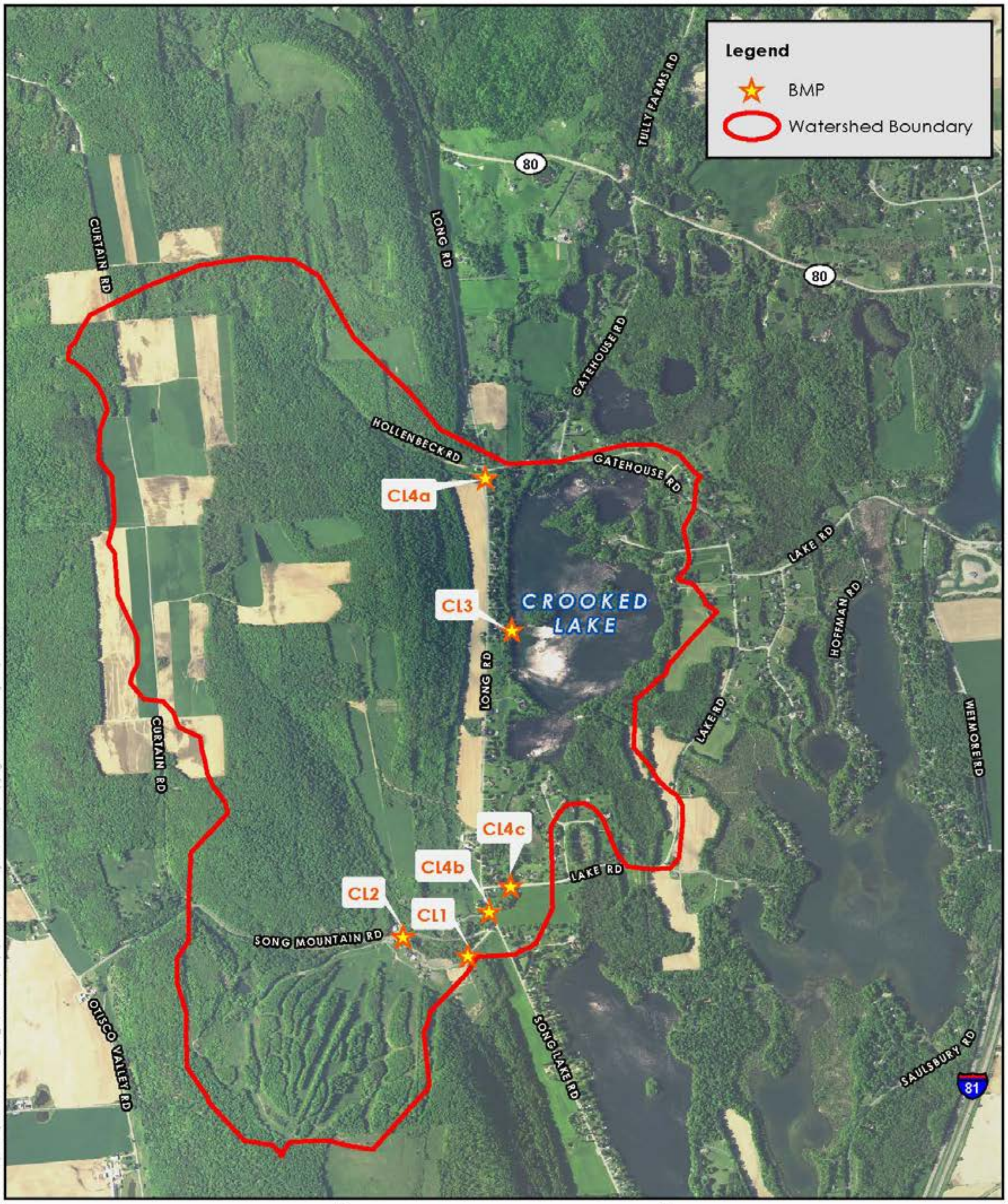

CROOKED LAKE BMPS

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