RECEIVED
APR 19 2017
BY:

Lake Oscawana 2016 Water Quality Monitoring & Aquatic Plant Management Report

Prepared By

NORTHEAST AQUATIC RESEARCH

Hillary Kenyon & George Knoecklein, Ph.D.
74 Higgins Highway
Mansfield, CT
06250

For the Town of Putnam Valley, New York

April 10, 2017

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Town of Putnam Valley and the Lake Advisory Committee has maintained a long-standing monitoring program at Lake Oscawana. Northeast Aquatic Research (NEAR) has been involved in periodically surveying aquatic plants and steadily conducting water quality sampling for over 20 years. The scope of monitoring is outlined in the *Standard Monitoring Explanation and Procedures* section of this report. Over the years, trends have been tracked in invasive Eurasian milfoil expansion and various water quality parameters. At present, the three main concerning trends are:

1. Eurasian milfoil is increasing in frequency lake-wide and is now found in deeper water (~17ft). There is no indication of control of invasive aquatic plants in the Lake. It is also probable that repeated cutting of the growing milfoil stems has allowed for more prolific and dense growth. Grass carp were introduced in 2016 for milfoil control, but it is too early to tell if they are able to reduce milfoil densities.

2. Anoxic water is a growing concern. The trend in increasing bottom phosphorus throughout the summer is due to the release of internal phosphorus from the sediments during seasonal anoxia in the deep waters. There was an unexplained period of reduced internal loading from 2009-2012, but in 2013-2016 the internal load resumed, following a trend similar to that before 2009. Bottom summer phosphorus from 2013-2016 is the highest it has ever been.

3. Seasonal average surface (1-meter) total phosphorus (TP) is increasing from 1994 - 2016. Similarly, the minimum surface TP is increasing at a comparable rate, and the threshold value of 15ppb TP is being exceeded for more months out of the year.

INTRODUCTION

Purpose

The purpose of the long term Lake Oscawana monitoring program is to collect an annual array of water quality data in order to make informed management decisions that will minimize human impact on the lake, while maximizing use of the natural resource. The Town of Putnam Valley and the New York State Department of Environmental Conservation recognize the recreational, ecological, and economic values of lake resources. Lakes naturally accumulate nutrients through earthly processes, but nutrient accumulation is drastically increased by human disturbances in the surrounding land, termed the watershed. With increased development in the watershed, there is a respective increase in nutrient pollution to the lake. Similarly, greater development of residential homes along the shoreline leads to greater disturbance of the local ecological habitat.

Lake management attempts to achieve balance between human enjoyment of the lake and maintaining ecological integrity of the waterbody. Conservation efforts, best management practices, and continued water quality monitoring allow for stability in lake management. If the collected data suggests that lake health is deteriorating, it is the responsibility of the stakeholders to slow that process, and to mitigate identified pollution sources so that they can continue to utilize the lake. For freshwater resources, this duty is typically to limit phosphorus input.

Scope of Report

The following report is outlined into five parts.

Part I describes the current monitoring program and lake study plan. This section also defines important limnological study parameters and general lake management concepts. Part II summarizes the 2016 aquatic plant survey information and makes reference to historical data, as well as current aquatic invasive species practices at the Lake. Part III details the water quality observations for the last two decades and identifies concerning trends in lake condition. Part IV is a summary and interpretation of past lake management reports and current efforts that the Town of Putnam Valley has taken towards mitigating nutrient pollution. Section V details recommendations and reviews the necessary steps in enacting an updated lake management plan.

Part I: Study Plan and Limnological Concepts

This section presents a concise explanation of critical components of the annual lake monitoring program conducted by Northeast Aquatic Research at Lake Oscawana. Key terms are underlined and accompanied by general descriptions. Much of the information included in later sections of this report makes reference to concepts that are discussed below.

Monitoring Stations

Station 1: the deep hole, 1994 - 2016
- Water clarity, temperature, dissolved oxygen, (4) nutrient samples, and plankton

Station 2: northern basin, 1997-2016
- Water clarity, temperature, dissolved oxygen, (2) nutrient samples

Station 3: southern basin, 1999-2016
- Water clarity, temperature, dissolved oxygen, (2) nutrient samples

7 Stream Inlets: 1994-2016 when flowing with water
- (1) nutrient sample from each, historically total coliform/fecal coliform bacteria

Maps of the Sampling Locations are included in ***Appendices 1 & 2***

Water Clarity - Secchi Disk Depth

Water clarity is measured during each visit to the lake at the three sampling sites. To do so, an 8-inch circular Secchi disk is attached to a measuring tape and lowered into the water on the shady side of the boat at the Lake's three main sampling stations. Using a view scope to shade out light in one's peripheral vision, the Secchi disk is lowered until it disappears from view in the water column. The average of the depth at which it is no longer visible and the depth at which it becomes visible again when lifted slightly, is recorded as the water transparency measurement. This Secchi value is dependent on light penetration, and is affected by phytoplankton and suspended sediments in the water column. Clearer waterbodies have greater Secchi transparency values. There are seasonal fluctuations in water clarity that NEAR tracks in relation to other limnological parameters such as plankton populations and nutrient levels. Long-term Secchi disk readings allow for a seasonal understanding of how Oscawana Lake reacts to both a changing watershed and in-lake manipulations, e.g. aquatic plant removal, fish stocking, etc.

Vertical Lake Profiles

Temperature and dissolved oxygen are measured at the three lake stations during each monthly visit from the spring through fall. Measurements are recorded at one-meter depth increments from the surface to the lake bottom. The dissolved oxygen in a lake is dependent on the temperature of the water, phytoplankton production, and consumption by aquatic organisms - though it is also influenced by meteorological conditions and salinity. At the surface of the lake, water is in direct contact with the atmosphere and oxygen is dissolved into the water column via wind mixing and surface turbulence. However, decomposition of rooted aquatic plants and algae requires dissolved oxygen (Biological Oxygen Demand - BOD) and can deplete the oxygen levels in the pond, beginning in the deepest waters. NEAR tracks the height of the anoxic boundary, or the layer of water at which dissolved oxygen is depleted below 1mg/L. Anoxic water is not suitable for respiring organisms like fish and invertebrates.

The percent oxygen saturation, and Relative Thermal Resistance to Mixing (RTRM) values are calculated between one-meter increments. The percent saturation tells us how much dissolved oxygen is in the water based on the water holding capacity at a given temperature. Oxygen can occur in the water at higher than 100%, or super-saturated conditions, due to prolific blooming phytoplankton and dense aquatic plant beds. Oxygen in water can be reduced by Biological Oxygen Demand (BOD). RTRM is a unit-less number that describes the temperature-induced density differences in the water column. Higher numbers specify strong stratification, or less mixing. The maximum RTRM defines the middle of the thermocline where the temperature creates a gradient that prevents oxygen rich surface waters from mixing through the hypolimnion (bottom water layer with little to no light penetration).

The thermocline, or the zone of rapid temperature change that separates the top and bottom layers of water during the summer season, is related to the Secchi disk water clarity. The greater the clarity, the farther the sun's rays are able to penetrate into the water column. Increased clarity will warm more surface water and the thermocline will be deeper in the water column during the hot spring and summer months. Essentially, the greater the clarity of a lake, the greater the volume of water that remains indirectly replenished with oxygen through mixing above the thermocline. When the intensity of the sunlight fades into autumn, the thermocline will weaken and the lake begins the regular 'fall-turnover' mixing event.

Water Chemistry Sampling

Water samples from Station 1 are taken from depths of 1, 4, 6, and 9-meters. At Stations 2 and 3, top (1m) and bottom (7m) samples are collected. Samples are analyzed for total phosphorus, total nitrogen, and additional nutrient chemistry as suitable for limnological investigation. Exact locations of sampling areas are shown in the bathymetric map in **Appendix 1**.

Phosphorus and nitrogen are the two critical nutrients that drive aquatic plant and algae growth in lakes. Nutrient inputs can come from the watershed in the form of septic leachate, farm runoff, lawn fertilizers, and sedimentation from roads or streams. In freshwater systems, phosphorus tends to be the limiting factor for productivity and is more heavily monitored for the health of inland ecosystems. For this reason, NEAR specifically tracks spring epilimnetic (surface) phosphorus, and hypolimnetic (bottom) water phosphorus. In addition to in-lake sampling, NEAR also samples the seven stream inlets to the lake. Monitoring the quality of the water entering the lake ensures that excess nutrient pollution is not accumulating due to watershed loading.

Plankton Assemblages

Phytoplankton and zooplankton samples are collected during each visit at Station 1 using a fine-mesh tow net and a vertical 3-meter algae collection straw. These samples are preserved with Lugol's iodine solution and examined under the microscope at a later date. When NEAR examines the zooplankton population, it is largely to gauge the dominant genera and approximate size classes because size influences zooplankton feeding preferences and water filtration capabilities. NEAR examines phytoplankton to make density estimates to understand the cyclical variation in species throughout the sampling season. Phytoplankton are known to correlate to the available nutrients in the water column. Excess phytoplankton causes a loss of water clarity and it is important to track bloom assemblages throughout the warm growing season. For the purposes of this report, phytoplankton are classified into blue-green algae (cyanobacteria), green algae (Chlorophyta), and diatoms (Bacillariophyta). NEAR has additional classification data on file that is usually not pertinent to include in an annual report but is used for better overall understanding of lake trophic (food web) interactions.

Aquatic Plant Survey

Aquatic plant surveys are conducted via thorough investigation of the littoral zone, or zone of light penetration where plants grow along the shoreline. This aquatic vegetation survey identifies the species present, as well as their approximate abundance and density. NEAR specifically notes the extent of the invasive species Eurasian watermilfoil, while ensuring that no new invasive species have become established. One of the most important things in the battle against aquatic invasive species is continuous monitoring of invasive and native plants. In 2016, an early-season aquatic plant survey was conducted on the lower half of the lake to investigate invasive Curly-leaf pondweed, and instead of a full-lake survey in August, NEAR conducted multiple months of transect surveying at various locations throughout the littoral zone.

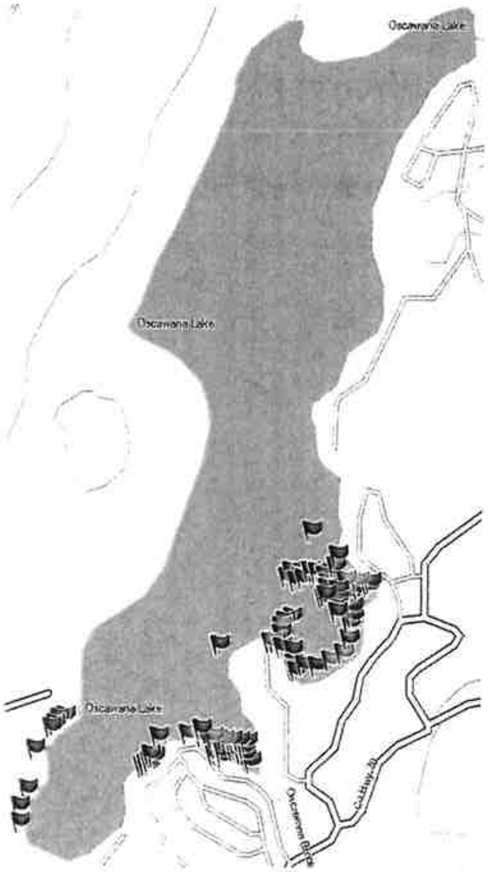
Stream Assessment

Stream samples are collected monthly from seven identified inlets to the Lake. Stream samples are collected as grab samples and represent a baseflow value of nutrient inputs. Samples are collected only when the respective inlets are flowing, as some of the inlets run dry during the summer months. In 2016, NEAR was able to collect one round of stormwater samples from the major inlets.

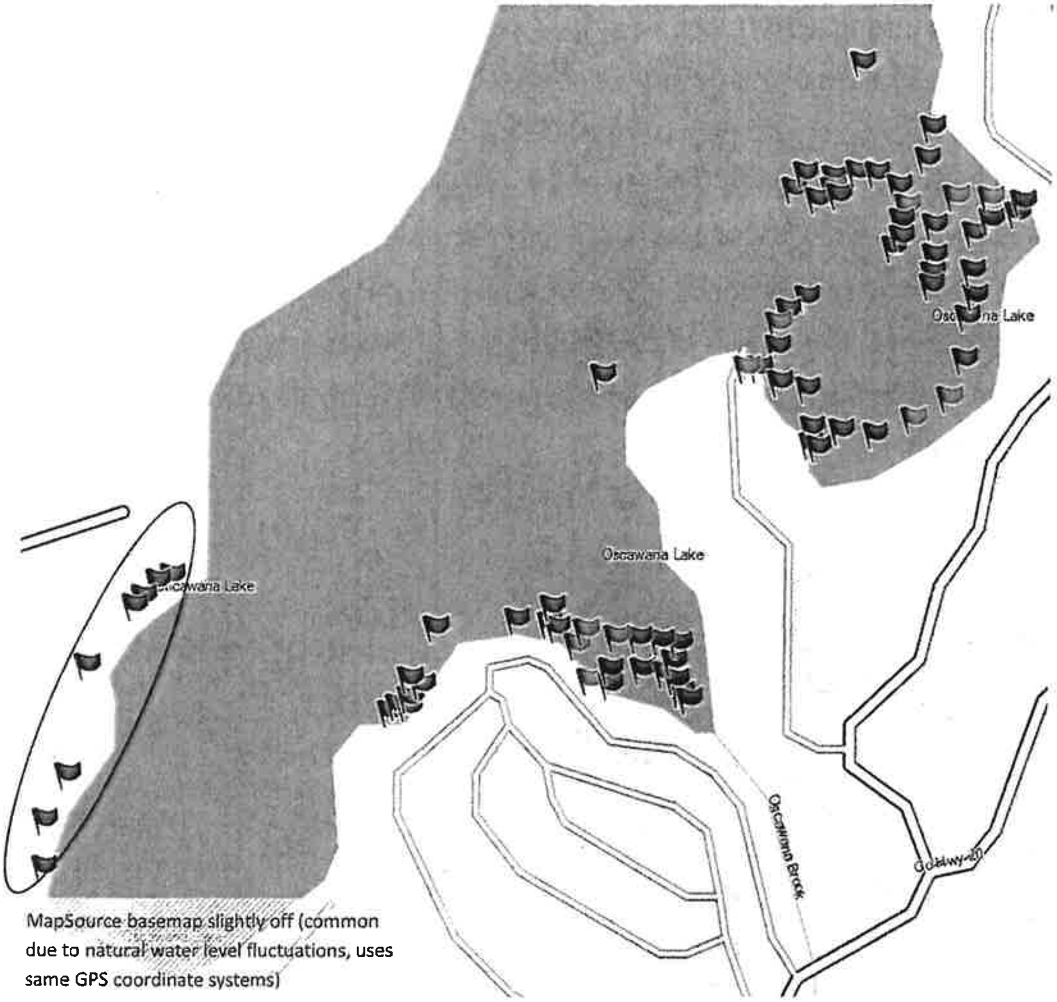
Part II: 2016 AQUATIC PLANT SURVEY RESULTS

Early Season Curly-leaf Pondweed Assessment

NEAR conducted an aquatic plant survey of the lower portion of the lake in early June to assess the extent of invasive Curly-leaf pondweed (*Potamogeton crispus*). Curly-leaf typically grows early in the season and is not seen in the height of summer, thus this survey aimed to document its locations in the lake. Due to time constraints, this survey was conducted over two days on May 12th and 19th, 2016. **Map 1** demonstrates the area that was surveyed. **Map 2** shows a close-up of waypoints where Curly-leaf pondweed was located and its respective density at each location. Waypoint flag colors represent density of curly-leaf pondweed: blue = sparse (0-20%), green = medium (20-50%), and red = dense (>=50%).



Map 1 Early Season Curly-leaf Pondweed Survey

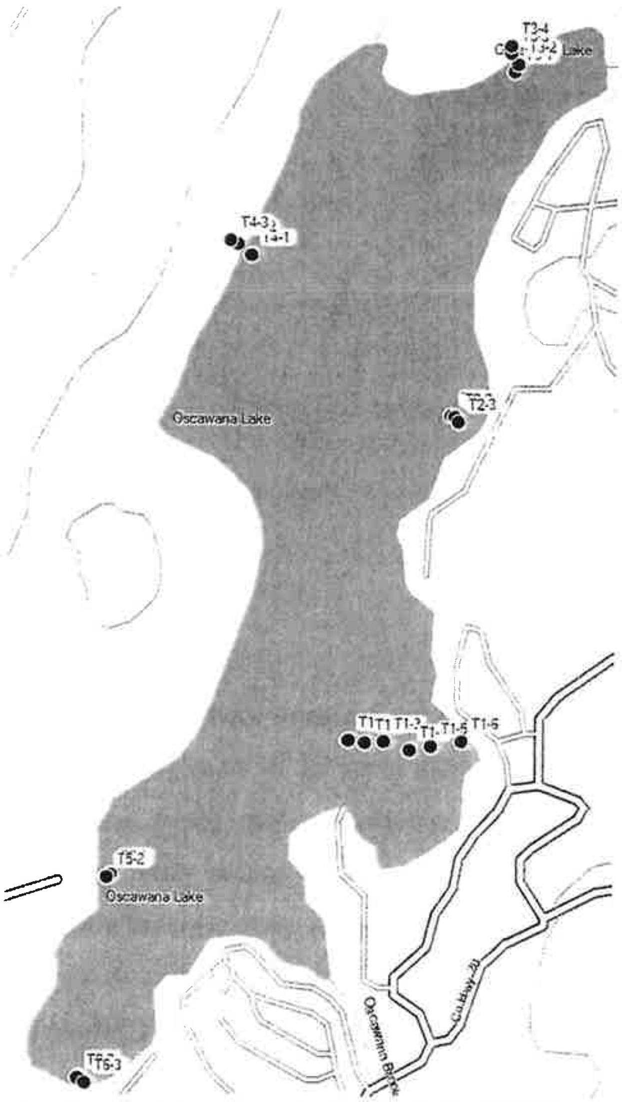


MapSource basemap slightly off (common due to natural water level fluctuations, uses same GPS coordinate systems)

Map 2 May 2016 Curly-leaf pondweed survey (Blue = Sparse, Green = Medium, Red = Dense)

Transect Surveying

In early years of management at Lake Oscawana, aquatic plant surveys were conducted without GPS technology, using a range-finder to determine the distance from shore of an established plant bed. Since 2008, aquatic plants have been surveyed using GPS technology which allows making geo-referenced Waypoints throughout the littoral zone. At each waypoint, the aquatic plant species and their respective densities were recorded. These types of surveys allowed for more accurate mapping of total invasive species cover in the lake. On June 15th, 2016 NEAR returned to continue the aquatic plant survey from May (5-12 and 5-19), however, the aquatic plant assemblage was drastically different than only two weeks prior. Though Curly-leaf pondweed had occurred in May throughout the lower lake, and sometimes in large dense patches, there was none to be found by mid-June. Thus, in order to track seasonal fluctuations in aquatic plant species abundance, a series of transects were established (T1 through T6) and surveyed in July, August, and September 2016. Table 1 describes the locations of these transects and they are shown on a map in **Figure 3.** Using transects is another form of aquatic plant surveying that is generally more useful in long-term statistical comparisons of certain areas, but that is not useful in determining overall plant acreages in the Lake. For this reason, no overall calculations were made for 2016 on the total acreage of Eurasian milfoil (*Myriophyllum spicatum*). The depth limit of Eurasian milfoil was, however, the same as recorded in 2015 - approximately up to 18ft deep - and visual densities very similar to 2015.



Map 3 Transect Locations (T1, T2, T3, T4, T5, T6) 2016

Table 1 Description of Transects

T1 (6 waypoints) is located at a very wide section of the littoral zone in a cove that is heavily infested with Eurasian milfoil. This is an area where the weed harvester is known to work.
T2 (3 waypoints) is located along the rocky northeastern edge of the lake in an area that with a narrower littoral zone.
T3 (4 waypoints) is located at the north end of the lake in a mixture of a large bed of *Pot. amplifolius* and E. milfoil. Inner waypoints are not inside swim area but are close to a resident's boat-house. Very mucky sediments with some rocks.
T4 (3 waypoints) along northwestern shore, not located by any houses. Narrow littoral zone, rocky, sharp drop-off to deeper water.
T5 (2 waypoints) is in a very sandy shallow area along southwestern shore. Ability to sample affected by water level.
T6 (3 waypoints) located in shallow water at the south end of lake. Very close to outfall pipe, walled shoreline, very mucky sediments.

The aim of the transect survey was to determine if the weed harvester had any effect on Eurasian milfoil frequency and density. At present there is no definitive method of tracking exactly where the harvester worked. In the future this issue could be remedied by having the harvesting operator use a continuously tracking onboard GPS unit. Nevertheless, it is known that the weed harvester spends a considerable amount of time in the area of Transect 1 (T1) and that it may spend some time near T3 and T6. The harvester does not spend time at T4. It is unknown if the harvester spends any time at T2 or T5. **Table 2** shows the species present at all transects over each survey date.

Table 2 Combined Transect Survey Results

Species	7/25/2016 %Occur	8/31/2016 %Occur	9/27/2016 %Occur	7/25/2016 AVG%	8/31/2016 AVG%	9/27/2016 AVG%	7/25/2016 Overall %	8/31/2016 Overall%	9/27/2016 Overall%
1 Myriophyllum spicatum	75	76	71	39	39	27	30	30	19
2 Ceratophyllum demersum	56	48	43	42	54	43	23	25	18
3 Zosterella dubia			5			10			0
4 Potamogeton robbinsii	44	43	43	71	63	77	31	27	33
5 Cyanomat	19	14	33	53	100	19	10	14	6
6 Nymphaea odorata		10	5			85			4
7 Wolfia/Lemna			5						
8 Potamogeton amplifolius	25	38	33	70	67	66	18	26	22
9 Vallisneria americana	13	5	10	20	100	95	3	5	9
10 Saggiteria graminea	6			5			0		
11 Potamogeton crispus									

Table 2 is not transect-specific but instead demonstrates the total percent occurrence, or frequency of waypoints at which a certain species was located over all transects (%Occur), the average percent (AVG%) cover, or density over the combined transects, and finally the product of the decimal percent cover and the percent occurrence (Overall%). The Overall% value represents an estimate of the total coverage of a certain species across all six transects. Overall transect results demonstrate that there was a small change in total Eurasian milfoil growth, from 30% in July and August to 19% in September. That drop came mostly from a reduction in the AVG% cover, which occurred at multiple transects.

Table 3 displays all of the Eurasian milfoil percent cover transect data. Transects are labeled in the form "T1 - 4" where "T1" is the transect and "4" is the waypoint number in that transect. Therefore, the table displays the monthly change in density of Eurasian milfoil at all 21 waypoints over the six transects. Transects 5 and 6 were not surveyed in July due to technical field difficulties.

Table 3 Eurasian Milfoil Percent Cover for Each Transect Waypoint

%Cover at WPT	7/25/2016	8/31/2016	9/27/2016
Myriophyllum spicatum			
T1-1	3	-	5
T1-2	40	20	10
T1-3	85	40	30
T1-4	100	40	70
T1-5	50	30	15
T1-6	20	60	10
T2-1	20	-	-
T2-2	20	10	5
T2-3	5	90	-
T3-1	10	70	10
T3-2	70	25	-
T3-3	-	15	-
T3-4	30	40	10
T4-1	-	-	-
T4-2	60	40	30
T4-3	-	-	20
T5-1	NA	15	10
T5-2	NA	15	80
T6-1	NA	-	-
T6-2	NA	20	70
T6-3	NA	100	30

Dash (-) means Milfoil not found at WPT on this date
NA means NEAR did not sample WPT on particlular date

From the above data, there appears to be a steady decline in Eurasian milfoil abundance at T1 from July to September. Transects 2 and 3 had large range in percent cover and did not follow a pattern. Transects 4 and 5 were assumed to be areas where the harvester did not work so variation could be due to other factors. T6-3 appeared to be disturbed and have less milfoil from August to September, but the overall transect was similar from month to month. There was a very thick mat of cyanobacteria that may have also caused some variation.

In Transect 1, the area known to be heavily harvested, growth factors were also recorded to document the relative height of the Eurasian milfoil plants in the water column. A weed harvester does not remove aquatic plants at the roots and thus, heavily harvested regions often have aquatic plants growing at high densities just a couple feet below the surface. **Table 4** shows the growth factors for Transect 1 over the season on a scale of 1-5, where 1 is near the bottom and 5 is topped out at the surface. Overall, it appears that harvesting Eurasian milfoil did keep much of the milfoil growth below the surface in the T1 area. Only one waypoint in August had a maximum growth height of 5, indicating that the whole area was passable by boaters for a large period of the summer.

Table 4 Growth Factor of Eurasian Milfoil at T1

Myriophyllum spicatum			
Growth Factor (Scale 1-5)			
WPT	7/25/2016	8/31/2016	9/27/2016
T1-1	2	0	2
T1-2	3	3	3
T1-3	4	3	3
T1-4	4	4	4
T1-5	3	4	3
T1-6	3	5	2

Eurasian Milfoil Coverage Estimates

Table 5 below displays the approximate acreages of Eurasian milfoil (*Myriophyllum spicatum*), Large-leaf pondweed (*Potamogeton amplifolius*), and Water lilies (*Nymphaea odorata* and *Nuphar variegata*) from surveys conducted since 2003. Estimates of coverage over time shows that Eurasian milfoil is expanding in coverage in Lake Oscawana. Eurasian milfoil is also growing in deeper water, in 2003 the maximum milfoil depth recorded was 12.5ft, in 2013, the milfoil was found at 15ft (see **Map 4**) while in recent surveys, it was found at 16-18ft.

Table 5 Aquatic Plant Acreages 2003-2015

Species	**2003**	**2008**	**2011**	**2013**	**2014**	**2015**
Eurasian milfoil	30.7	30.0	44.0	41.3	48.5	76.4
Large-leaf pondweed	23.2	20.4	16.5	2.1	7.8	1.2
Water lilies (White&Yellow)		8.6	7.5	4.1	9.7	9.6
Computer Mapping Program	AudCAD	AutoCAD	AutoCAD	Google	ArcMap	ArcMap
NEAR member	GK	GK	GK	GK	HLK	HPK/HLK

Notes: Water lily acreage varies heavily with time of year and may explain decreased 2013 value.

Map 4 Eurasian milfoil coverage 2013-2015

Water Clarity - Secchi Disk Depth

During the 2016 field season, Secchi disk depth was measured six times at Station 1, the deepest part of the lake. Stations 2 and 3 were measured in June, July, and September 2016 (**Figure 1**).

- Average 2016 Secchi disk depth was 3.2 meters. The average 2015 Secchi disk depth was 3.5 meters
- Historical average (1987-2015) = 3.0 meters
- Average since 2000 = 3.1 meters
- Maximum 2016 = 4.2 meters (St. 1; 6/15/16), Maximum 2015 = 5.1 meters (St. 1; 5/28/15)
- Minimum 2016 = 1.8 meters (St. 1; 9/-27/16), Maximum 2015 = 2.0 meters (St. 1; 4/30/15)
- Long-term Spring (April to early May) at St. 1 = 2.8 meters
    - ➢ Spring clarity worse than historical seasonal average.
    - ➢ **Figure 1** (below) displays trend in Spring Secchi clarity, where the horizontal red dotted line is the "poor clarity" threshold, and the blue dotted line is the "better clarity" threshold for Lake Oscawana. Goal is for < 4.0 meter Spring clarity.

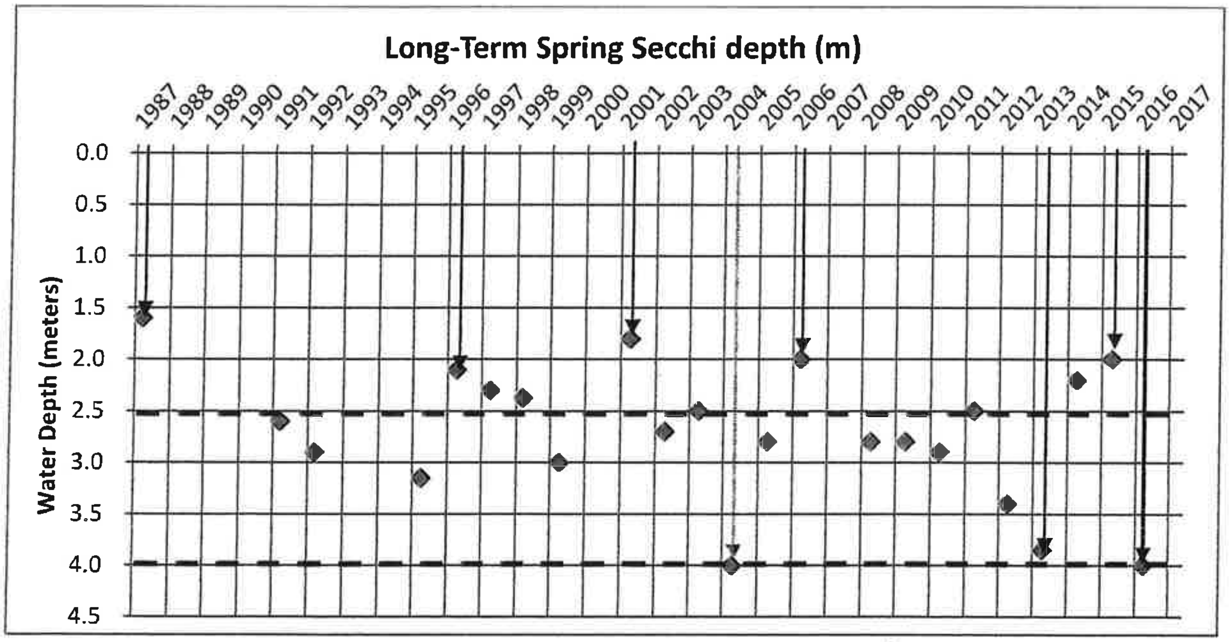


Figure 1 Long Term Spring Water Clarity (Secchi disk depth - meters)

Figure 1 demonstrates that there is a wide annual variation in spring water clarity. Years with spring clarity (Station 1) greater than 4.0-meters are considered good for Oscawana, while years with spring clarity less than 2.5-meters are considered poor. Spring water clarity is likely affected by the degree of ice covering and potential timing of spring snow melt from the watershed.

Figure 2 below illustrates the trend in seasonal maximum Secchi disk water clarity from 2000 to 2016. Pre 2000, a Secchi view scope was not regularly used, so for the purposes of identifying true trends, we excluded values that may have occurred without a view scope in earlier years. A view scope enhances one's ability to see into the water by shading out light in one's peripheral vision. It is a much more accurate means of acquiring visually based water clarity measurements and minimizes error. **Figure 2** also displays the similar but opposing trend in increasing average seasonal surface Total Phosphorus (TP) for the same time span. The seasonal average surface TP trend is statistically significant, while the annual maximum Secchi trend is not statistically significant but is overall negative and tending towards worsening clarity over time.

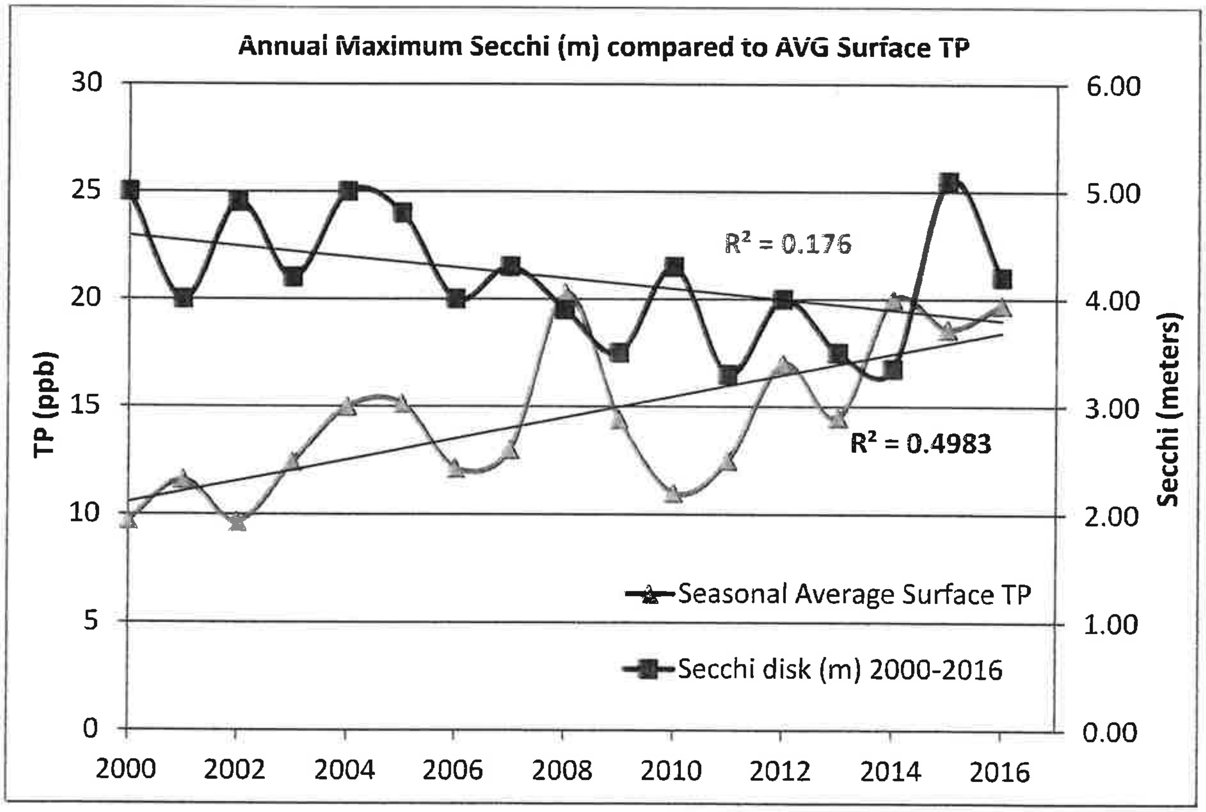


Figure 2 Annual Maximum Secchi disk depth and Seasonal Average Surface TP 2000-2016 (St. 1)

Given data pre-2000, the trends are not quite as strong. For maximum Secchi and average surface TP (Station 1) from 1994 to 2016 the R^2 values are: Secchi $R^2 = 0.08$ (not significant) and AVG surface TP $R^2 = 0.41$ (still significant). The lesser trend in maximum Secchi disk clarity since 1994 is a result of two years with poor clarity 1995 and 1999. Historically, the period of good clarity tends to occur in late June to July, while in 1995 that clear-water phase did not occur, and in 1999 no Secchi disk value was recorded for late June (**Figure 3**). Years 2015 and 2016 saw better max clarity than expected based on the seasonal surface TP values. Further explanation of TP values is included in a following subsection of Water Quality Monitoring Results.

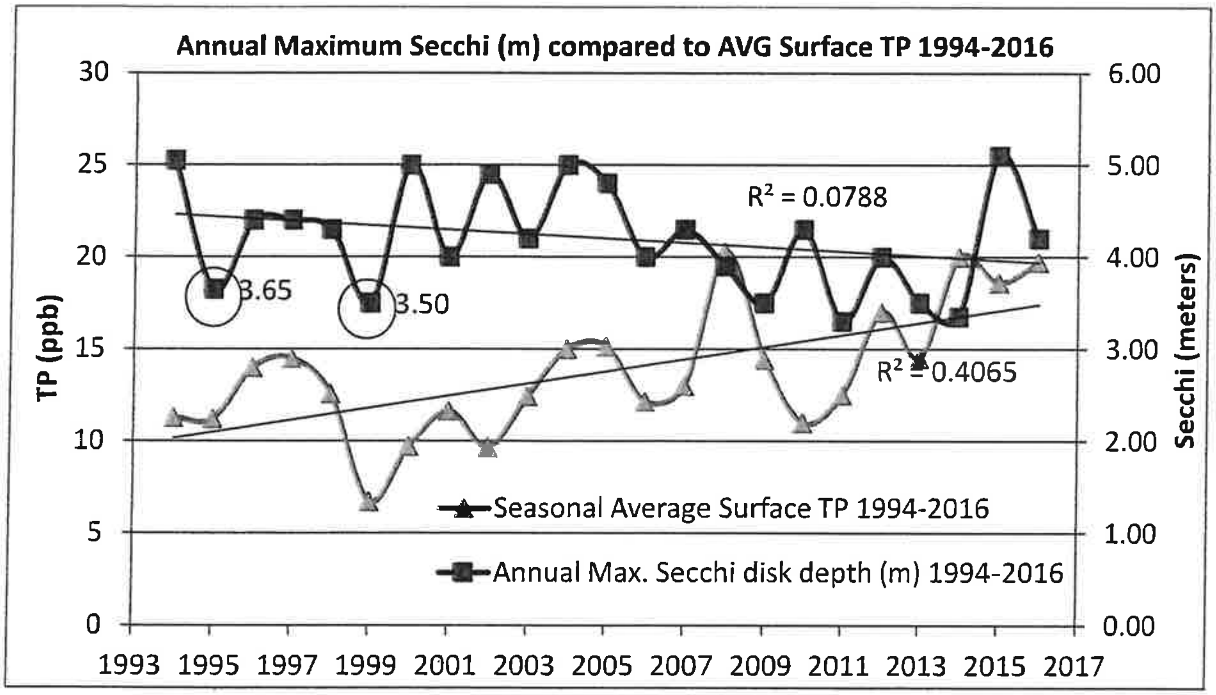


Figure 3 Annual MAX Secchi and AVG Surface TP 1994-2016

The "poor clarity" threshold for Lake Oscawana has been established as 2.5 meters. **Table 6** lists when Secchi disk depth dropped to and below this lower boundary. **Table 6,** all Station 1 values, displays that poor clarity occurs during most months of the year, especially summer months August September, spring months of April and May, and the fall month of October. June, and July, almost wholly exempt from **Table 6,** are typically when the lake experiences maximum Secchi disk depths >2.5 meters. The months highlighted in pink depict full lake mixing conditions. September months are indicative of the annual deepening of the thermocline and start of fall 'lake turnover.' August and September months indicate the annual peak of anoxia and internal phosphorus loading.

Table 6 All Secchi values less than or equal to 2.5 meters

Secchi values less <2.5 m

Date	Secchi(m)	Month
4/15/1987	1.6	April
5/12/1987	1.6	May
5/23/1987	2.1	May
8/5/1987	2.2	August
8/24/1987	2.1	August
9/9/1987	2.3	September
9/28/1987	2.2	September
10/1/1989	2.0	October
9/1/1990	1.9	September
10/1/1990	2.3	October
8/1/1991	2.2	August
10/1/1991	2.3	October
8/1/1992	2.2	August
9/1/1992	2.0	September
8/2/1994	2.50	August
8/25/1994	2.40	August
9/22/1994	2.30	September
4/26/1996	2.10	April
8/6/1996	2.50	August
9/24/1996	2.40	September
4/23/1997	2.30	April
8/20/1997	2.30	August
9/3/1997	1.75	September
10/5/1997	2.30	October
3/31/1998	2.30	March
4/2/1998	2.38	April
5/16/1998	2.30	May
9/18/1998	2.40	September
9/30/1999	1.50	September
10/29/1999	1.70	October
8/9/2000	2.00	August
8/22/2000	2.50	August
9/28/2000	2.10	September
10/5/2000	2.5	October
4/27/2001	1.8	April
8/30/2001	1.5	August
9/27/2001	2.1	September
10/10/2001	2.5	October
9/26/2002	2	September
10/3/2002	2.5	October
4/30/2003	2.5	April
9/24/2003	2.2	September
11/18/2003	2.5	November
7/27/2004	2.2	July
8/30/2004	2.5	August
9/20/2004	2	September
9/29/2005	2.2	September
10/20/2005	2.2	October
4/12/2006	2	April
5/9/2006	2.3	May
8/9/2006	1.8	August
9/27/2006	2.5	September
10/17/2007	2.4	October
9/28/2009	1.9	September
4/20/2011	2.5	April
10/11/2011	2.5	October
8/21/2012	2.3	August
9/25/2012	2.1	September
10/17/2012	2.4	October
8/6/2013	2.4	August
4/22/2014	2.2	April
9/26/2014	2.5	September
11/4/2014	2.2	November
4/30/2015	2	April
8/30/2016	2.5	August
9/27/2016	1.8	September

Water Column Profile Data

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen were measured monthly at one-meter increments at each sampling station during 2016. **Table 7** is the 2016 record of dissolved oxygen (DO) at Station 1. Cells highlighted in red are less than 1 mg/L DO and represent the depth of anoxia. Based on the temperature and dissolved oxygen concentrations, the percent oxygen saturation and thermal resistance to mixing were calculated (see Part I for description of terms). The following is a bulleted summary of 2016 profile data:

- Maximum height of anoxia at Station 1 = 5.7-meters on 8/31/2016
- Station 1 approximate duration of anoxia = >104 days (calculated based on available information from sampling dates)
- 2016 rate of oxygen depletion = 0.128 (negative) mg/Liter/day
- Linear trend in AVG 6&7-meter oxygen depletion 2006-2016 slightly significant, R^2= 0.5479

Table 7 Dissolved Oxygen Profiles Station 1

Dissolved Oxygen concentrations in mg/L

Depth in meters	**13-Apr-16**	**19-May-16**	**15-Jun-16**	**25-Jul-16**	**31-Aug-16**	**27-Sep-16**	**8-Nov-16**
0	10.8	10.1	9.3	8.5	9.4	7.8	9.6
1	10.8	10.1	9.4	8.7	9.4	7.6	10.0
2	10.8	10.1	9.5	8.8	9.3	7.3	10.0
3	10.8	9.9	9.3	6.7	9.0	7.1	10.0
4	10.8	9.9	9.2	8.5	7.4	7.1	10.0
5	10.7	9.7	7.0	7.3	2.6	7.3	9.9
6	10.7	9.4	4.4	7.3	0.3	7.9	9.9
7	10.7	6.0	0.5	0.2	0.2	8.0	9.9
8	10.7	5.2	0.3	0.2	0.1	2.1	9.9
9	10.6	4.9	0.2	0.1	0.1	0.3	9.9
10	10.6	3.7	0.2	0.1	0.1		10.0
11							9.9

Table 8 Hypolimnetic Oxygen Loss Rates 2006-2016

Hypolimnetic Oxygen Loss	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
SLOPE of 6-meter oxygen loss	-0.079	-0.106	-0.079	-0.071	-0.138	-0.119	-0.071	-0.122	-0.176	-0.039	-0.097
SLOPE of 7-meter oxygen loss	-0.087	-0.032	-0.072	-0.082	-0.057	-0.123	-0.099	-0.114	-0.159	-0.174	-0.160
AVG btw 6-7m	***-0.083***	***-0.069***	***-0.076***	***-0.077***	***-0.098***	***-0.121***	***-0.085***	***-0.118***	***-0.167***	***-0.107***	***-0.128***

Table 8 represents the rate of hypolimnetic oxygen loss from 2006 to 2016. Rates prior to 2006 were not calculated for this report. The rate of oxygen loss is calculated as the slope of the dissolved oxygen concentration at a given depth (6 and 7 meters) over time. Rate of oxygen loss was calculated using 6 & 7 meter data because this allowed for a great number of data points per year and rate calculations that better represent the total area below the anoxic boundary. The values are reported in mg/L/day. These data are shown graphically in **Figure 4**. The rate of oxygen loss has significantly increased since 2006, meaning that the biological oxygen demand of the lake (based on Station 1 data) is increasing annually. The R^2 value for this trend is 0.548. The only year that had a lessened rate of oxygen loss was 2012, which corresponded to a year of drastically reduced internal loading of which The cause is still unknown.

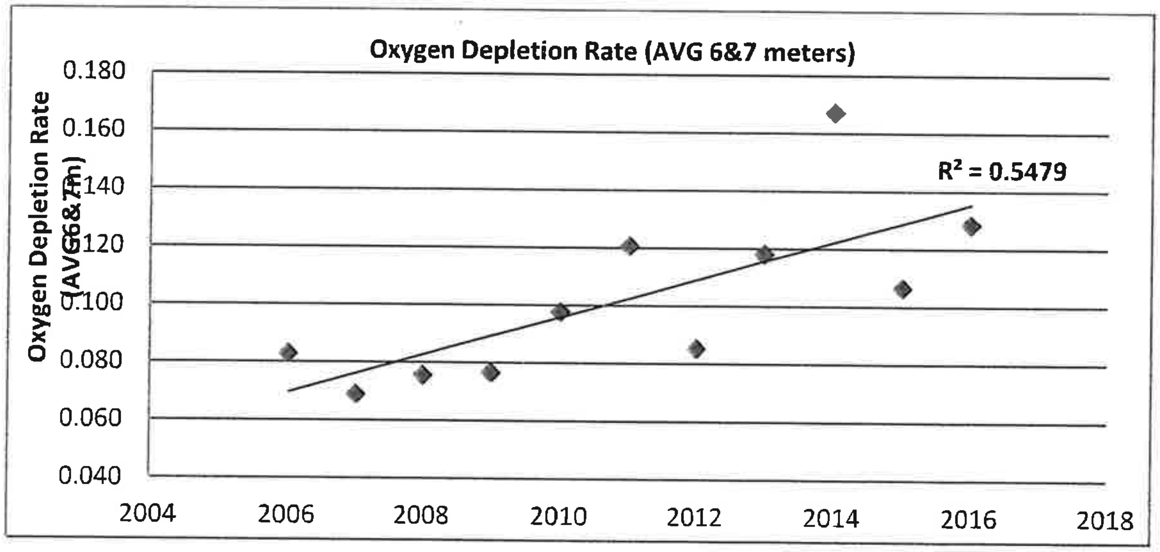


Figure 4 Oxygen Depletion Rates (AVG 6&7 meters)

The anoxic boundary is tracked over time and does not appear to be increasing. In other words, the annual cycle of anoxia has not drastically increased the volume of anoxic water since the early 1990s. The annual maximum height of anoxia tends to be around less than or equal to 6 meters. Approximately seventy five percent of the last 29 years showed an anoxic boundary height of 6-meters or less (**Figure 5**). The remaining twenty-five percent had anoxia deeper than 6 meters so those dates are not shown on the graph. The greatest historical volumes of anoxic water were recorded in July-early August 1996, 1998, and 2013.

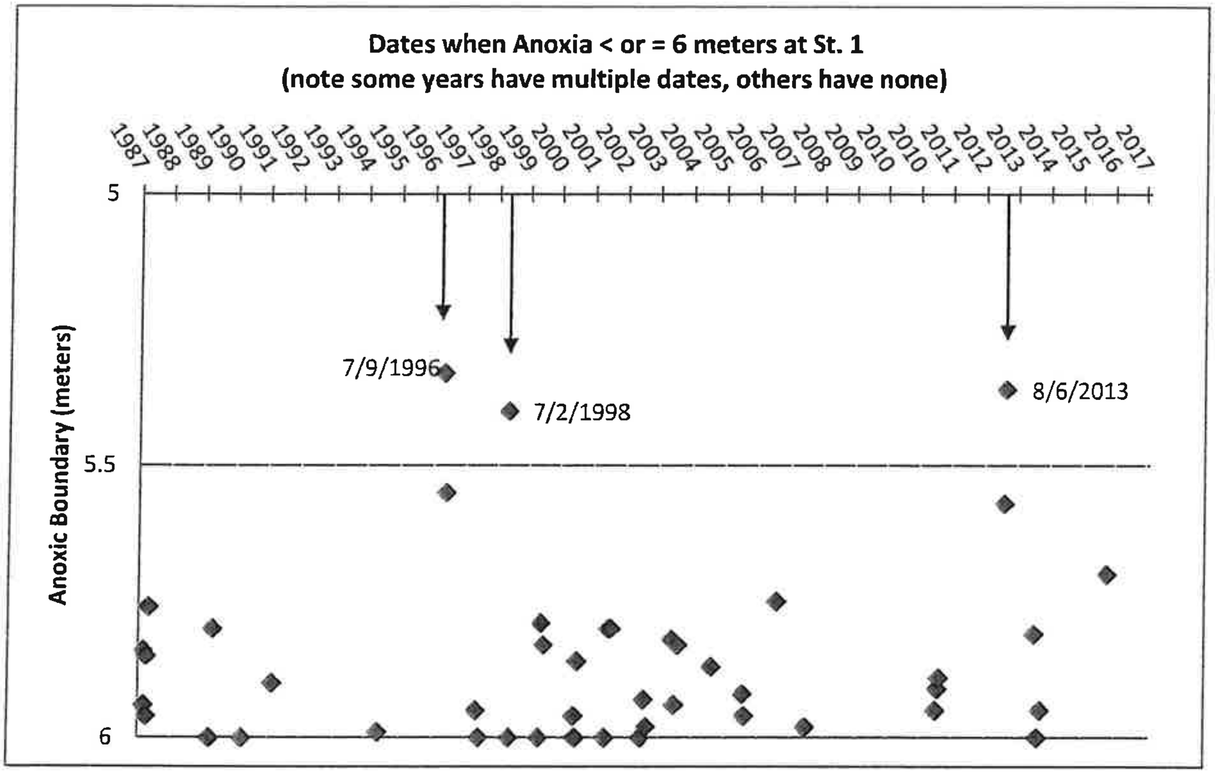


Figure 5 Anoxia < or = to 6.0 meters at Station 1 (1987-2016)

Table 9 shows the dissolved oxygen concentrations (mg/L) at Stations 2 and 3 in 2016. Both stations continually experience summer bottom-water anoxia. A 6-meter anoxic boundary encompasses approximately 62% of the Lake Oscawana total surface area, which translates to about 15-17% the total volume of the lake that becomes seasonally anoxic.

Table 9 Station 2 and 3 Dissolved Oxygen

	Dissolved Oxygen (mg/L)					**Dissolved Oxygen (mg/L)**				
	Station 2					**Station 3**				
Depth in meters	**5/19/2016**	**6/15/2016**	**7/25/2016**	**8/31/2016**	**9/27/2016**	**5/19/2016**	**6/15/2016**	**7/25/2016**	**8/31/2016**	**9/27/2016**
0	10.0	8.9	8.7	9.4	7.7	10.0	9.2	8.9	9.1	7.5
1	10.1	9.1	8.8	9.3	8.0	10.1	9.2	9.0	9.1	7.4
2	10.0	9.1	8.8	9.2	7.0	10.1	9.2	8.7	9.0	7.0
3	10.1	9.1	8.7	8.7	6.7	10.2	9.2	8.7	8.9	7.0
4	9.9	9.1	8.8	7.6	6.6	10.0	8.7	8.8	8.1	7.0
5	8.6	9.5	6.9	4.3	6.7	9.7	8.1	7.9	4.5	6.9
6	6.0	4.6	1.5	0.6	6.6	8.9	2.9	1.6	0.4	6.7
7	4.8	0.6	0.3	0.2	5.6	6.1	0.7	0.2	0.2	4.6
7.5	4.2	0.3	0.2	0.2	1.2	5.7	0.3			3.2

Relative Thermal Resistance to Mixing

The Relative Thermal Resistance to Mixing (see RTRM in Part I for explanation) at Station 1 was calculated from the temperature profile data below in **Table 10**. For reference, a slightly negative value represents a reverse mixing (cold to warm) and a value above 55 is indicative of a strengthening thermocline. Values above 130 indicate very stable water layering and strong thermal boundaries.

Table 10 Station 1 RTRM

RTRM **Station 1**							
Depth in meters	**4/13/2016**	**5/19/2016**	**6/15/2016**	**7/25/2016**	**8/31/2016**	**9/27/2016**	**11/8/2016**
0							
1	2	17	38	14	10	17	11
2	2	10	11	7	3	5	1
3	0	4	5	14	0	3	4
4	2	6	5	64	7	0	1
5	1	6	93	69	46	0	4
6	1	4	28	108	74	5	0
7	0	16	35	65	66	0	1
8	0	5	7	21	55	11	3
9	0	3	5	15	36	57	0
10	1	5	7	20	34		1
11				5			
SUM	*8.2*	*75.4*	*236.2*	*403.3*	*330.1*	*98.6*	*26.7*

Table 11 displays 2016 RTRM values for Stations 2 and 3. In both Tables 10 and 11, RTRM values over 55 are highlighted in red to indicate a weak or forming thermocline. The June Station 2 surface RTRM value of 58 is a result of very warm surface temperatures that created an ephemeral resistance to mixing. There were no values over 130 in 2016, though these higher values have occurred in six out of the last 10 years at Station 1 during peak summer.

Table 11 Station 2 & 3 RTRM

	Relative Thermal Resistance to Mixing					**Relative Thermal Resistance to Mixing**				
	Station 2					**Station 3**				
Depth in meters	**5/19/2016**	**6/15/2016**	**7/25/2016**	**8/31/2016**	**9/27/2016**	**5/19/2016**	**6/15/2016**	**7/25/2016**	**8/31/2016**	**9/27/2016**
0										
1	8	58	15	3	26	26	21	15	3	14
2	6	29	11	0	11	4	15	29	0	5
3	6	9	21	3	3	6	11	28	0	3
4	8	5	35	7	0	8	33	34	3	3
5	15	82	100	27	0	8	59	62	27	0
6	14	49	99	84	3	6	62	114	105	0
7	5	28	74	83	5	14	20	72	63	3
7.5	3	11	25	58	13	3	9			3
SUM	*66*	*271*	*379*	*264*	*61*	75	231	354	201	30

Water Chemistry

Phosphorus Summary

Water samples were analyzed for Total Phosphorus (TP). Results are displayed below in **Tables 12-14**. The average (AVG) surface TP from Station 1 alone was 20 ppb, which is at the 20 ppb threshold for concern and is higher than nearly all seasonal averages since 1994 (2008 and 2014 had 20 ppb season surface TP averages). This trend is shown graphically in **Figure 5**. The bullet list highlights 2016 TP data:

- Station 1 surface (1-meter) seasonal average = 20 ppb; St. 2 = 19 ppb and St. 3 = 17 ppb.
- Spring 4/13/16 lakewide average TP = 17 ppb
- Maximum bottom TP = 724 ppb, at St. 1 on 9/27/16
- Minimum surface TP = 10 parts per billion (ppb), at Station 3 on 7/25/16
- 2016 maximum surface TP = 32 ppb, at Station 2 on 9/27/16

Table 12. 2016 Station 1 Total Phosphorus

	Total Phosphorus (ug/L or ppb) Station 1					
Year	Date	1-meter	4-meters	6-meters	9-meters	Average
2016	4/13/2016	17	18	16	18	17
	5/19/2016	18	18	18	21	19
	6/15/2016	18	15	17	23	18
	7/25/2016	16	19	30	135	50
	8/30/2016	20	26		556	201
	9/27/2016	31	24	22	724	200
	11/8/2016	18	32	**242**	**19**	78

Unfortunately a sampling error was made, and a 6-meter sample was not collected on 8-30-16 at Station 1. The Station 1, 6-meter sample from November is displayed in red (**Table 8**) because it is believed to have been contaminated or to be an inaccurate lab test. It is unusually high and does not make sense with the concentration at 9-meters, which is an accurate value. The 9-meter sample was re-run by the laboratory because it was originally thought to be the source of error.

Table 13. 2016 Station 2 Total Phosphorus

	Total Phosphorus (ug/L or ppb) Station 2					
	Date	**1-meter**	**4-meters**	**6-meters**	**7-meters**	Average
2016	4/13/2016					
	5/19/2016	**17**			**20**	19
	6/15/2016	**15**			**22**	19
	7/25/2016	**13**			**39**	26
	8/30/2016	**20**			**33**	27
	9/27/2016	**32**			**42**	37
	11/8/2016					

There were no drastic increases in bottom water TP at Station 2 (**Table 13**). The maximum bottom water value was 42 ppb, which was near the end of the seasonal anoxia and relatively low for this time of year. In years when this area becomes anoxic earlier in the season there are increased bottom TP values. Since 1999, nine years have had >100ppb maximum bottom TP values at Station 2. No 4 or 6-meter samples were taken at Station 2.

Table 14. 2016 Station 3 Total Phosphorus

	Total Phosphorus (ug/L or ppb) Station 3					
	Date	1-meter	4-meters	6-meters	7-meters	Average
2016	4/13/2016					
	5/19/2016	19			18	19
	6/15/2016	15			21	18
	7/25/2016	10			40	25
	8/30/2016	19	22		**121**	54
	9/27/2016	24			20	22
	11/8/2016					

The Station 3 bottom (7-meter) TP value from 8/30-16 was 121 ppb and is bolded in **Table 14** above because this value represents a distinct internal phosphorus loading due to anoxia over the 7-meter area of the layer bottom.

As previously stated, the 7-meter sample from the same date at Station 2 did not demonstrate the same quantity of internal phosphorus loading (TP value of 42 ppb- **Table 9**). Thus, it is apparent that internal loading is not uniform across the bottom when it occurs at the 7-meter layer of water. By reviewing all data from Stations 2 and 3 since the year 2000, 7-meter TP does not tend to be higher at one station (2 or 3), instead the max bottom TP concentrations fluctuate from station to station depending on the year. The highest bottom TP ever recorded at 7-meter at Station 2 was 440 ppb on 8/30/2006. At Station 3, the highest recorded TP at 7-meters was 221 ppb on 8/9/2006, just a couple weeks prior.

Long-Term Trends in Phosphorus Data

The data base for phosphorus testing for Lake Oscawana dates back to 1984, but it was not until 1994 that TP was tracked annually. Using the long-term TP data, there are several evident trends, many of which have been illuminated in past lake reports.

- Minimum seasonal surface TP values are increasing ($R^2 = 0.4035$) at Station 1 (**Figure 7**).
- Seasonal variability obscures long-term trends in surface TP, but seasonal averages (mean) exhibit a positive linear trend ($R^2 = 0.4065$) at Station 1 (**Figure 7**).

- Maximum seasonal surface TP values display a weak trend form 1994-2016, but 1987 data negates any trends because the surface TP at that time was so elevated (original spark for the monitoring program (**Figures 8 & 9**).
- Maximum bottom (9-meter) TP is increasing at Station 1, but there is no such trend at Station 2 and 3 at 7-meters (**Figure 10 & 11**).

Figure 6 depicts all Station 1 surface (1-meter) Total Phosphorus data since 1994 to today. Statistically, there is no significant trend, but the linear trend-line is slightly positive and may indicate that there is a small amount of change over time. In terms of phosphorus concentrations, a change from 5 ppb to 20 ppb seems miniscule, but it actually spells the difference between clear-water and nutrient-polluted water. This very small threshold has been mentioned in all of the Lake Oscawana reports and is well documented in the scientific literature. However, because lakes undergo seasonal variation in phosphorus concentrations, and because the thresholds from good (<10 ppb) to concerning (>20 ppb) levels is so narrow, it seems impossible to pick up on minute trends over time unless one looks to trends in average, minimum, and maximum concentrations as depicted in **Figures 7 and 8**.

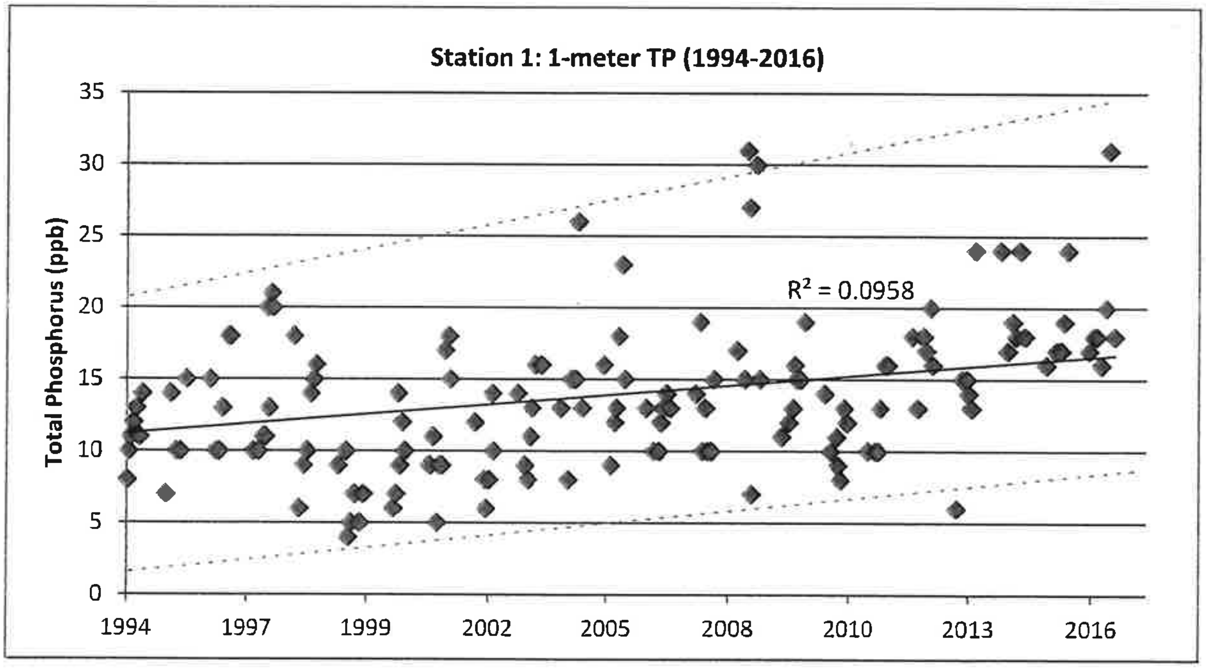


Figure 6 Long-Term Station 1 Surface Total Phosphorus Data

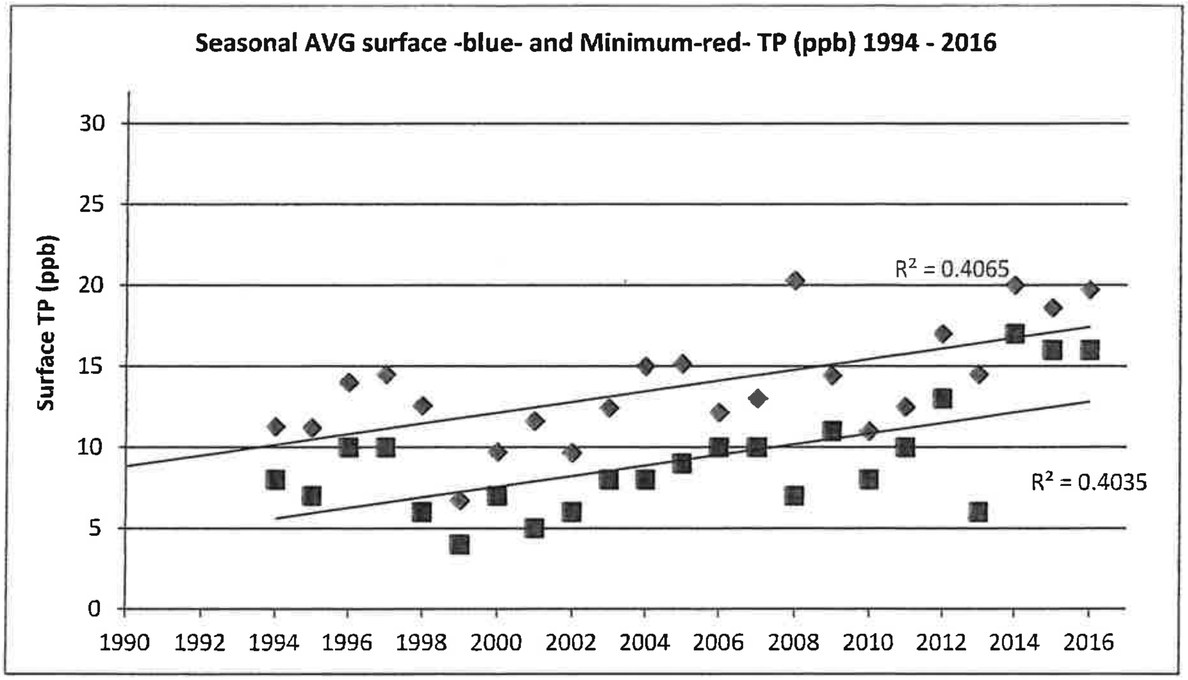


Figure 7 Station 1 Surface Seasonal Average and Minimum TP

Figure 7 illustrates an increasing trend in Station 1 surface TP from 1994-2016. The average seasonal 1-meter TP has a significant positive linear trend with an R^2 value of 0.4065 (also displayed in **Figure 2** as trend since year 2000 in relation to Secchi disk depth). The minimum seasonal surface TP appears to have a similar pattern of statistically significant increase with a nearly identical R^2 value. In other words, the minimum surface TP concentrations appear to be driving the increase in seasonal average, not the maximum which has a less significant trend (**Figure 8**).

It is also important to note that when the elevated surface TP values recorded in 1987 are included in the graph, they effectively negate any linear trend as the R^2 values drop nearly to zero. However, 1987 values were the worst on record and unlike any of the historical records since that time. It is possible that Lake Oscawana was in dire condition of high phosphorus and poor clarity at that time, but then dramatically improved due to a large reduction in nutrient inputs during the 1990s, and has since been steadily increasing in surface phosphorus until today. **Figure 8** shows the linear trends without 1987 data. **Figure 9** demonstrates a possible polynomial pattern in surface TP given the very high 1987 data (2nd degree polynomial curve).

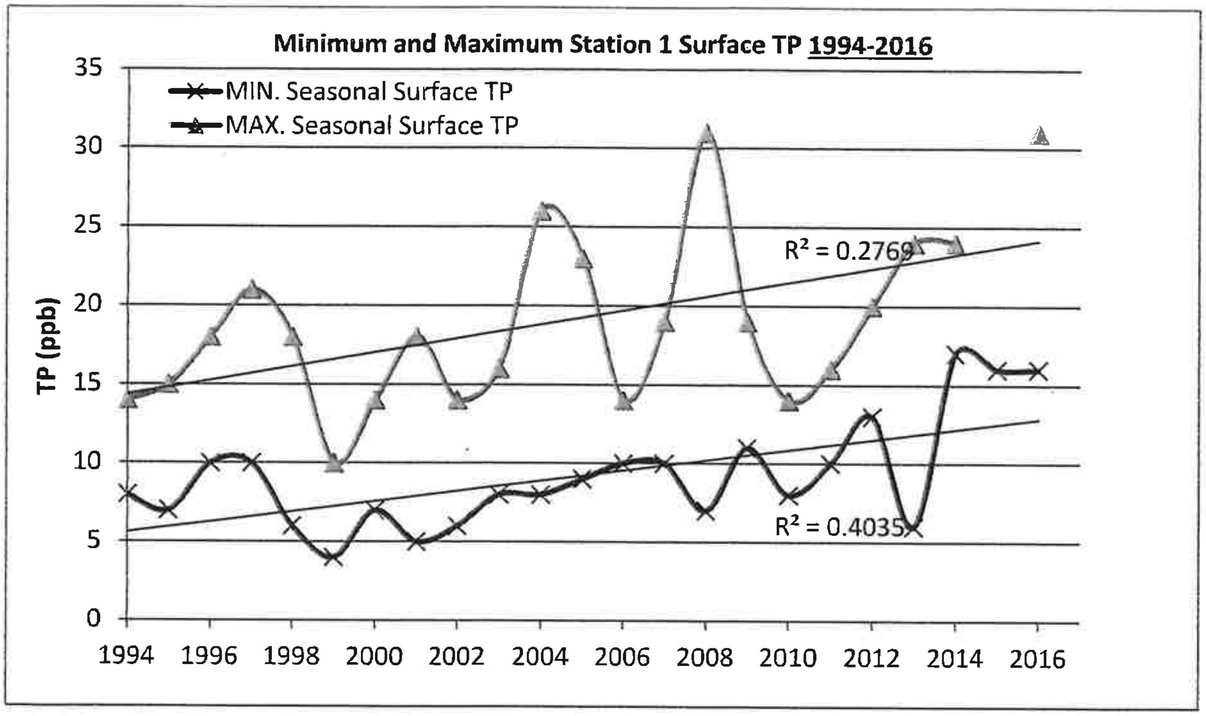


Figure 8 Linear Trend in Minimum and Maximum Surface TP 1994-2016

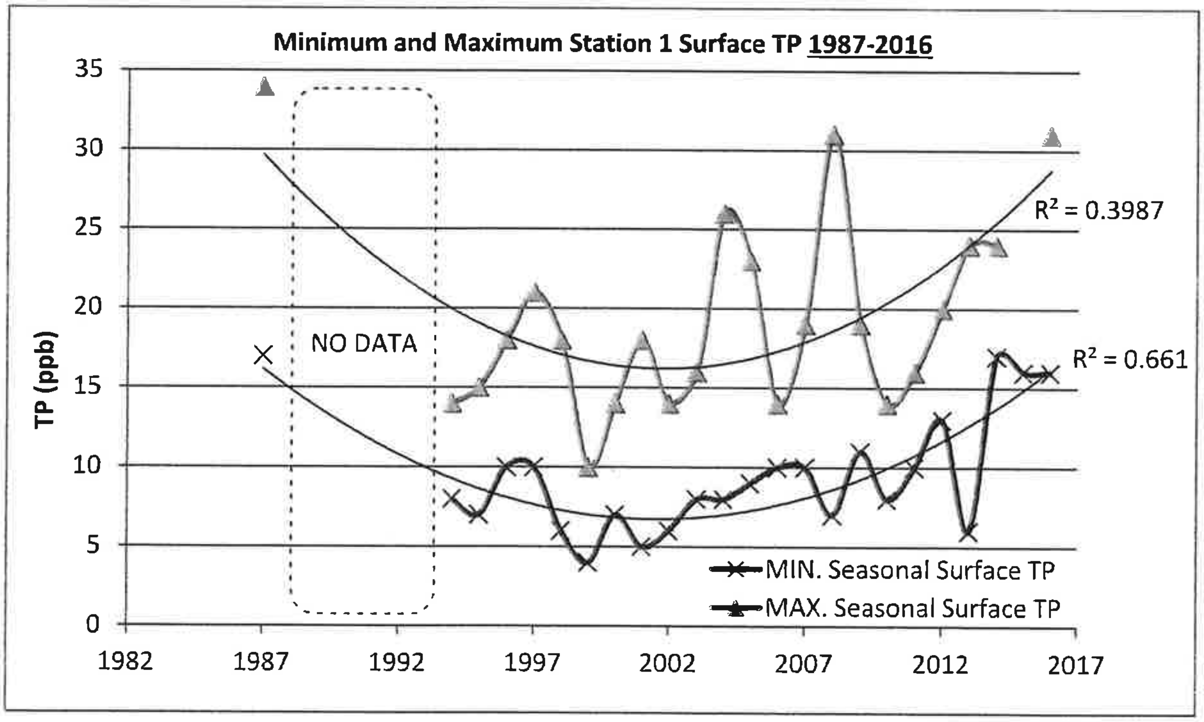


Figure 9 MIN and MAX Surface TP including 1987 Data, 2nd Polynomial Trend

The trend in Station 1 bottom TP is much more obvious. Anoxic conditions at the bottom of the Lake initiate internal sediment release of phosphorus, which has been estimated as the primary contributor to the whole-lake phosphorus budget. At this time, it is still unknown exactly how much bottom-water (hypolimnetic) phosphorus is entrained into the surface waters (epilimnion) at any given point in the year. However, at the end of the summer, during fall turn-over, it is estimated that the mixing of the water column initiates large movements of phosphorus from bottom to surface, which could stimulate late season cyanobacteria blooms.

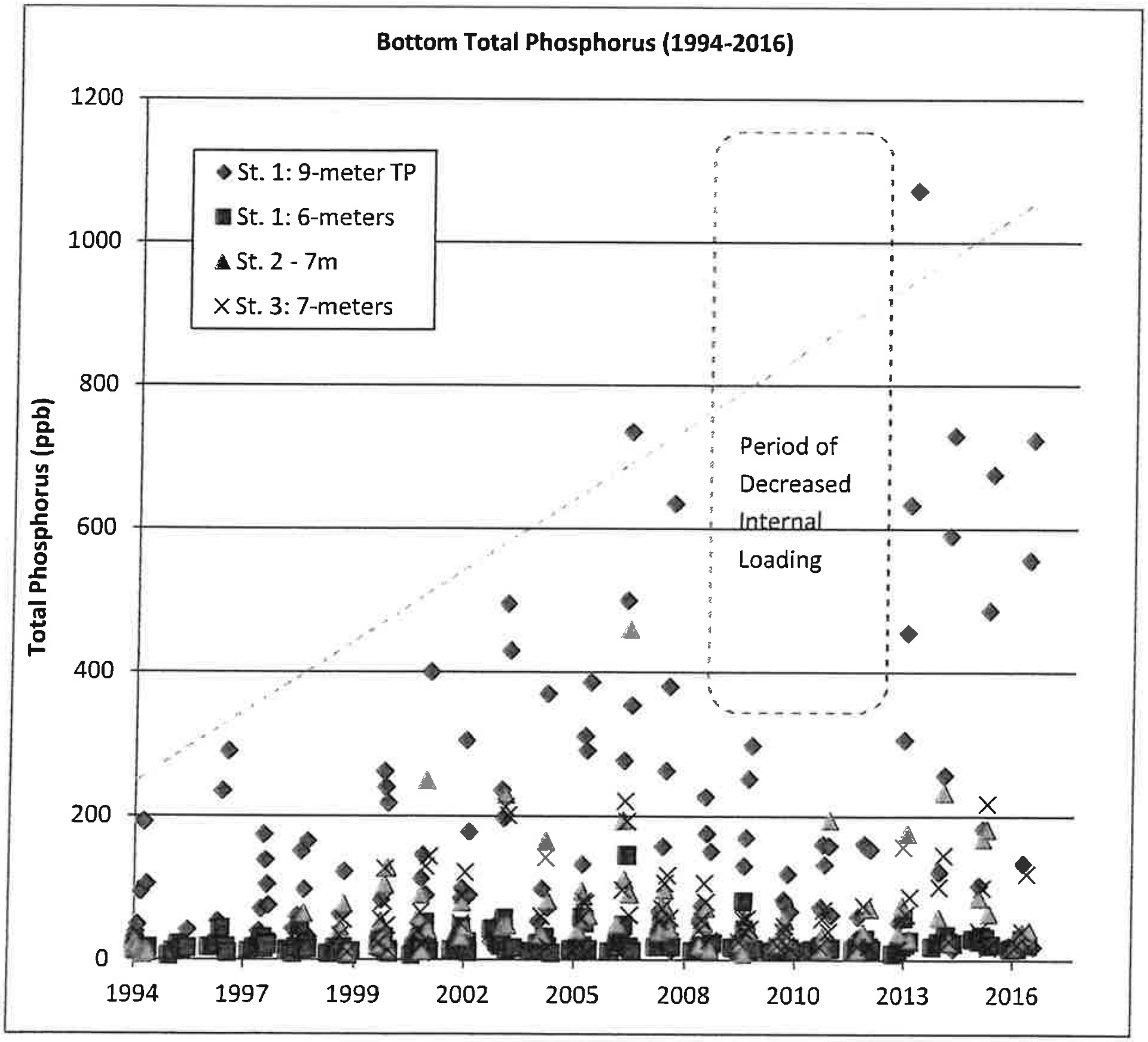


Figure 10 Long-Term Bottom Total Phosphorus

Figure 11 demonstrates that the bottom TP at Stations 2 and 3 is not generally increasing. Instead, both Stations appear to fluctuate from year to year, related to the annual duration of anoxia. Water at the bottom must be anoxic for several months for Stations 2 and 3 to internally load phosphorus and experience greatly increased bottom TP concentrations.

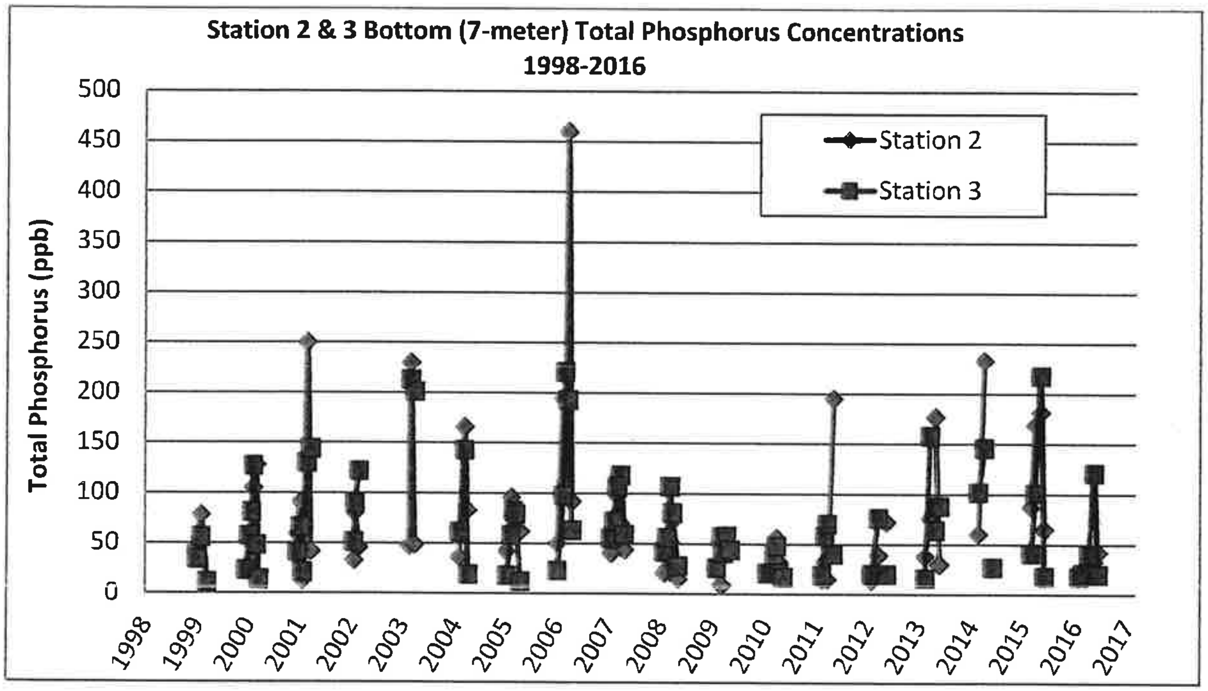


Figure 11 Station 2 and 3 (7-meter) Bottom TP

Total Nitrogen

The 2016 seasonal average surface Total Nitrogen (TN) was lower than the long term average with values of 298ppb and 341ppb, respectively. Long term surface TN demonstrates that the Lake experiences drastic changes throughout the season. Yet overall the surface TN appears to have a slightly negative trend, as shown in **Figure 12**. However, this trend will need to be continually evaluated in future sampling years.

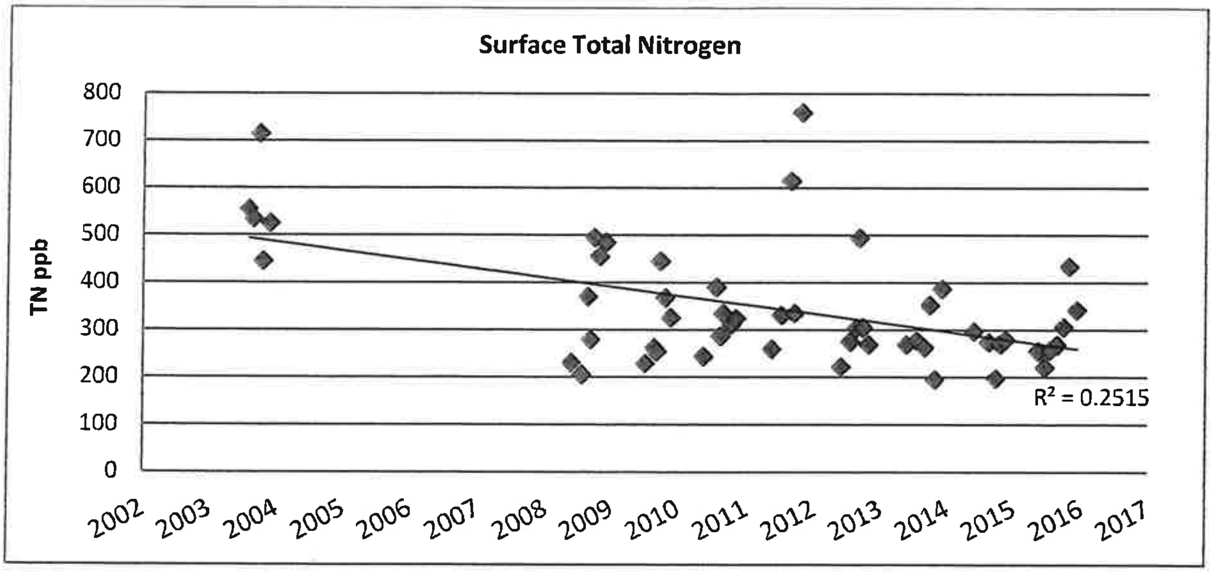


Figure 12 Surface Total Nitrogen 2004-2016

To minimize the large-scale TN variability from month to month, seasonal average surface TN was also examined. The average concentrations do appear to be decreasing since 2004 (**Figure 13**), which is unusual given the apparent increase in phosphorus concentrations over time. The R^2 value of 0.5985 indicates a relatively strong linear correlation, but again, this trend seem unusual and will be monitored into the future.

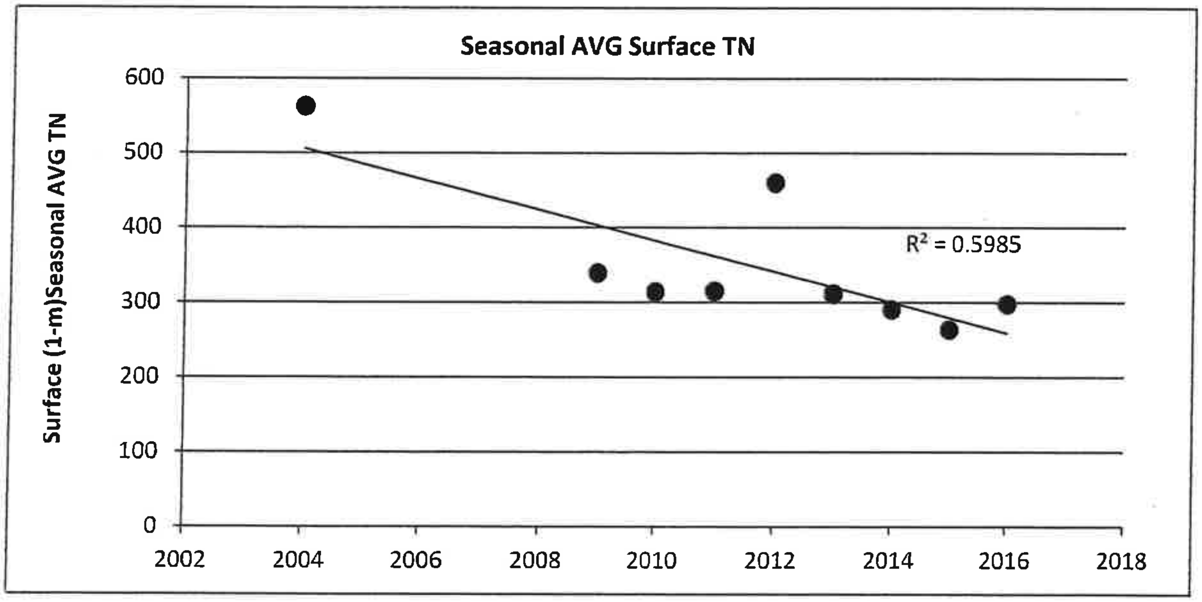


Figure 13 Seasonal Average Surface TN (ppb)

Conductivity

Conductivity, or specific conductance of a fluid, measures the dissolved ionic content of the water. For lake studies, conductivity is a proxy of the salt content of the water. Conductivity of lake water was collected from 1993 to 2004, discontinued from 2004 to 2015, and was then resumed in 2016. Conductivity recorded in 2016 falls directly in-line with strong correlation of increasing conductance suggested by earlier data, shown in **Figure 14** below. Values in 2016 rose steadily from May to October from 284 to 322 uS/m then came down to 318 uS/m in November. This small seasonal increase in conductivity is normal and related to many factors, but the long term increases in conductivity point to a drastically increased salt content in Lake Oscawana. This trend is similar to trends seen in freshwater across the US and is related to increased runoff from road salts and septic system inputs. Future years will include conductivity sampling.

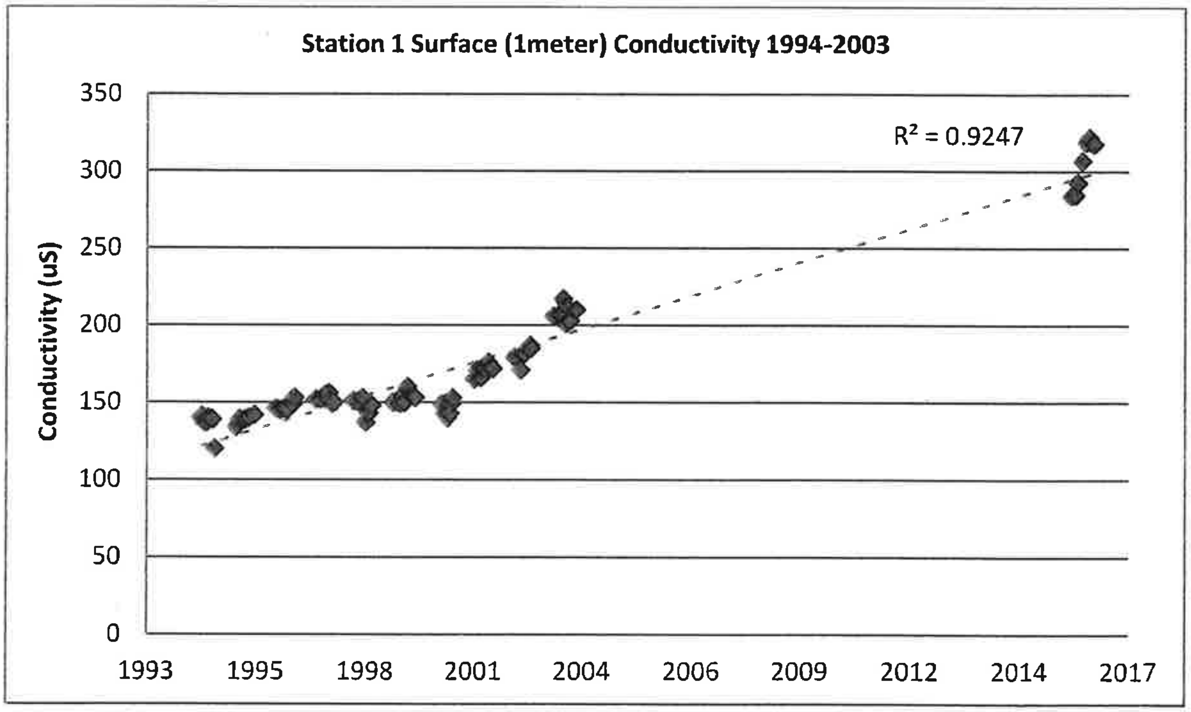


Figure 14 Conductivity Trend Given Available Long-Term Data

Inlet/Stream Data

Stream data at the seven inlets was collected if water was flowing on the date of our sampling trips. Samples were analyzed for total phosphorus (TP) and Nitrate nitrogen (NOX). TP results are shown graphically in **Figure 15** in mg/L (parts per million) due to larger concentrations. The July Inlet 4 data is off of the chart because it would skew all other data if included. The horizontal red dotted line indicates the concentration threshold of concern for dry inlet sampling.

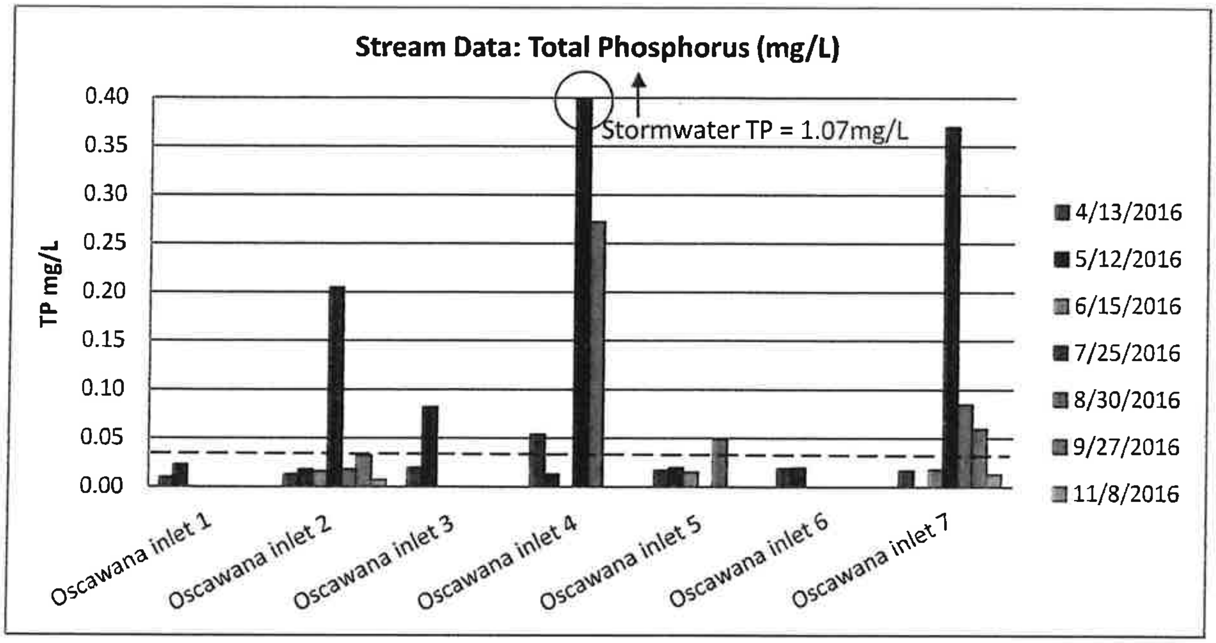


Figure 15 Stream (Inlet) Total Phosphorus Concentrations (mg/L)

On July 25, a flash thunderstorm presented the opportunity to collect stormwater inlet samples, including a test of the catch basin insert technology at Inlet 4 (**Table 15**). Flow data was also collected at this time, but the dilution factor from upstream to downstream is not totally accounted for because there was roadway runoff from both directions on both sides of the street. However, the concentration of TP upstream of Inlet 4 (regular sampling location) was extremely high at 2.320 mg/L (= 2320 ppb). The subwatershed for Inlet 4 is very small and concentrations should not be as high as they are, even despite the dramatic residential development. NEAR has identified a private pond upstream of Inlet 4 that may be contributing excessive nutrients to the Lake.

Table 15 Stormwater Sampling of Inlet #4

Sample Description	Weather Conditions	Collection Date	mg/L (ppm) NOX	mg/L (ppm) TP
Oscawana Inlet 4 from road	Storm	7/25/2016	**0.996**	**0.690**
Oscawana inlet 4 upstream	Storm	7/25/2016	**1.570**	**2.320**
Oscawana inlet 4 downstream	Storm	7/25/2016	0.439	**1.070**

In general, the catch basin inserts visually appeared to be trapping much sediment and organic material, which does drastically reduce the amount of nutrients flowing downstream into the lake. With proper maintenance, these filters will continue to benefit the lake, but additional steps will be necessary to mitigate water flowing before it reaches the catch basin inserts. The overall goal for stormwater management would be to reduce the amount of water that has to flow into the stormdrain system by implementing better onsite infiltration of roof, driveway, and roadway runoff.

Plankton Community

Phytoplankton and zooplankton were collected from Station 1. The overall pattern in phytoplankton community structure is similar as it has been in previous years. Diatoms and green phytoplankton dominate in the spring, while cyanobacteria increase throughout the summer months to become the dominant taxa in August and September **(Figure 16**). The cell counts for all cyanobacteria were relatively low over the 2016 season. The August cell count for cyanobacteria was the highest at around 25,000 cells/mL, which is just at the threshold to be considered a cyanobacteria bloom.

The pattern observed in years past is very similar to the 2016 data. Overall, cyanobacteria numbers were highest in late August, but then dropped off by late September. Though water quality and phytoplankton are definitively related, cyanobacteria prevalence does not appear perfectly aligned with phosphorus and clarity. September had higher phosphorus concentrations and worsened clarity than the August sampling date, yet that was not directly seen in the phytoplankton community. However, during the September date, the deepening of the anoxic boundary and weakening of the thermal stratification may be responsible for reduced cyanobacteria prevalence because they no longer had a competitive advantage in mixing waters, a question requiring more investigation.

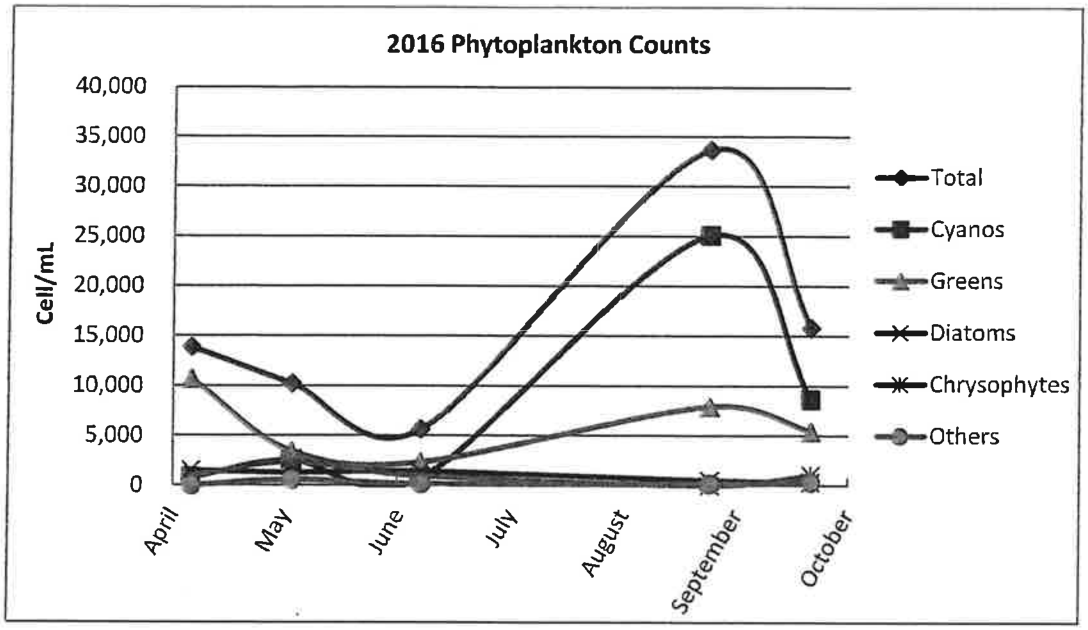


Figure 16 2016 Phytoplankton Community

The zooplankton community saw another year of high Rotifer populations with few large-bodied Copepods and Cladocerans (**Figure 17**).

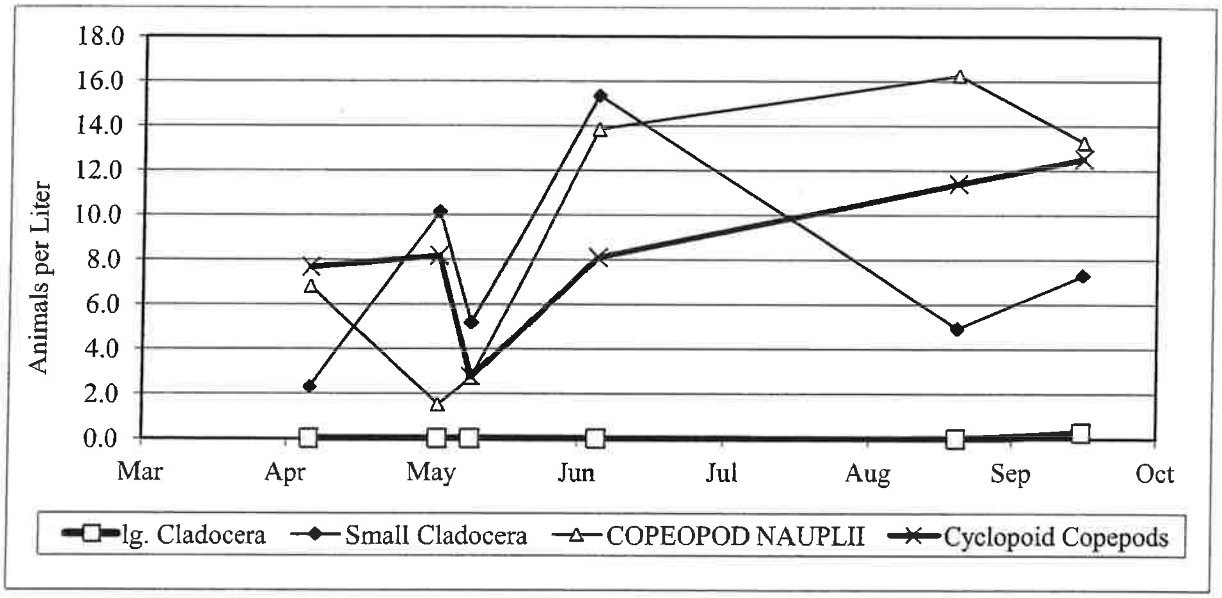


Figure 17 Zooplankton Populations 2016

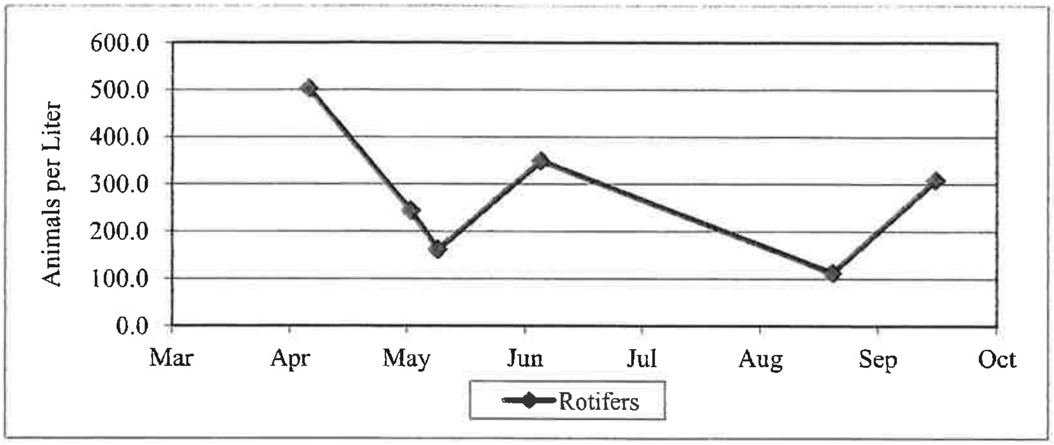


Figure 18 Rotifer populations for 2016

Part IV: Timeline of Lake Management Efforts & Report Review

Timeline of Management Efforts

Lake Oscawana has an extensive history of water quality monitoring and management reports that date back to the early 1980s. The purpose of this timeline is to put lake management efforts into perspective and to identify what has been done, as well as what needs to be accomplished in the coming years.

1980s - Introduction of Eurasian water milfoil. Exact date unknown.

1987 - The first water quality data were collected on Lake Oscawana by Ecosystem Consulting Services.

1991 - From 1991-1994 there is record of the State of New York Citizens Statewide Lake Assessment collecting some nutrient data.

1991 - Report published by The Lake Man, Peekskill, NY in 1991 and 1992

1993 - Benson Environmental Inc. Water Quality Monitoring and Report Series

1994 - In 1994-1997, water quality sampling was resumed by Ecosystem Consulting Services. Some record of Eurasian milfoil harvesting beginning during this time.

1994 - Insite Engineering and Surveying conducted an engineering report for Lake Oscawana outlet

1998 - Town of Putnam Valley begins working with Northeast Aquatic Research to continue long-term annual monitoring of the Lake.

1995 - 1998 - Ecosystem Consulting Services monitoring and status reports.

1998 - The most recent fisheries survey of Lake Oscawana was conducted over five summer sampling dates; report published by the NYS Department of Environmental Conservation in 2001.

1998 - 2015 - Northeast Aquatic Research first monitoring report, annual water quality reports from 1998-2015

2003 - ENSR Assessment of Long Term Lake Water Quality

2008 - Princeton Hydro completes the a Lake Oscawana Management Plan using the long-term dataset collected by Northeast Aquatic Research. Includes phosphorus loading estimates.

2008 - Cadmus Group completes Total Maximum Daily Load (TMDL) report - estimates watershed P load

2009 - 2015 - Northeast Aquatic Research conducts long-term water quality monitoring, aquatic plant surveys, and summary reports

In summary, Lake Oscawana has been plagued with Eurasian milfoil since water quality monitoring began. There is no real information on when the invasive plant became established, but the available plant survey data indicates that the milfoil has expanded in range and lakewide dominance regardless of control measures.

Nearly thirty years ago, internal phosphorus loading was identified as a large source of nutrients. Around that time, multiple environmental studies confirmed that watershed loading and septic system loading were also major contributors to the excess phosphorus in the Lake. It is unknown what the Town of Putnam Valley has accomplished in limiting development in the watershed since the 1990s.

In the meantime, Lake Oscawana was listed on the New York State Impaired Waterbodies list for excess plant and algae growth, spurred by high levels of nitrogen and phosphorus from nonpoint source pollution (widespread watershed sources). It was not until 2007, when the first modeling attempts were made to quantify the nutrient pollution loading. However, the TMDL report prepared by the Cadmus Group did not include internal phosphorus into the annual nutrient budget. The Princeton Hydro 2008 Lake Management Plan also attempted to quantify nutrient loading with estimates based largely on runoff coefficients. Despite inherent error in modeling nutrient loading, there are many good take-aways from these two reports that should be used moving forward with managing watershed pollution today.

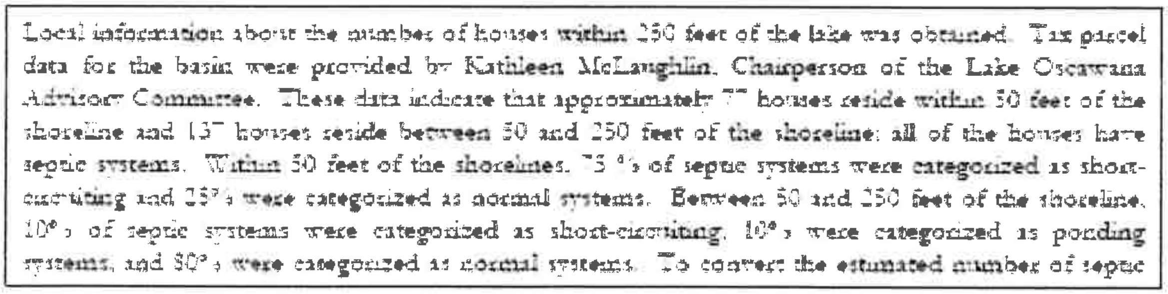
In essence, the Town of Putnam Valley has already received good septic system and stormwater management recommendations from multiple sources, but implementation is extremely challenging when a large percentage of nutrient pollution originates on private property. The following section revisits recommendations from past reports that are relevant today and deserve **immediate attention.**

Key Points from Cadmus Group Report:

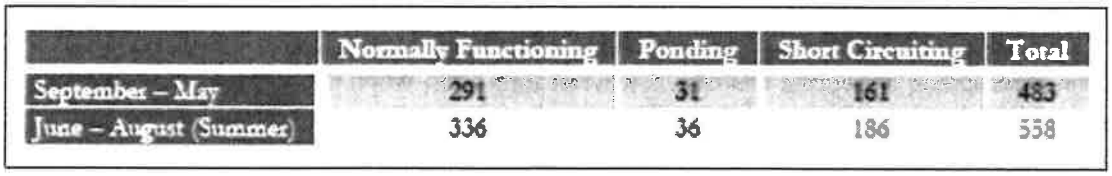
(Numbered points indicate 2008 Cadmus Group TMDL findings and recommendations. Bullet points designate NEAR updated comments and recommendations. Red boxes are direct quotes from 2008 Cadmus Group report.)

1. **Septic loading estimated circa 2008 at 313 lbs per year (47% of total external P load to Lake). The allocated septic load to achieve TMDL predicted at 284 lbs/yr, which equates to approximately a 9% needed reduction.**

    - The Town of Putnam Valley adopted a 3-yr mandatory *Septic Tank Pump-out Law* in February 2010, aimed at reducing phosphorus loading. This program is regulated by the Town Code Enforcement Officer and requires homeowners to submit proof of pumpout.



Local information about the number of houses within 250 feet of the lake was obtained. Tax parcel data for the basin were provided by Kathleen McLaughlin, Chairperson of the Lake Oscawana Advisory Committee. These data indicate that approximately 77 houses reside within 50 feet of the shoreline and 137 houses reside between 50 and 250 feet of the shoreline; all of the houses have septic systems. Within 50 feet of the shorelines, 75 % of septic systems were categorized as short-circuiting and 25% were categorized as normal systems. Between 50 and 250 feet of the shoreline, 10% of septic systems were categorized as short-circuiting, 10% were categorized as ponding systems, and 80% were categorized as normal systems. To convert the estimated number of septic



	Normally Functioning	Ponding	Short Circuiting	Total
September – May	291	31	161	483
June – August (Summer)	336	36	186	558

Quotes 1 (Cadmus Group, 2008. pg. 11) Watershed septic system function data

- What record of individual septic system malfunctioning exists? The list of normally functioning, short circuiting, and ponding septic systems within 250 feet of the lake should be revisited and updated in 2017.
- The Town should investigate advanced onsite wastewater treatment systems geared towards reduced phosphorus and nitrogen loading near sensitive lakeside areas. NEAR will provide guidance as necessary. Good record keeping is essential and should be included in the ongoing lake dataset.
- The University of Rhode Island Center for Onsite Wastewater Treatment has very good information on advanced treatment options, but it will be necessary to work with the NYS and local Public Health Departments to determine which innovative onsite wastewater systems are currently approved for NY.

2. **MS4 loading reductions - Cadmus Group estimated that an 18% decrease in P loading was necessary to achieve the approved TMDL. They also recommended that the Town identify and eliminate illicit MS4 discharges (i.e. roof gutters, yard drainage, sump pumps, etc.)**

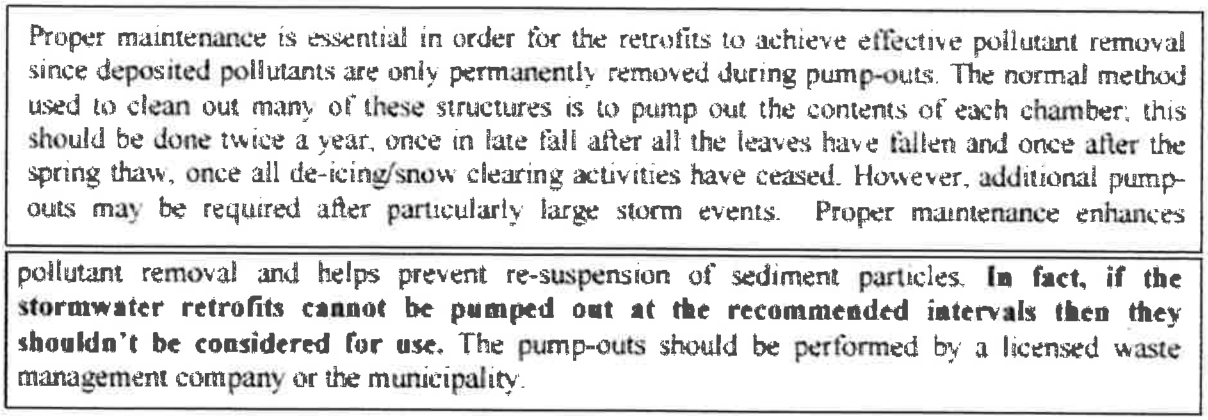
   - TMDL Report estimated that MS4 developed land in Lake Oscawana watershed contributes 93 lbs/yr phosphorus to the Lake. This report required an 18% reduction in P loading from these regulated MS4 areas to meet the TMDL. It is unknown if this reduction is feasible with the current level of watershed development, or if this reduction has been achieved in recent years.

Key Points from Princeton Hydro Report:

(Numbers indicate 2008 PH stormwater recommendations. Bullet points designate NEAR updated comments and recommendations. Red boxes are direct quotes from the 2008 PH report.)

1. Manufactured stormwater treatment retrofits, i.e. catch-basin inserts.

- Recent Town (MS4) improvements included the purchase, installation, and maintenance of catch-basin inserts. After the July 2016 stormwater sampling, these inserts appear to be functioning properly and reducing the amount of sediment and organic particulate matter flowing to the lake. It is not likely that these inserts capture any dissolved nutrients, but the fact that they limit sedimentation alone will lower phosphorus inputs during storm events. However, the Town needs to be continually responsible for maintenance (**Quote 1; PH, 2008. pg. 40-41**).



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

Quote 2 (PH, 2008. pg 40-41) Catch basin insert maintenance

- Without proper cleaning and maintenance, the catch basin inserts may slowly release the captured material as it breaks down into dissolved nutrient forms. The Town needs to clean the filters after every major storm if continued use is intended. Priority should be placed on cleaning catch basins that flow directly to the lake (final convergence).

2. **Mapping of existing stormwater conveyance system using GPS to develop digitized GIS maps to overlay with watershed and soil data layers.**

- NEAR has little knowledge if this mapping has been completed or updated recently. However, NEAR did confirm that the Town of Putnam Valley has paper copies of stormwater catch basins maps. This project was likely completed as part of the MS4 requirements in recent years.

3. **Update catch basins on a sub-watershed basis with prioritization to shoreline areas in sub-watersheds of the south-southeastern area of the Lake (sub-watershed of Inlet #4).**

- The Town of Putnam Valley has since purchased a vacuum truck for catch basin cleaning and it is unknown which, if any, catch basins in the shoreline areas have been completely replaced. NEAR recommends keeping track of this information in an Excel spreadsheet that corresponds with GPS/GIS maps of the MS4 catch basins.
- In general, updating conventional stormwater conveyances and catch basins can only do so much to capture sediment and nutrients. The PH report recommended multiple technological retrofits (e.g. nutrient separating baffle box, Aqua-filter, Aqua-Swirl, Aqua-Guardian, Stormceptor, & grated inlet skimmer boxes- **PH, 2008. pg. 41**), however, the effectiveness of

these devices is highly variable and such devices only protect against large particles and (floatable) debris and may not be worth the high costs of purchase and installation.

- It is possible to get better, more long-term solutions to watershed nonpoint source pollution through homeowner property Low Impact Sustainable Development (LISD) retrofits such as rain barrels, small rain gardens, etc. (dependant on local soil conditions). The overall goal would be to reduce the water runoff from individual properties. In small quantities, homeowners may be able to deal with roof, driveway, and lawn runoff for minimal costs and prevent overloading the Town stormwater conveyances to the Lake. Water is much more difficult to deal with at large downstream convergences.

4. Suggested methods for internal phosphorus control: Artificial Circulation, Hypolimnetic Aeration, or Alum Phosphorus Inactivation Treatment

- The PH Lake Management Report acknowledged that the nutrient problem is a combination of sources and attempted to estimate the internal phosphorus load, which is something that NEAR has been monitoring for decades, but due to the fine chemical details of the lake, are not completely understood. Estimates are usually very crude. The time of the year, height of the anoxic boundary, depth of the thermocline, and the presence of buoyant cyanobacteria all factor into how much phosphorus is entrained from the bottom to the surface waters during the season. It is a highly variable rate, and NEAR has not been able to find good correlations between surface and bottom water phosphorus concentrations during peak anoxia.
- Although internal phosphorus load should not be ignored, there are very limited methods for control and the options are not fool proof. Currently, Alum treatments for phosphorus inactivation of bottom sediments are still not permitted in the State of New York. For that reason, Alum is not worth further investigation at this time. The available technologies for aeration and artificial circulation are costly and case study success is extremely variable. There are many cases where improper design of circulation systems worsened phosphorus and algae problems and there are a great number of aeration case studies where systems were unable to improve internal loading, despite measurable increases in hypolimnetic oxygen. Furthermore, continued external phosphorus input from the watershed will reduce the effectiveness of internal control efforts. For these three reasons, **NEAR recommends focusing on watershed nutrient loading before addressing internal load remediation**.

Phosphorus Loading Model Comparisons (Cadmus Group vs. Princeton Hydro)

Performed by:	Watershed P Load	Internal P Load	Surface Runoff P Load	Septic Systems P Load
Camus Group, 2008	663 lbs/yr	Not Calculated	221 lbs/yr	313 lbs/yr
Princeton Hydro, 2008	835.2 lbs/yr	1,247.4 lbs/yr	480 lbs/yr	407.3 lbs/yr
% difference	21%	NA	54%*	23%*

*Note: Cadmus Group included 122 lbs/yr Groundwater P input which could theoretically be redundant to Septic System P Loading rate given above. Seepage rates for developed areas include more than just rainwater infiltration, which is considered background groundwater P loading. NEAR is uncertain of exact calculation methods.

To summarize the differences between the two 2008 phosphorus loading models, the margin of difference for surface runoff P loading is very wide. This range in nonpoint source P loading estimates indicates that the true load is largely unknown and that much more on the ground data collection is necessary to identify and mitigate specific watershed nutrient pollution areas. Additionally, the internal P loading is not entirely understood and may vary drastically from year to year depending on lake thermal stratification and anoxia. One important note is that the multiple-year duration of reduced internal phosphorus release from 2009-2012 (**Figure 10**) does not perfectly align with anoxia. During the years where there was much lower hypolimnetic phosphorus concentrations at Station 1, there was still large amounts of anoxic water. The only explanation for this phenomena is that there was less phosphorus to be released for some reason, potentially due to lesser amounts of accumulated decomposing biological material.

Part V: Summary and Recommendations

Aquatic Plants:

Eurasian milfoil has increased its depth range, thus expanding the littoral zone and overall acreage of invasive aquatic plant growth in the Lake. Prior reports have attributed this expansion to deep-water root-runner growth and to the widespread use of weed harvesting in the Lake. Weed harvesting produces considerable fragmentation and each Eurasian milfoil fragment has the potential to establish a new bed. We consistently see adventitious root structures on floating fragments during routine monitoring visits to the Lake. Weed harvesting is a temporary and symptomatic solution to the Eurasian milfoil problem at Lake Oscawana.

Nutrient loading from septic systems at Lake Oscawana is the most probable cause for extensive growth of shoreline milfoil and other aquatic plants. Maximum aquatic plant growth is achieved when plants have excess available nutrients to extract from the lake sediments. Lake Oscawana has encircling septic systems that continually replenish littoral sediments with ground water rich in nitrate and phosphorus. Conventionally, phosphorus will be somewhat contained in the sediments, but with high water tables and long-term leaching, the sediments will not accept unlimited quantities of phosphorus. At this point, the thick organic littoral sediments are now sustaining the extensive aquatic plant growth from year to year, while the harvester simply facilitates new milfoil shoot growth.

The newly stocked grass carp have the potential to greatly reduce the biovolume of aquatic plants in the lake. Though they have also been known to allow increased Coontail (*Ceratophyllum demersum*) growth, they are expected to graze heavily on other aquatic plants and to reduce the Eurasian milfoil densities lakewide. In order to effectively monitor the impacts of grass carp on aquatic plants, we recommend to continue transect monitoring, while also conducting an intensive survey of Abele Cove every two months throughout the growing season.

Recommendations for Aquatic Plants -

1. Monitor affects of weed harvesting and grass carp on Eurasian milfoil in 2017
    - Survey the 6 transects during regular water quality monitoring visits
    - Conduct 3 surveys of Abele Cove using gridded waypoints (June, August, September)
    - Conduct one whole-lake aquatic plant survey to estimate total lake Eurasian milfoil coverage in acres
2. Install a GPS tracker on the weed harvester to maintain a comprehensive harvesting record

Water Quality

Long-term phosphorus data suggests an increasing trend in minimum seasonal surface TP. An increasing trend was also found for average seasonal surface TP. This increasing surface phosphorus does not directly correlate with the recorded Secchi disk values, but increases in surface phosphorus are well known to increase phytoplankton growth and may lead to more frequent harmful cyanobacteria blooms in years to come.

Maximum bottom TP is increasing at Station 1, following a period of reduced TP from 2009-2012, but there is no such trend at Station 2 and 3 because the duration of anoxia at 7-meters is more variable from year to year, thus affecting internal sediment phosphorus release from those two stations.

Recommendations for Water Quality -

1. Continue monthly in-lake and stream sampling from April to October
2. Conduct littoral zone conductivity monitoring to identify "hot spots" for potential septic loading
3. In the month of September, during peak anoxia, collect six additional water samples to monitor phosphorus migration from bottom to surface waters.

Integrating Lake and Stormwater Management BMPs

Nearly all previous reports since the 1980s have identified that nonpoint sources of phosphorus and nitrogen are negatively impacting the water quality of Lake Oscawana. However, by definition these nonpoint sources are extremely difficult to track down and are related more to the overall surface water runoff and septic nutrient contribution to the Lake. It is a widespread problem that will require multiple days of on-the-ground site investigation to correctly identify and catalog.

Based on the information included in the Cadmus Group 2008 report about septic systems, some of this work has already been completed and we may only need to quantify improvements made in the last ten years. We expect this to be a cooperative effort between the town of Putnam Valley, Lake Oscawana Advisory Committee, NEAR, and the many local homeowner associations.

Stormwater BMPs and updates that are required of the Town via the NYS MS4 permit program need to be made in concert with lake restoration efforts. If the Town is willing to have us more involved in the watershed planning and remediation efforts, we are very willing to expand our watershed investigation program and to be in direct communication with the Town Stormwater Manager. Low Impact

Sustainable Development (LISD) has the potential to minimize the stresses on Town conveyances, while also serving as a vast educational opportunity to lake residents.

Recommendations for Stormwater and Septic Management -

1. Review maps of existing conveyances and any other water sampling data from MS4 drains
2. Identify improvements to MS4 and private septic systems within 50 ft and 250 ft of lake shore
3. Lake involvement with MS4 program planning and citizen education

We thank you for the opportunity to continue working for the Town of Putnam Valley in an effort to monitor and preserve Oscawana Lake.

APPENDIX 1

Bathymetric Map of Lake Oscawana Showing In-Lake Sampling Stations