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

Prepared for:

Cortland-Onondaga Federation of Kettle Lake Associations
Attn: Ms. Tarki Heath
1900 Rittenhouse Square
Tully, New York 13159

Prepared by:

Princeton Hydro, LLC
203 Exton Commons
Exton, Pennsylvania 19341
(P) 610.524.4220
(F) 610.524.9434
www.princetonhydro.com
Offices in New Jersey, Pennsylvania, Maryland and Connecticut

December 2017

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

Contents

Primary Author
Michael Hartshorne

QA/QC Officer
Fred Lubnow, PhD

1.0 Introduction

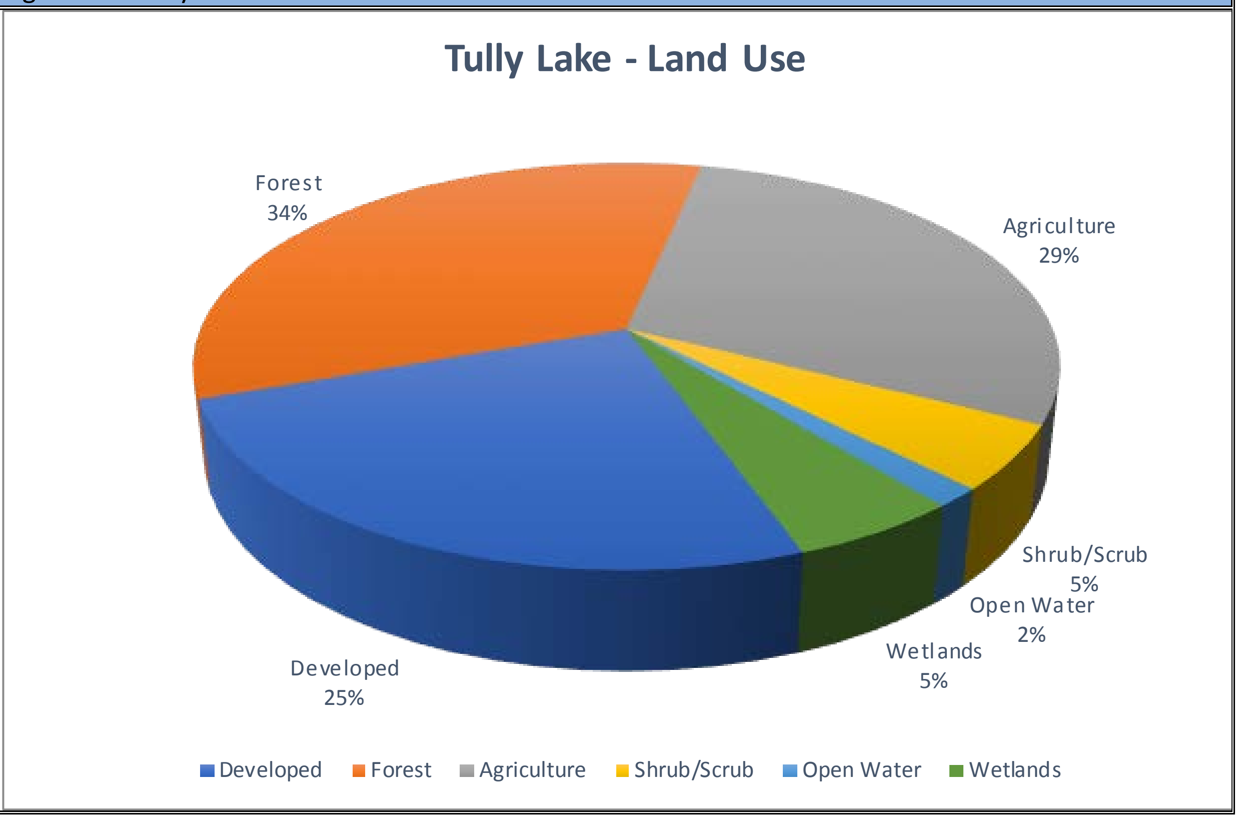
Tully Lake, located in the Towns of Tully and Preble, Onondaga and Cortland Counties, New York, is part of a kettle lake system. Historically, this lake has suffered from symptoms of eutrophication such as dense aquatic vegetation, elevated phosphorus concentrations, lack of oxygen (anoxia), and algal 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	Secchi	Depth	Temp	SpC	DO	DO %	pH
	(m)	(m)	(m)	(C)	(mS/cm)	mg/L	(%)	(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

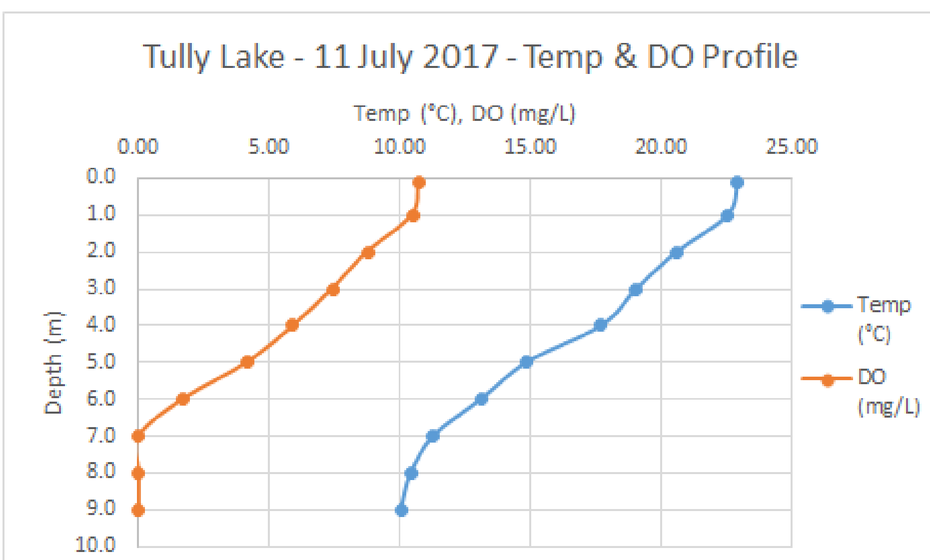


Table 3.2: Tully Lake – Plankton Data

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

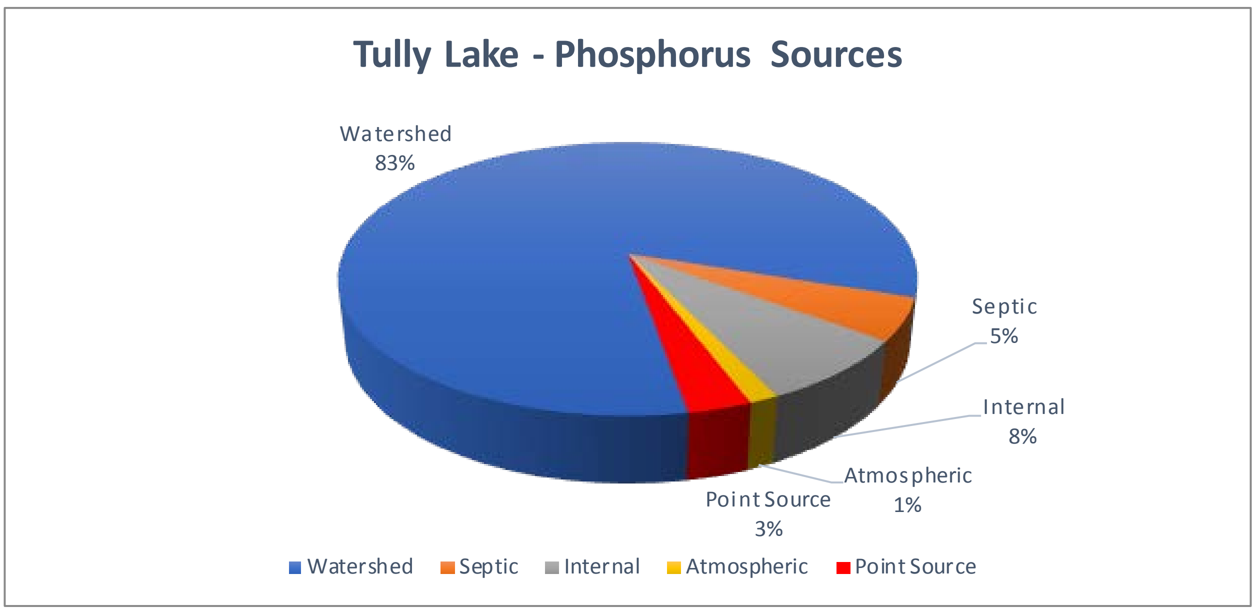
Summary results for nutrient loading to the lake are presented in table 4.1.

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.

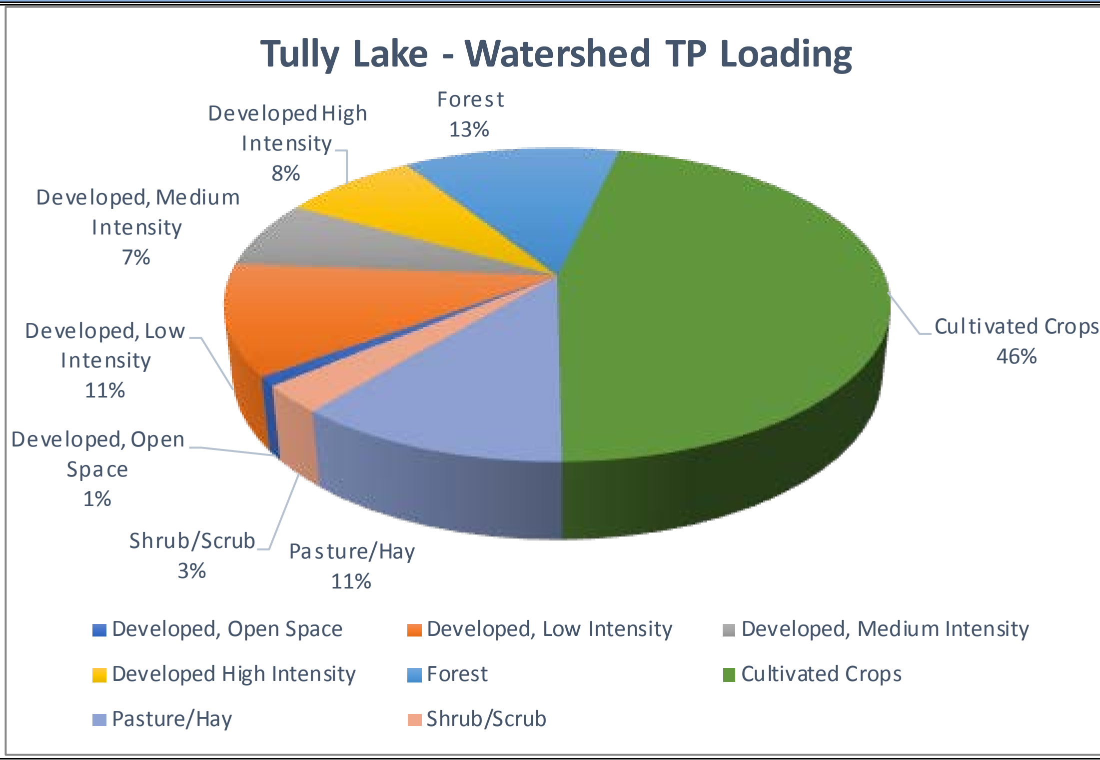
Figure 4.1: Tully Lake TP Loading Summary



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

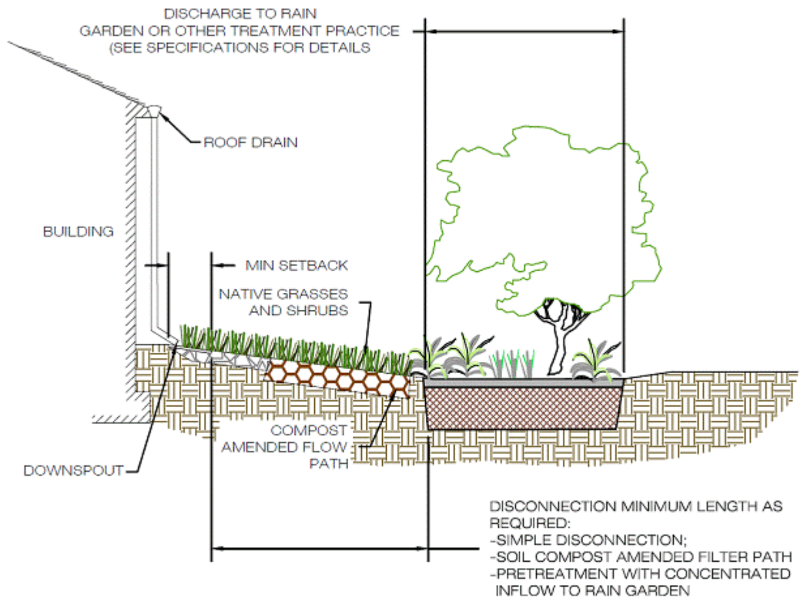
Priority: High

Examples of the recommended BMPs are provided below.

Figure 5.1: Sunfish Bay Circle

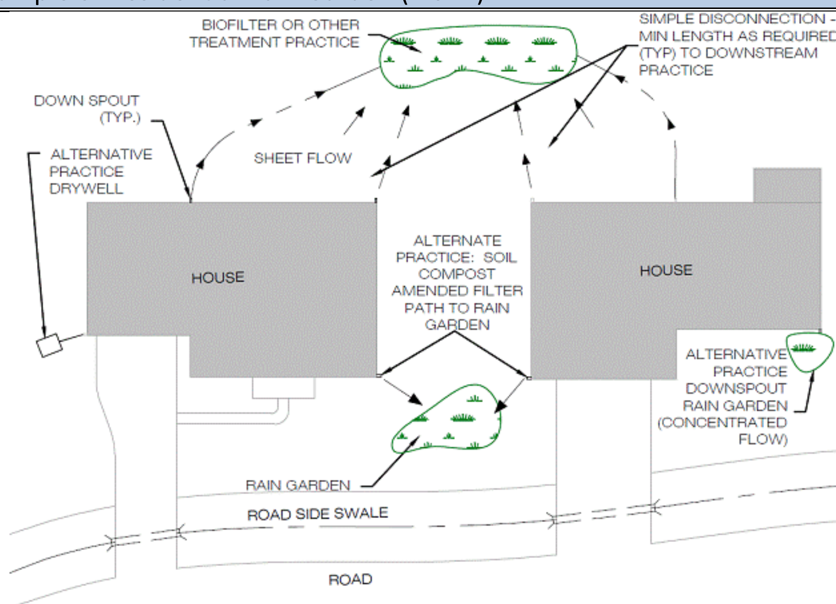
Figure 5.2: Example of Roadside Swale

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.

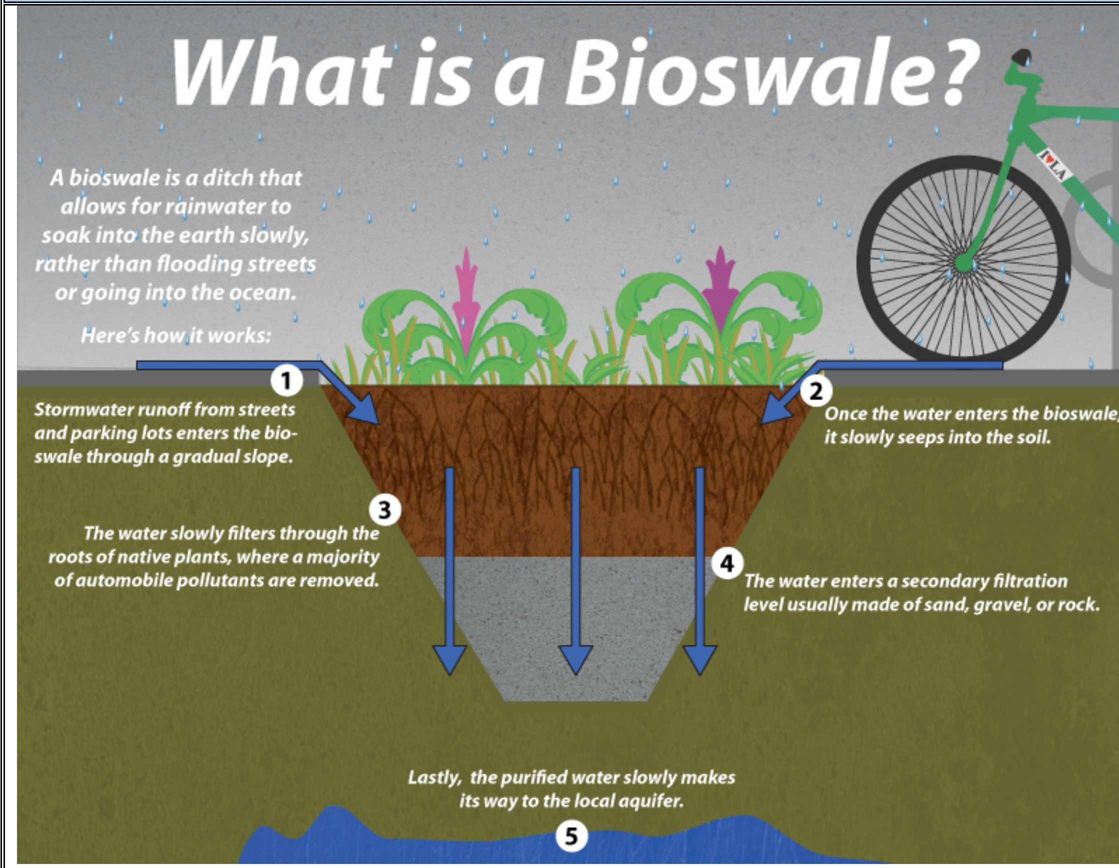
Pollutant Removal: TSS 52 kg/yr, TP 0.04 kg/yr, TN 0.14 kg/yr

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.

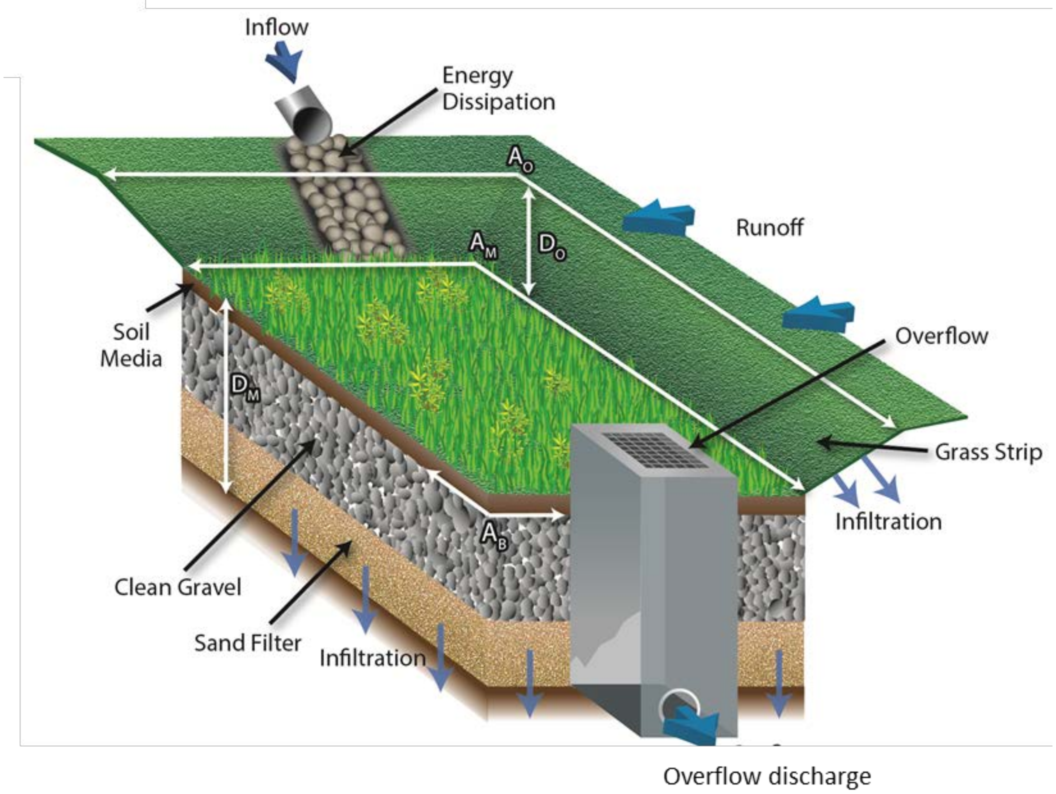
Pollutant Removal: Biofiltration / Infiltration TSS 6,321 kg/yr, TP 4.5 kg/yr, TN 16 kg/yr. Each raingarden TSS 30 kg/yr, TP 0.02 kg/yr, TN 0.1 kg/yr

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.

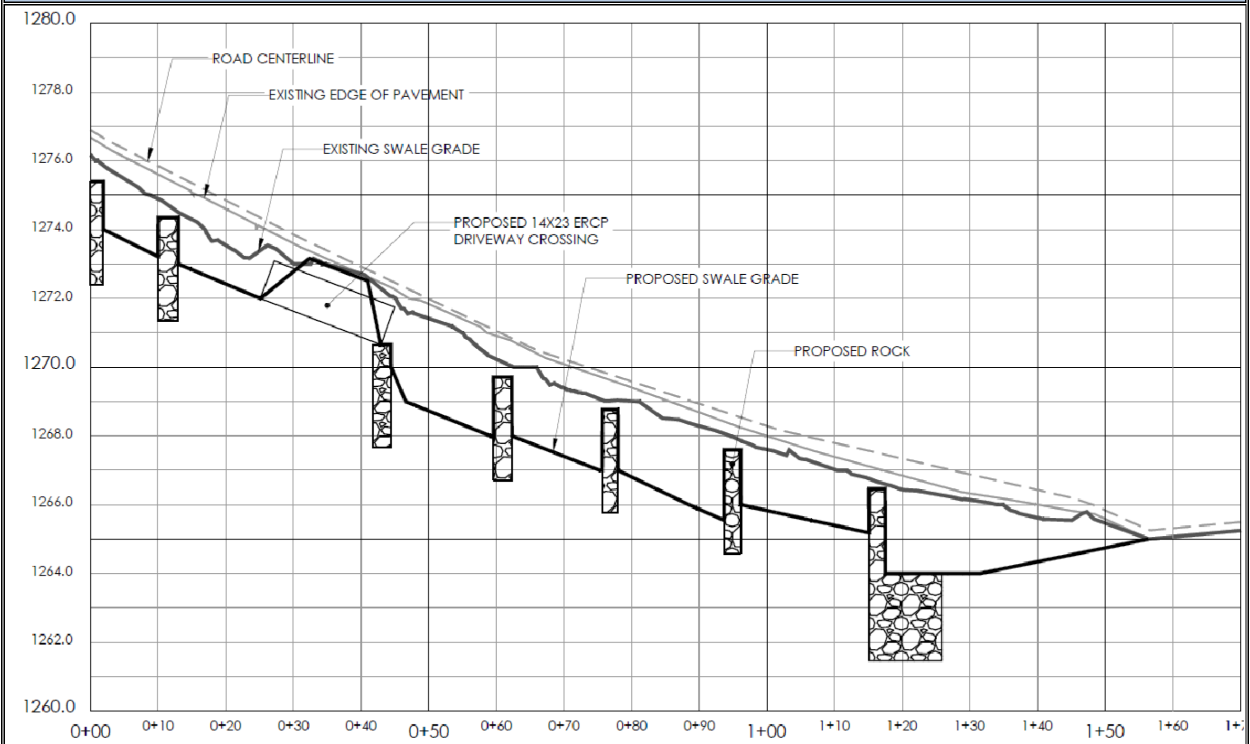
Pollutant Removal: TSS 14,569 kg/yr, TP 12.3 kg/yr, TN 299 kg/yr

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

Day, L.D. 2001. Phosphorus Impacts from On-site Septic Systems to Surface Waters in the Cannonsville Reservoir Basin, New York. Delaware County Soil and Water Conservation District. Walton, New York

Evans, B. 2014. Mapshed Version 1.1 Users Guide. Penn State Institutes of Energy and the Environment.

Gold, A. 2006. Special Issue: Fate of Phosphorus in Septic Tanks (Autonomous Waste Water Treatment Systems). Scope Newsletter No. 63.

Kappel, William et.al., 2011. Hydrogeology of the Tully Lakes Area in Southern Onondaga and Northern Cortland Counties, New York. United States Geologic Survey.

Nedohin, David. 1996. The Effects of Motor Boats on Water Quality in Shallow Lakes. Toxicological and Environmental Chemistry, Vol. 61, pp. 127 – 133.

New York State Department of Environmental Conservation. 2015. New York State Stormwater Management Design Manual. Albany, New York

Pennsylvania Department of Environmental Protection. 2006. Pennsylvania Stormwater Best Management Practices Manual. Harrisburg, Pennsylvania.

Princeton Hydro. 2011. On-Site Wastewater Treatment System Management Plan for the Township of West Milford. West Milford, New Jersey.

Reckhow, K.H. 1979. Quantitative Techniques for the Assessment of Lake Quality. EPA-440/5-79-015. Washington, D.C.

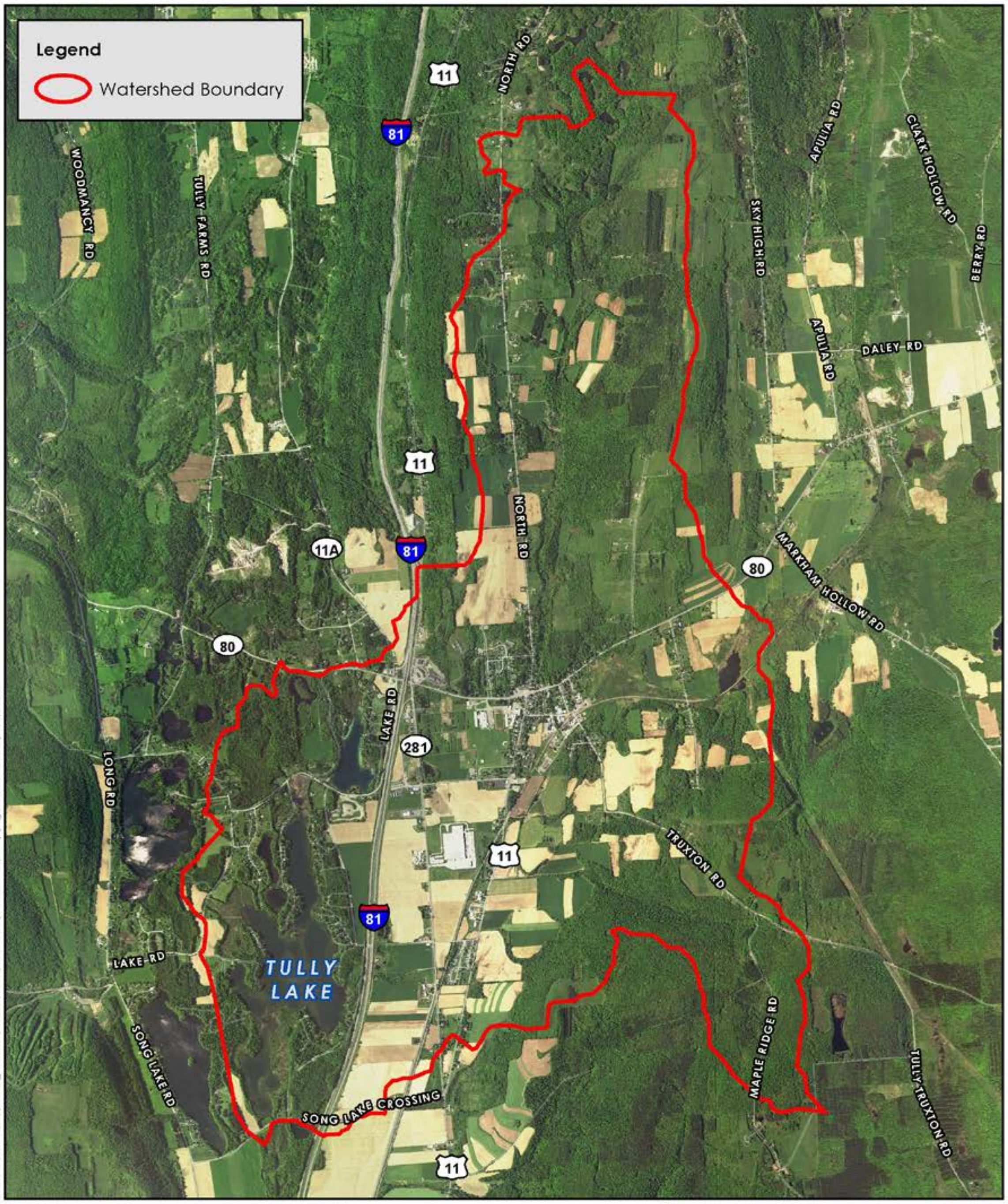
USEPA. 2001. 66 FR 2959 – National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitations Guidelines and Standards for Concentrated Animal Feeding Operations.

USEPA. 1987. Clean Lakes Program Guidance. Washington, D.C.

Yousef, Y.A. 1979. Changes in Phosphorus Concentrations Due to Mixing by Motor Boats in Shallow Lakes. Water Research, 14 pp. 841-852

Zehnder, C.M. 1997. Estimating Feedlot Nutrient Budgets and Managing Manure Output. Minnesota Cattle Feeder Report B-450.

Appendix I



File: E:\GIS_Projects\KettleLakes\MXD\TullyLake_WS.mxd, 10/16/2017, Drawn by sbreitbart, Copyright Princeton Hydro, LLC.

TULLY LAKE WATERSHED

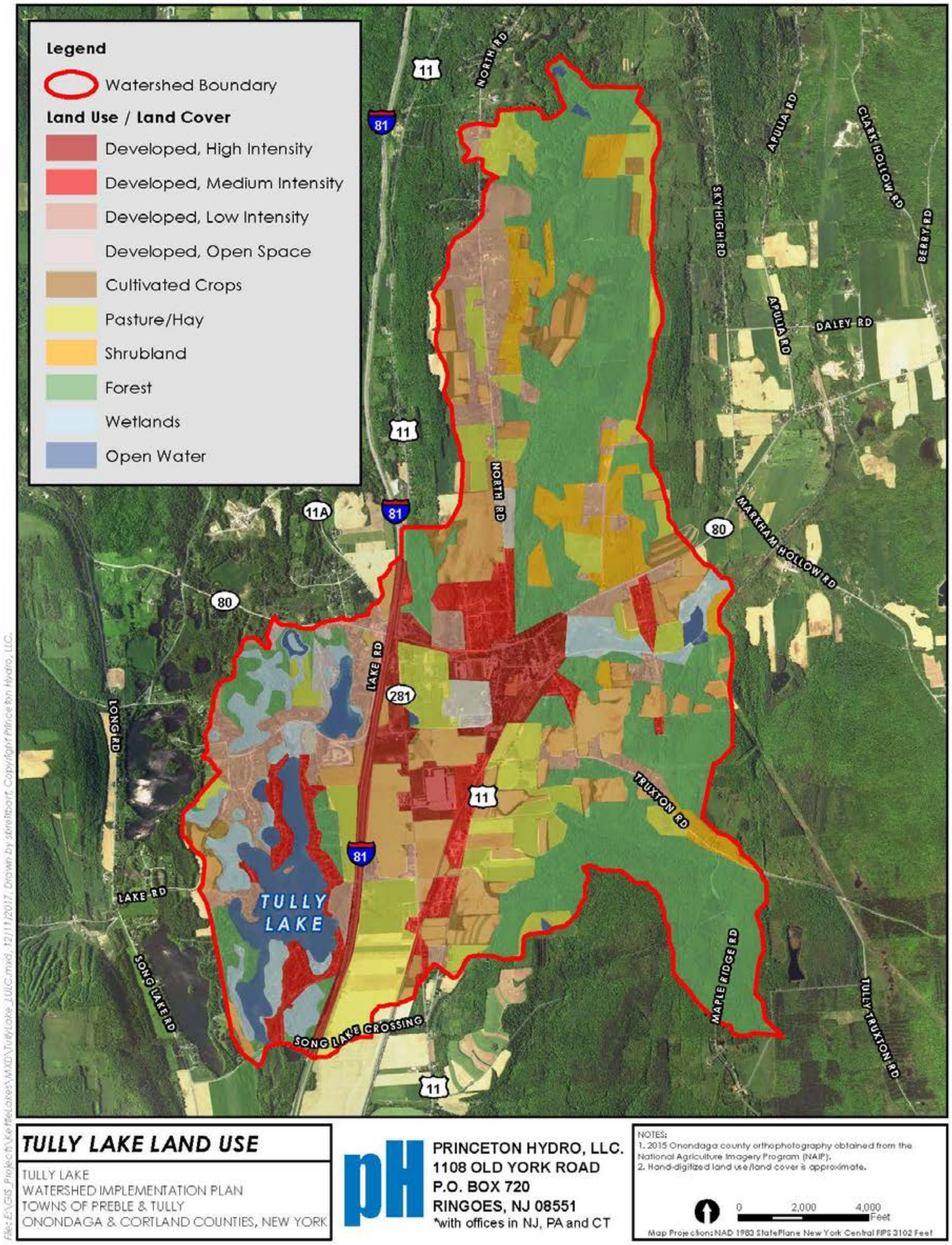
TULLY LAKE
WATERSHED IMPLEMENTATION PLAN
TOWNS OF PREBLE & TULLY
ONONDAGA & CORTLAND COUNTIES, NEW YORK

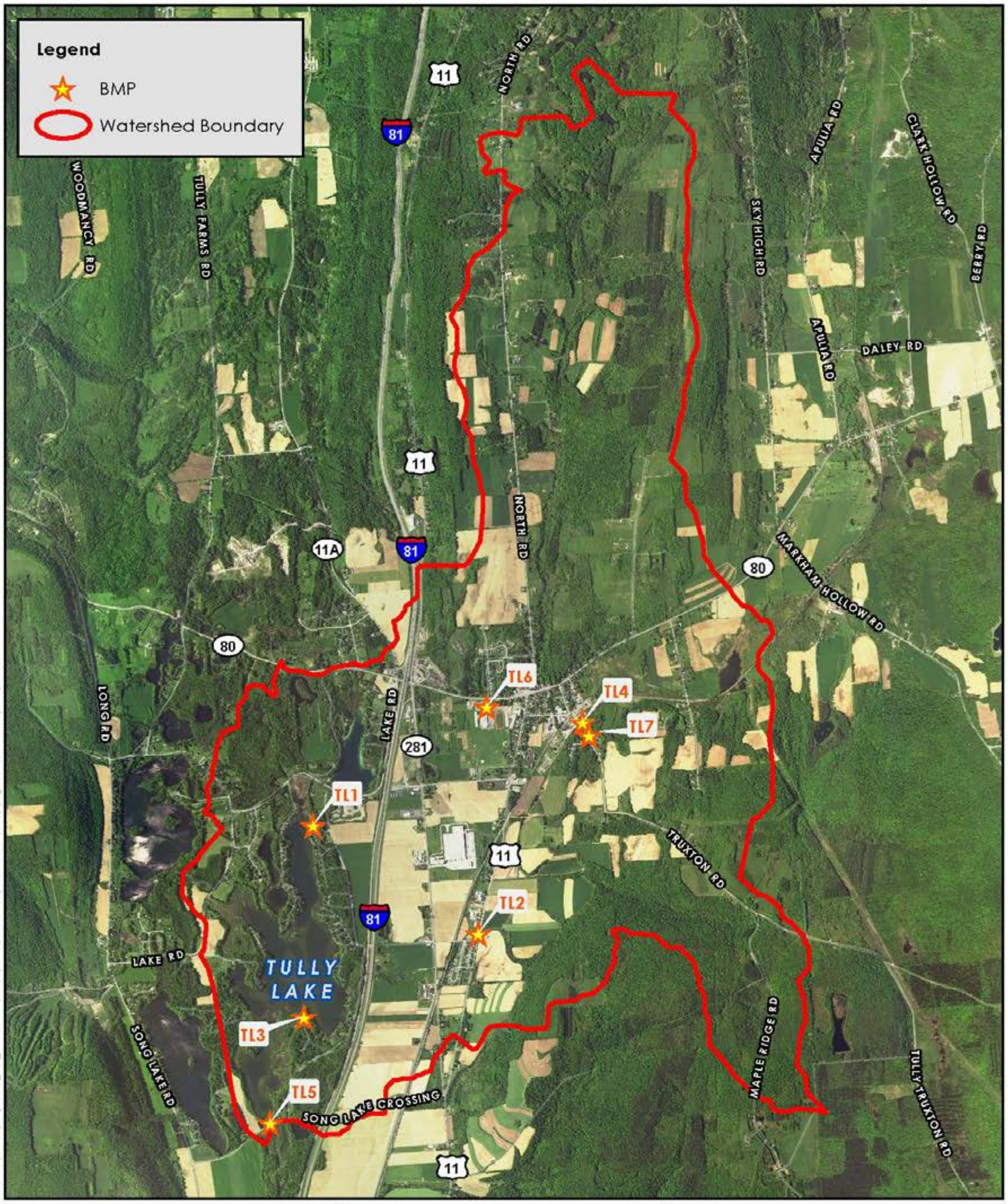
PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

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

0 2,000 4,000 Feet

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
TULLY LAKE
NORTH RD
APULIA RD
CLARK HOLLOW RD
SKYHIGH RD
BERRY RD
DALEY RD
MARKHAM HOLLOW RD
LAKE RD
LONG RD
TRUXTON RD
MAPLE RIDGE RD
SONG LAKE RD
SONG LAKE CROSSING
TULLY TRUXTON RD
11
81
11A
80
281
TULLY LAKE LAND USE
TULLY LAKE
WATERSHED IMPLEMENTATION PLAN
TOWNS OF PREBLE & TULLY
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 Onondaga county orthophotography obtained from the National Agriculture Imagery Program (NAIP).
2. Hand-digitized land use/land cover is approximate.
0
2,000
4,000
Feet
Map Projection: NAD 1983 StatePlane New York Central FIPS 3102 Feet



TULLY LAKE BMPS

TULLY LAKE
WATERSHED IMPLEMENTATION PLAN
TOWNS OF PREBLE & TULLY
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 Onondaga county orthophotography obtained from the National Agriculture Imagery Program (NAIP).

0 2,000 4,000 Feet

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