TETRA TECH

TECHNICAL MEMO

To:	Kitsap County Long Lake Management District 614 Division Street Port Orchard, WA 98366
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Subject:	2018 Annual Summary Technical Memo

1.0 Introduction

The purpose of the Long Lake Integrated/Adaptive Lake Management Program is to achieve water quality and aquatic habitat goals established during the 2006 – 2010 lake management efforts. The current Long Lake management program is being implemented through the Kitsap County's Long Lake Management District 2018 through 2022. Targeted management of the lake will lead to an ecologically sustainable and balanced ecosystem with aesthetic appeal that supports water contact recreation, sport fishery, downstream water quality needs, and salmon migration. The lake management program will limit internal phosphorus loading in order to reduce excessive phytoplankton production, will control excessive growth of rooted aquatic plants, and will eliminate, where possible, non-native plants such as Eurasian watermilfoil and Brazilian Elodea. The integrated management program for Long Lake includes six basic elements; project management, integrated/adaptive planning, monitoring, implementation, reporting, and public education. This technical memo provides an annual assessment of in-lake activities and monitoring data collected in 2018, as well as recommended activities for 2019.

Figure 1. Map of Long Lake and surrounding area

Long Lake is a shallow, lowland lake located approximately four miles south of Port Orchard in

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southern Kitsap County in Western Washington State (T2 3N-R2E) (Figure 1). Long Lake lies at an elevation of 118 feet (ft.) (36 meters [m]) above sea level. The 339-acre (137 hectare) lake has a historical volume of 2,200 acre-feet (2.69 X 10^6 cubic meters [m^3]), average depth of 6.5 ft. (2 m), and center depth of 12 ft. (4 m) (Bortleson et. al., 1976). Nearly 75% of the lake is less than 10 ft. (3 m) in depth, providing a large littoral area. The drainage area is approximately 9.4 square miles (24.3 square kilometers [km^2]), encompassing an increasingly urbanized watershed. Salmonberry Creek is the major inlet, entering on the western shore. The single outlet, Curley Creek, drains the lake at the northeastern end, eventually flowing into the Puget Sound. Several unnamed streams enter at the southern end of the lake. Long Lake exhibits a rather high flushing rate varying from 3.6 to 8.0 yr^{-1} (Jacoby et. al., 1982).

2.0 2018 In-Lake Activities

2.1 Citizen Volunteer Monitoring Training

In May and early June 2018 Tetra Tech conducted two on-site citizen monitoring training workshops to train citizen volunteers on data collection procedures and data reporting. Tetra Tech also trained citizen volunteers on equipment calibration methods and reviewed the Quality Assurance Project Plan (QAPP) and Sampling and Analysis Plan (SAP).

Tetra Tech staff provided the following information at the two monitoring training workshop:

- An introduction to Long Lake and its management history, as well as an overview of eutrophication
- An overview of the water quality monitoring plan, including what parameters would be measured, and why, and when water quality monitoring should occur
- Safety procedures for conducting water quality monitoring in Long Lake
- Information on the exact location of monitoring sites in Long Lake and Salmonberry Creek
- An overview of equipment used to conduct water quality monitoring
- Detailed procedures for instrument calibration
- Detailed procedures for in-situ water quality monitoring and for water sample collection
- Instructions for preparing sample for delivery to IEH Analytical Laboratory
- Guidelines for testing, inspecting, and maintaining monitoring equipment

2.2 Monitoring by Citizen Volunteers

Citizen volunteers conducted in-situ monitoring on a monthly basis (May through October) for dissolved oxygen (DO), conductivity, temperature, and pH at three sites in Long Lake and in the inlet of Salmonberry Creek (Figure 2). At the lake sites, these parameters were measured at 1-meter intervals within the water column. Citizens recorded secchi disk depth, or transparency, at each station, and made notes on the weather at the time of sampling and water condition. At the mid-lake site, citizen volunteers also collected a water sample at a depth of 0.5 meter for laboratory analysis. From mid-May to mid-October, a second water sample was collected at the mid-lake site at a depth of 2.5 meters. These lake water samples were analyzed to determine total phosphorus (TP) concentrations and concentrations of soluble reactive phosphorus (SRP) and chlorophyll (chl). During each monitoring event, citizen volunteers also collected a grab sample from Salmonberry Creek. The creek water sample was analyzed for TP. All samples were packed with ice and sent to IEH Analytical Laboratory on the same day they were collected.

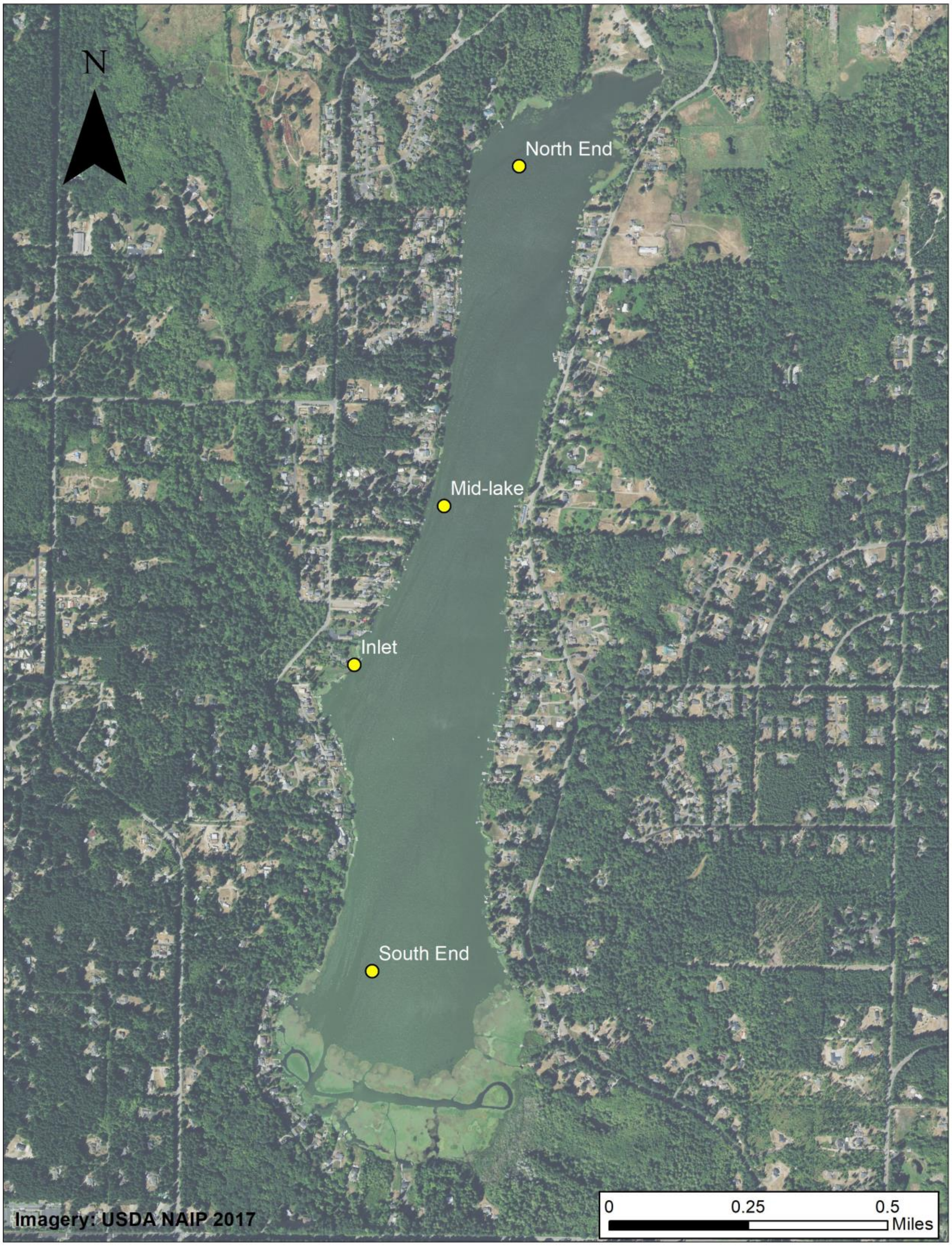

Figure 2. Map showing sampling locations.

2.3 Aquatic Plant Management

2.3.1 Aquatic Plant Survey

In June 2018, Tetra Tech staff conducted an aquatic plant survey of Long Lake (Figure 3). Brazilian elodea (*Egeria densa*) was the dominant submersed plant observed during the survey and was observed throughout the lake. Lilies are abundant in the nearshore areas near each end of the lake with the invasive fragrant white lily (*Nymphaea odorata*) as the dominate species. The native yellow pond lily, *Nuphar lutea*, covered less than 30% of the emergent plant beds. Eurasian water milfoil (*Myriophyllum spicatum*) was observed throughout the lake but in small groupings of relatively isolated plants. This was also the case for the invasive Curly-leaf pondweed (*Potamogeton crispus*). Several other pondweed species were observed throughout the lake with a relative small percent cover (Figure 3).

Brazilian elodea has existed in the lake for over 40 years. It was not observed in the south end of the lake in the mid-1960s where endemic pond weeds were more abundant. The exotic elodea allegedly was introduced around 1970. During the 20-year study by University of Washington (UW), this plant composed at least 2/3 of the total plant mass (dry weight) and much of that time over ¾ of the biomass (Welch, 1996). In 1985, its abundance dropped to only 10% of total mass and summer TP and chl averaged 66 and 36 µg/L, respectively due to increased internal loading. Harvesting in the 1990s had no effect on the dominance of Brazilian Elodea. Eurasian water milfoil was not present during the 20-year UW study, but it was observed in the 1996 IAVMP (Water Environmental Services, 1996) so it is a more recent invader. Curly-leaf pondweed is also a more recent invader and was first observed in 2006.

Aquatic plant management during 2006-2010 resulted in a more diverse plant community within Long Lake. The density of native macrophytes species in heavy boat use areas declined while the diversity (number of species) increased over that time period. Eurasian watermilfoil had nearly disappeared but the Brazilian elodea population in the open lake and south end had remained stable (Tetra Tech, 2010).

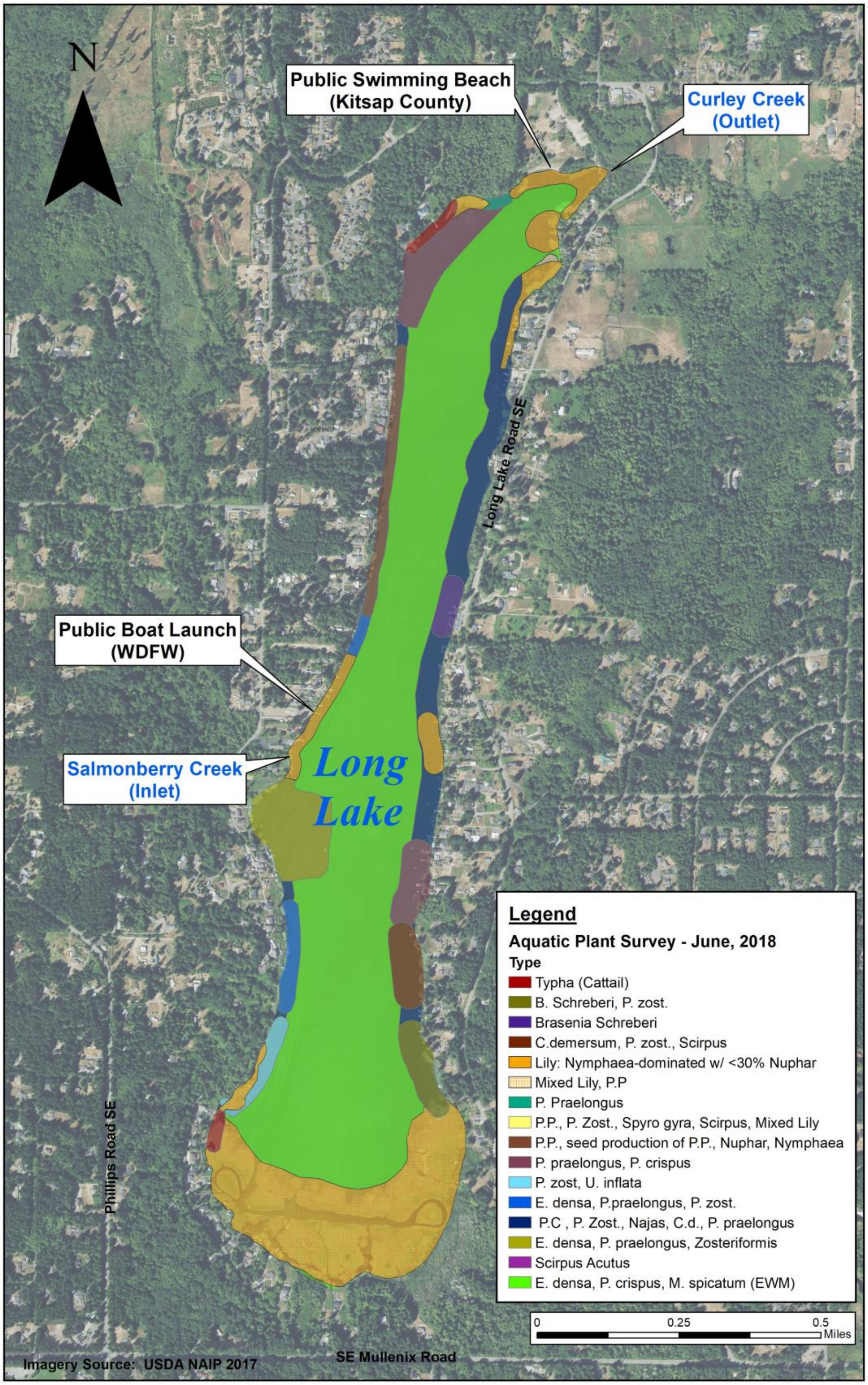

Figure 3. Aquatic Plant Distribution from June 2018 Survey.

2.3.2 Aquatic Plant Treatment

The goal of any aquatic plant treatment at Long Lake is to target noxious invasive non-native weeds that are already present and were documented in the 2010 report, confirmed during a preliminary survey on May 11th, 2018 and mapped during a detailed aquatic plant survey on June 2nd, 2018. The excess density of these plants and the dominance of non-native species within the plant community adversely impacts aquatic habitat, fisheries, and direct recreation. It also decreases water quality, leading to the release of phosphorus, which in turn leads to cyanobacteria toxic blooms. Following the pattern of rotating treatment sites used for aquatic plant treatment in 2006-2010, small areas of the littoral zone are anticipated to be treated each year in Long Lake. As in past studies, the expected result is a dramatic decrease in the density of non-native species, a dramatic increase in the presence of native species, and a reduction in the overall density of nuisance species (including non-natives), leading to an improvement in aquatic habitat. Controlling both cyanobacteria blooms and invasive plant species in 2006-2010 improved aquatic habitat, increased plant community diversity, reduced release of phosphorus that stimulated excess production, and improved conditions for recreational use.

Aquatic plant management activities restarted in 2018 with a late growth season treatment of 25% of the shallow littoral area targeting the invasive, non-native (AIS-aquatic invasive species) white lily, Brazilian elodea, and Eurasian water milfoil (Figure 4). Also, included in this treatment were excessively dense beds of native pond weed that also included a small amount of targeted invasive, non-native species.

On September 20th, 2018, 16.5 acres of the littoral zone were treated with the aquatic herbicide diquat dibromide, targeting Eurasian watermilfoil, Brazilian elodea, and pondweeds. This herbicide application was covered under an Aquatic Plant and Algae Management General Permit issued by the Washington Department of Ecology to Kitsap County on September 12th, 2018 (permit number WAG994398). The herbicide was applied by a licensed applicator, Kyle Langan of AquaTechnex. This application was followed up by an application of glyphosate on October 3rd and 4th, and then again on October 16th, that targeted 4 acres of the invasive fragrant water lily.

In August 2018, prior to treatment, Kitsap County published a public notice in the Kitsap Herald on two separate dates and distributed this public notice to residents within ¼-mile of the lake. In addition, a more detailed business and residential notice with details on the treatment plan was mailed on September 5th, 2018 to all lakefront owners and residents, as well as anyone in a homeowner's association with waterfront access. Twenty-four hours before the September 20th treatment, the applicator posted signage along the shoreline and at the boat launch that provided a map of the area to be treated and details on the herbicides to be used.

In spring 2019, the carryover effectiveness of the 2018 treatment will be evaluated during an aquatic plant survey. At this time, other priority treatment areas for summer 2019 will be identified, as well as, potential retreatment of some of the targeted 2018 treatment areas. If the carryover effectiveness of the 2018 treatment is 80% or greater in the treated areas, these areas will not be treated until potentially 2021 or after, if needed. This will allow re-establishment of native plants and corresponding aquatic habitat as in the 2006-2010 program.

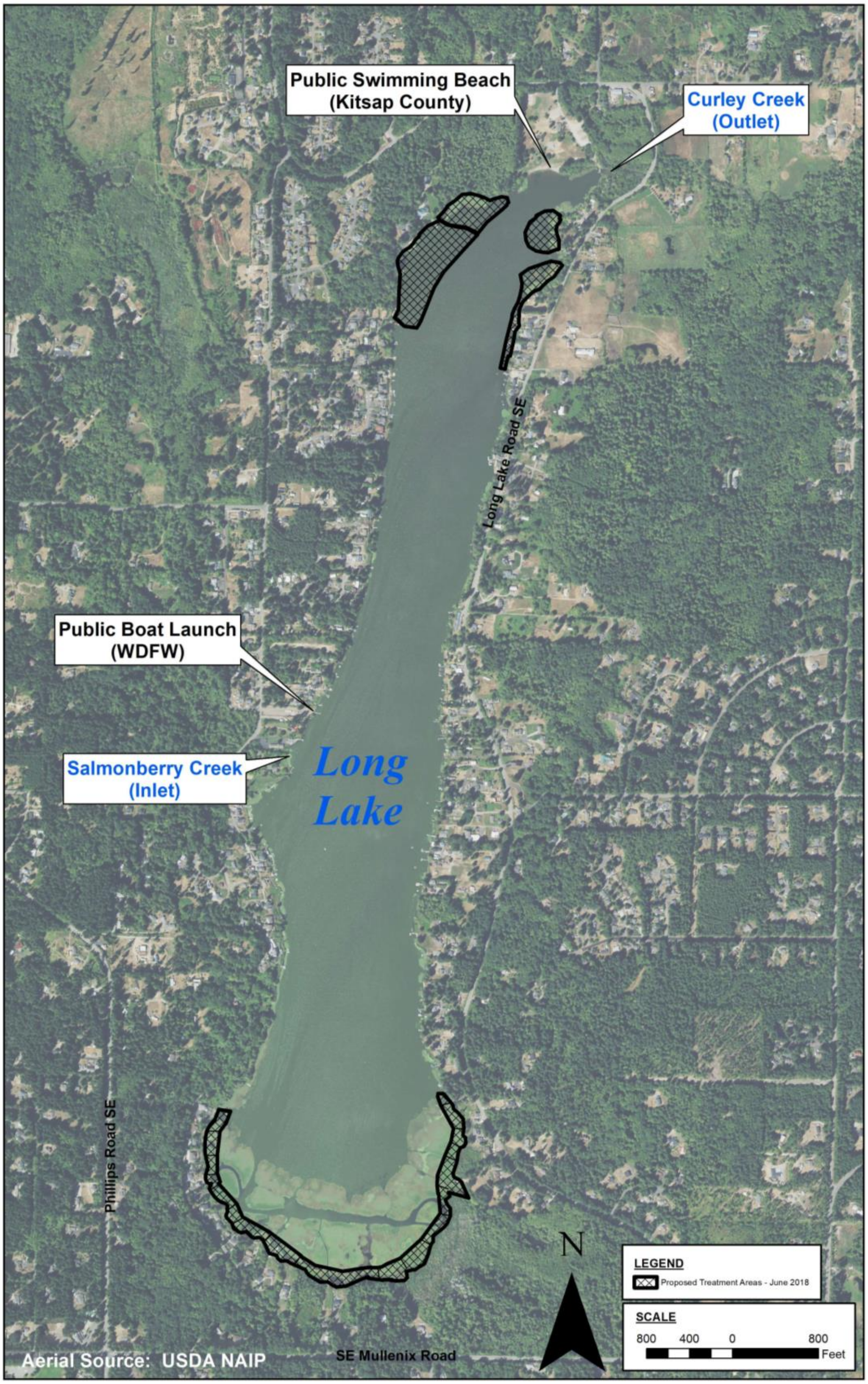

Figure 3: Aquatic plant treatment areas (hatched areas)

3.0 Monitoring Results

3.1.1 Water Level

A data logger that records water level in Long Lake was installed in June 2018 on a homeowner's private dock. The logger records lake level continuously at hourly intervals. Since the logger was installed halfway through 2018, a detailed assessment of lake level and changes in level with season will be conducted following June 2019 and included in the 2019 annual summary report.

A data logger was also supposed to be installed in Salmonberry Creek, the main inlet to Long Lake, since Kitsap County does not maintain a gage on the creek. At the time of installation in June 2018, a suitable location near the mouth of Salmonberry Creek, could not be located due to concerns with vandalized or theft. Loggers that have been previously installed on Salmonberry Creek have succumbed to both vandalized and theft in the past.

3.1.2 Total and Soluble Phosphorus

Surface TP concentrations at the mid-lake station averaged 26 µg/L and ranged from 18 to 34 µg/L during May through early October 2018 (Table 1, Figure 5). Bottom (2.5 m) TP concentrations were similar and ranged from 21 to 36 µg/L (Table 1, Figure 5) with a May to October average of 27.2 µg/L, just slightly higher than the surface average concentration. Total phosphorus concentrations in the lake, both surface and bottom, were lower than the inflow, Salmonberry Creek, during spring and early summer. In late summer and fall, the inlet TP concentrations were lower, below 25 µg/L, while lake concentrations were between 26 and 34 µg/L (Figure 5). In fact, the maximum surface TP concentration measured at the mid-lake station (34 µg/L) occurred on August 30th. Average inlet TP for May to October was 30.8 µg/L. Soluble phosphorus concentrations were low throughout the monitoring season, with concentrations below 5 µg/L (Table 1, Figure 5).

Table 1. TP and SRP Concentrations in Long Lake (Mid-Lake Stations) and Salmonberry Creek in 2018.

Date	Depth	TP (µg/L)	SRP (µg/L)	CHL-a (µg/L)
5/11/2018	0.5	23	4	2.1
	2.5	21	3	1.8
	Salmonberry Creek	33	--	--
6/18/2018	0.5	18	2	3.7
	2.5	22	4	3.4
	Salmonberry Creek	36	--	--
7/24/2018	0.5	28	1	9.9
	2.5	36	1	5.3
	Salmonberry Creek	41	--	--
8/30/2018	0.5	34	1	39
	2.5	30	1	24
	Salmonberry Creek	24	--	--
10/4/2018	0.5	26	2	5.9
	2.5	27	2	6.2
	Salmonberry Creek	20	--	--

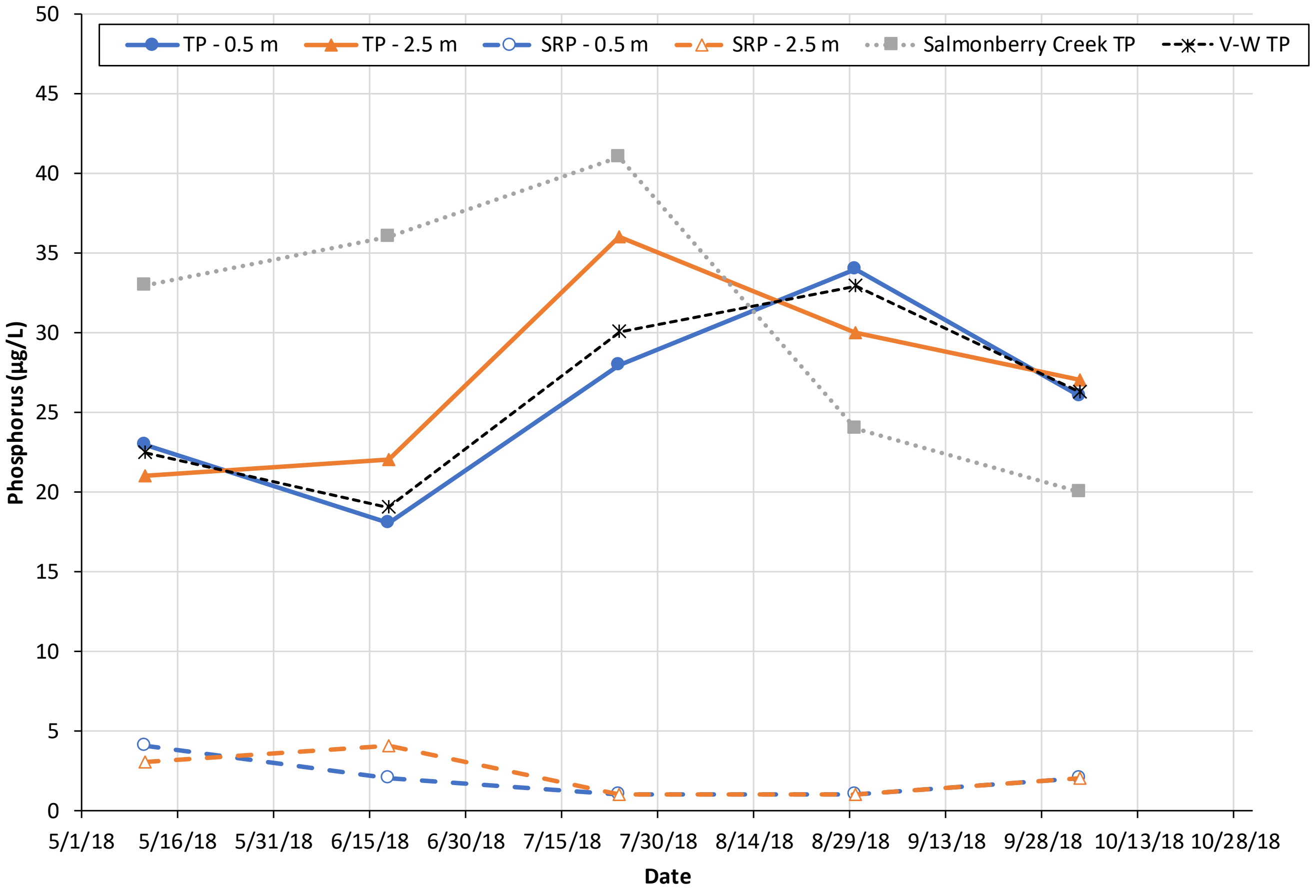

Figure 5. Phosphorus concentrations in Long Lake and Salmonberry Creek in 2018.

3.1.3 Chlorophyll-*a*

Surface chl concentrations averaged 12.1 µg/L over the monitoring period and ranged from a low of 2.1 µg/L in May to a maximum chl of 39 µg/L in late August (Table 2, Figure 6). Chlorophyll concentrations at 2.5 m were slightly lower, as expected, and averaged 8.1 µg/L. Minimum chl at 2.5 m was 1.8 µg/L in May and maximum chl was 24 µg/L in late August (Table 2, Figure 6). The maximum chl concentrations observed on August 30th correspond to the maximum surface TP and volume-weighted TP concentrations in the lake (Figure 5).

Table 2. Chlorophyll Concentrations in Long Lake (Mid-Lake Stations) in 2018.

Date	Depth	CHL-a (µg/L)
5/11/2018	0.5	2.1
	2.5	1.8
6/18/2018	0.5	3.7
	2.5	3.4
7/24/2018	0.5	9.9
	2.5	5.3
8/30/2018	0.5	39
	2.5	24
10/4/2018	0.5	5.9
	2.5	6.2

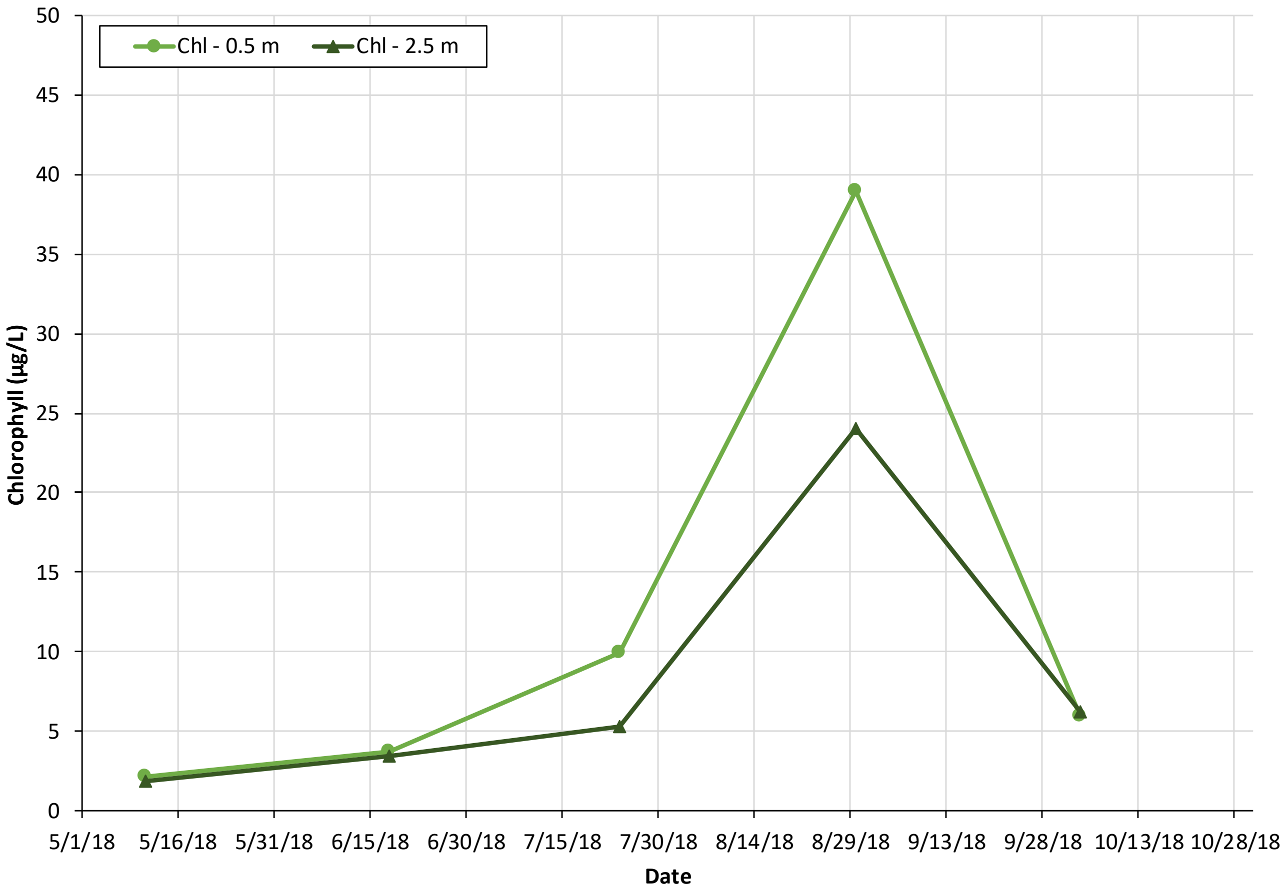

Figure 6. Chlorophyll concentrations in Long Lake in 2018.

3.1.4 Water Clarity

Water clarity, or transparency, as measured with a secchi disk, ranged from 0.9 to 2.6 m at the mid-lake station, 0.9 to 2.2 m at the north lake station, and 0.9 to 2.1 at the south station (Figure 7). Minimum secchi disk (0.9 m) was observed at all stations at the end of August when maximum chl concentrations were observed. Maximum secchi disk was observed in the spring (mid-lake station) and early summer (north and south lake stations) and not surprisingly corresponded with minimum chl concentrations.

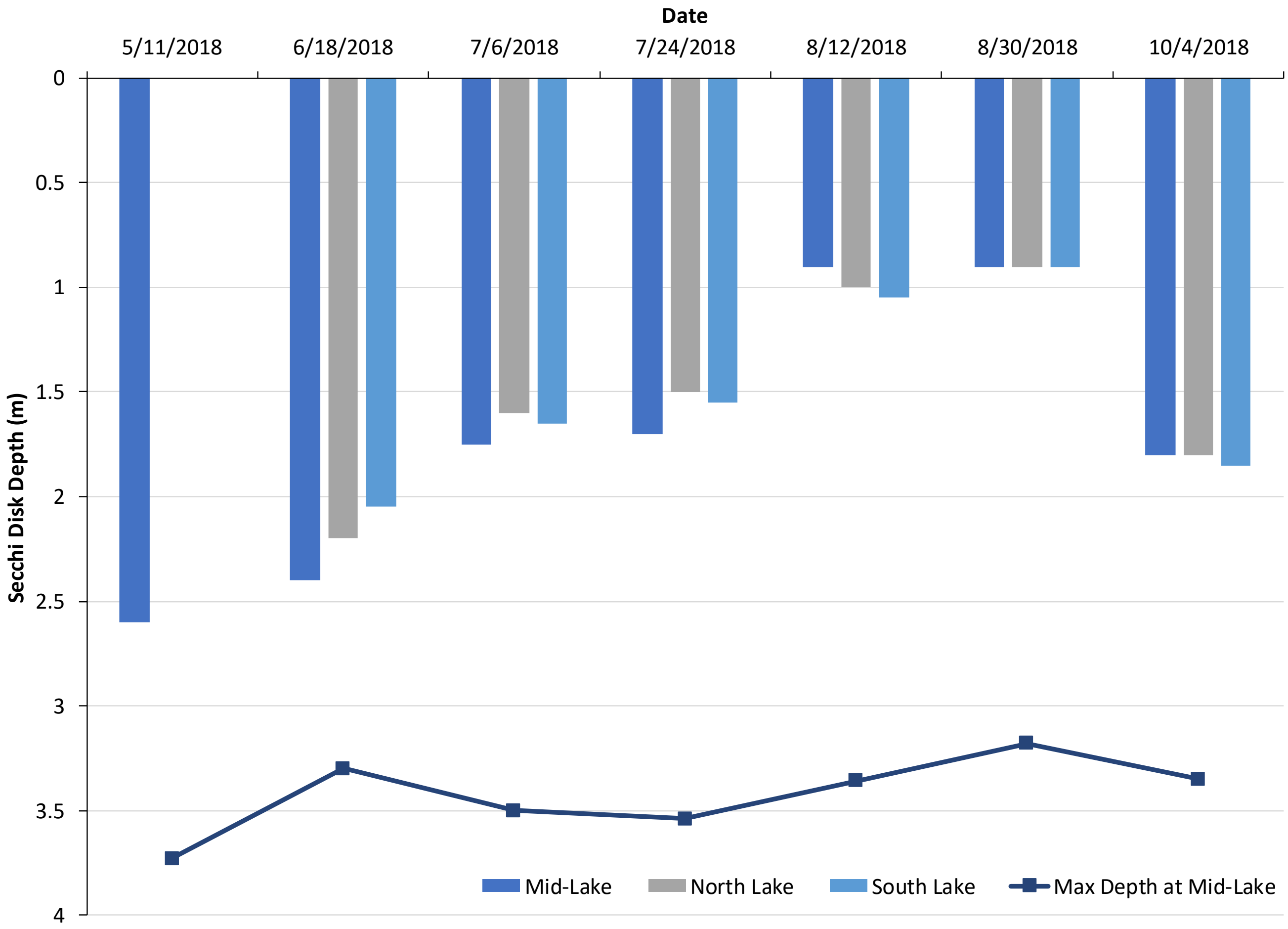

Figure 7. Secchi disk depth (water transparency) in Long Lake during 2018.

3.1.5 Water Temperature, Dissolved Oxygen, Conductivity, and pH

Profiles of water temperature, DO, conductivity, and pH were measured at each station during the 2018 monitoring period (only at the mid-lake station in May and off a resident's dock in December). Water temperature profiles are shown in Figure 8. Temperatures ranged from 15.4°C to 25.7°C at all stations, with minimum temperatures occurring in October and maximum temperatures occurring at the surface at the end of July (Figure 8). Long Lake is a shallow lake and mixes frequently throughout the year. Weak stratification was observed in 2018 during June (just near the bottom), late July and August (Figure 8). Water temperatures at the 3 stations were relatively similar during 2018 with the exception of late July when there was a distinct difference in profiles between the stations (Figure 8).

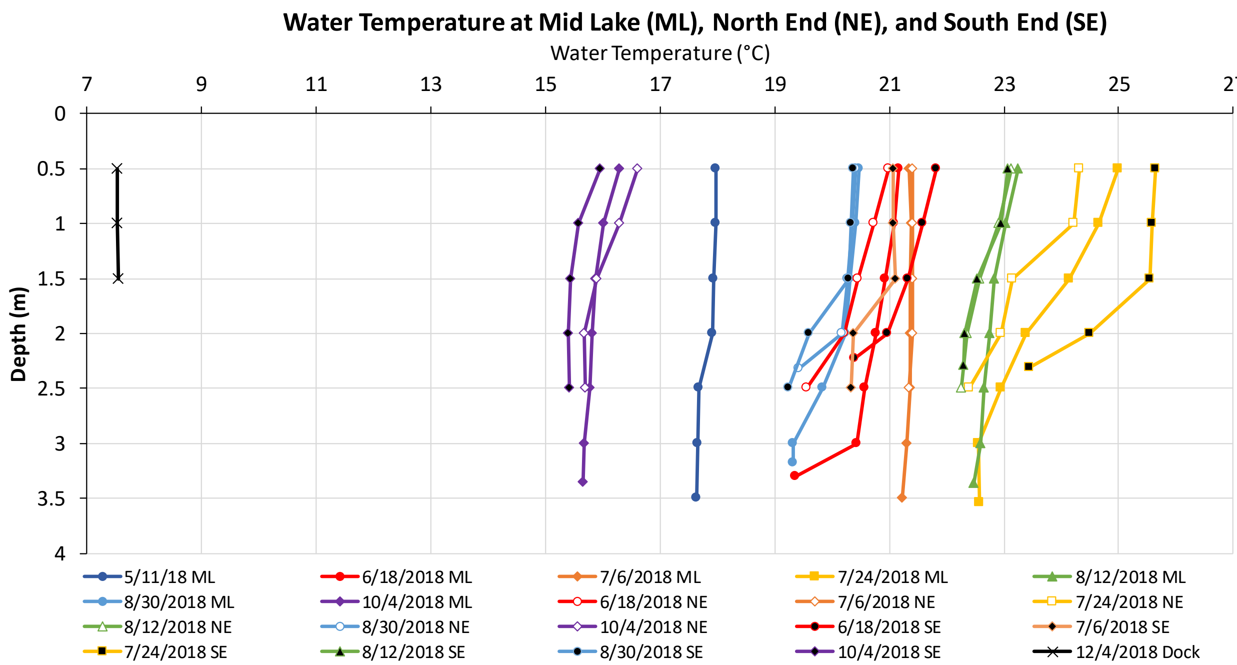

Figure 8. Water Temperatures in Long Lake, 2018.

Dissolved oxygen concentrations ranged from 0.73 to 10.4 mg/L at the mid-lake station, from 1.9 to 10.6 mg/L at the north lake station, and from 0.13 to 9.8 mg/L at the south lake station (Figure 9). Minimum DO occurred near the bottom at all stations but at various times throughout the season; end of July at the mid-lake station, when the water column was the most strongly stratified, October at the north lake station, and at the end of August at the south lake station. For the most part, DO concentrations measured in Long Lake were greater than 6 mg/L, with only a handful of observations measured at less than 4 mg/L (Figure 9). Maximum DO observed at the mid-lake station and the north lake station occurred in late August along with maximum chl concentrations. Dissolved oxygen percent saturation near the surface during late August was around 117%, super saturated, due to phytoplankton photosynthesis.

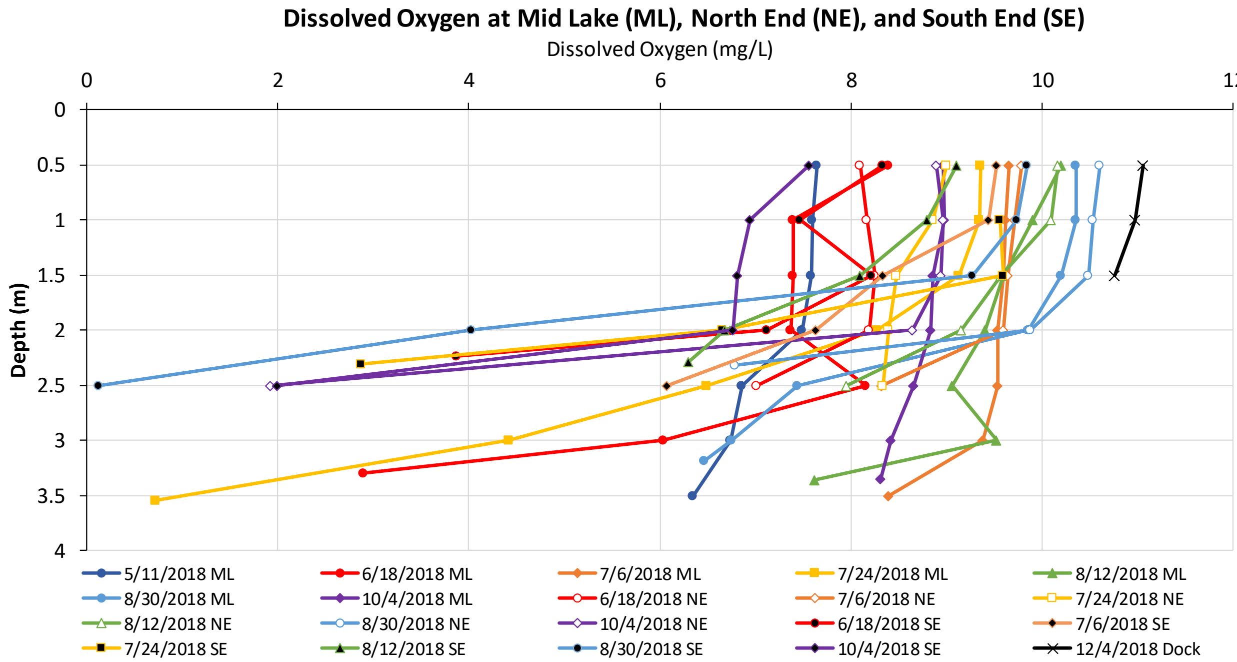

Figure 9. Dissolved Oxygen in Long Lake, 2018.

pH varied throughout the water column and ranged from 6.5 to 8.7 at all stations during the 2018 monitoring season (Figure 10). Maximum pH was observed at the surface of the mid-lake station in mid-August. pH was also high at the north lake station in mid-August (Figure 10). Water column pH followed similar profile patterns as DO, with higher values near the surface and lower values measured near the bottom. At the north lake site, pH was more uniform throughout the water column than the south lake site and to some extent the mid-lake site. pH was most likely influenced by photosynthesis both from phytoplankton in the water column as well as aquatic plants.

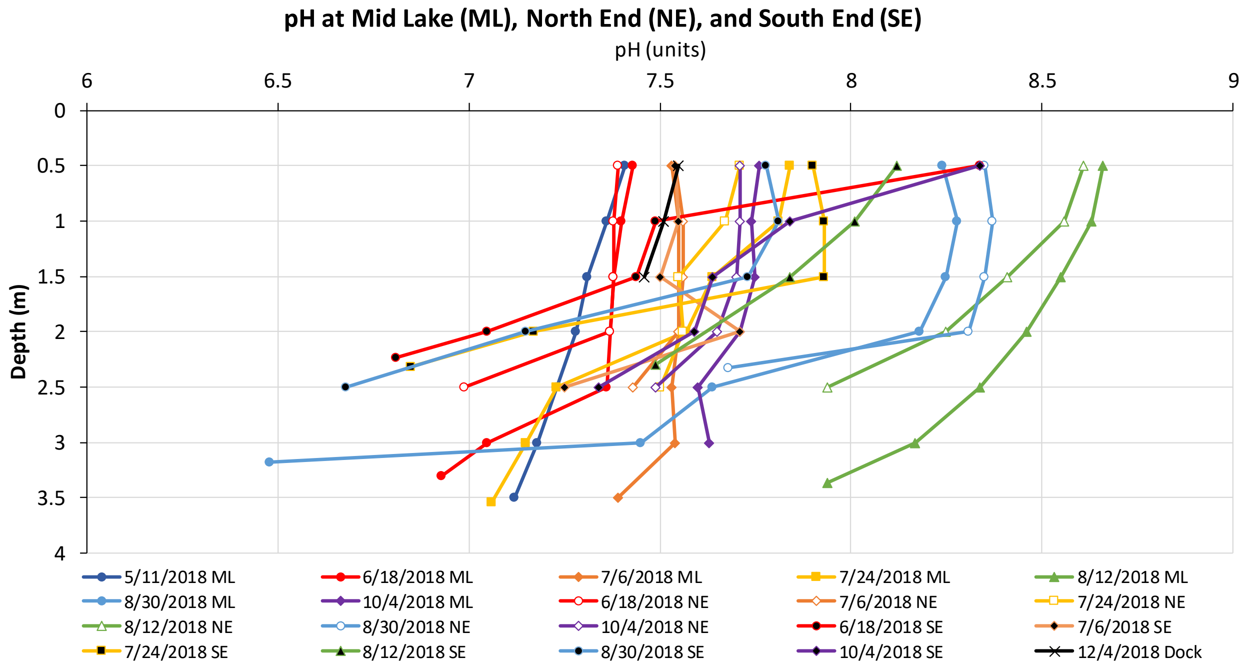

Figure 10. pH in Long Lake, 2018.

Conductivity was similar between the three monitoring stations during each sampling event but varied over the course of the monitoring period (Figure 11). Conductivity ranged from maximums around 130 µS/cm in late August to a minimum of just below 100 µS/cm in May. Conductivity was uniform throughout the water column with just slight variations near the bottom (Figure 11).

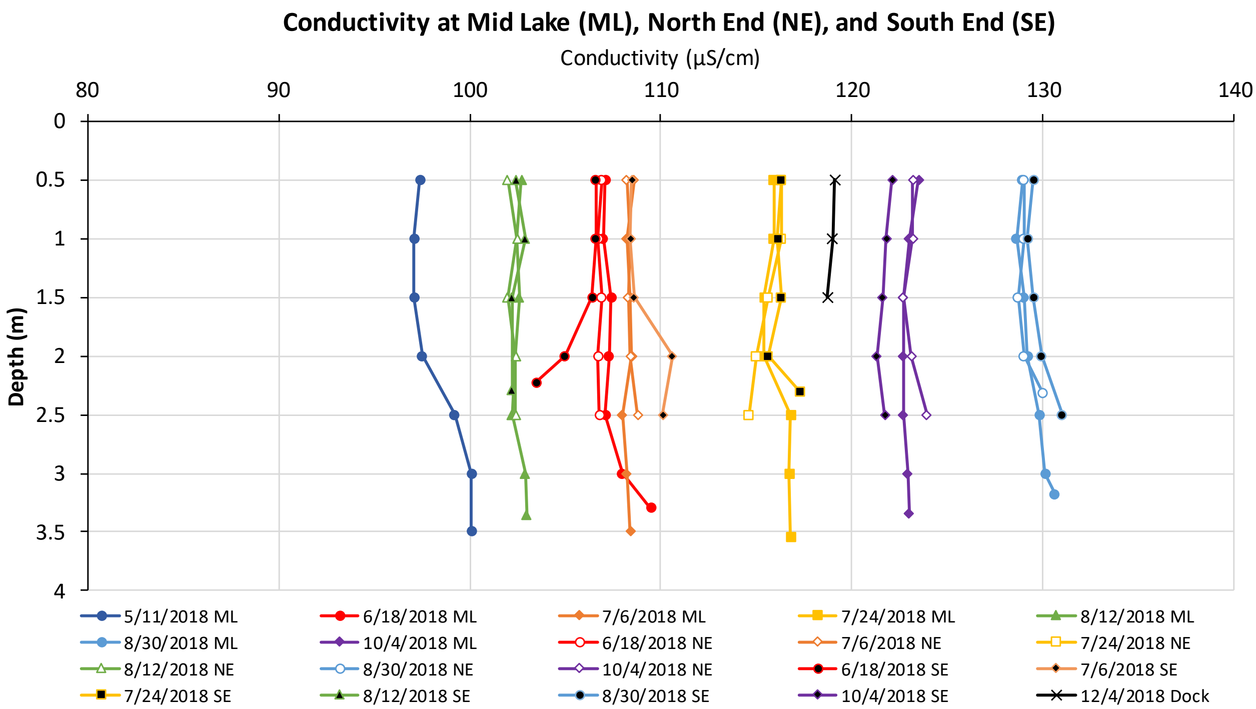

Figure 11. Conductivity in Long Lake, 2018.

4.0 Discussion

This was an interesting year for lake water quality in Long Lake. The volunteer monitoring team monitored the lake from May through November, with water samples for laboratory analysis collected May through October. Below is a summary of noteworthy findings from the 2018 monitoring season:

- Weather appears to have been a very influential factor in the nutrient dynamics of the lake in 2018.
    - The lake experienced a very wet winter and spring which most likely resulted in a significant flushing of the nutrients out of the lake through May 2018.
    - This flushing may have reduced the available carryover nutrients in the lake significantly, which could have contributed to lower than normal summer phosphorus concentrations.
    - The dry warm summer and relatively good water clarity allowed for outstanding photosynthetic conditions for aquatic rooted plants and phytoplankton.

- The summer lake phosphorus concentrations were significantly less than observed prior to the 2006 and 2007 phosphorus inactivation treatments and only approached levels observed in 2008-2010 in the late July and August in 2018.
    - 2018 TP concentrations only ranged from 18 to 36 µg/L, which is 3 to 4 times less than concentrations observed in 2006.
    - Summer mean (June-September) surface TP for the lake was 26.7 µg/L, just above the eutrophic boundary of 25 µg/L.
    - There was a slight increase in lake TP concentrations at the end of August that did not correspond to an increase in input TP from Salmonberry Creek.

- Chl, the indicator of algal biomass, remained in the very low productivity range (oligotrophic), an indicator of good water quality, until mid to late July where it was in the mid productivity range (mesotrophic). However, by mid to late August the phytoplankton productivity had increased to the eutrophic range with a maximum of 39 µg/L. Still this was well below previous year’s levels prior to 2007.

- It is important to understand that the ratio of chl to TP (Chl:TP) based upon the worldwide lake average which is 0.3:1. In 2018 that ratio ranged from 0.09:1 to 0.9:1 in Long Lake.
    - From May through July the Chl:TP ratio was less than the world average reflecting relatively good water quality.
    - However, in August the ratio changed to 0.9:1 which is 3 times the worldwide average indicating the cyanobacterial (blue-green algae) production was exceeding the phosphorus supply resulting is a bloom.
    - In early October, the chl:TP ratio was back down to 0.2:1, much closer to the world wide average.

5.0 Recommendations for Future work

Every year going forward 15-25% of the lake shallow littoral area should be treated based on a rotational 4-year coverage adaptive program to ensure the re-establishment of native plant communities for aquatic ecosystem recovery, while maximizing the direct beneficial uses of the lake. In the late spring of 2019 the 2018 treatment effectiveness will be assessed and new, as well as re-treatment areas, will be identified for a summer 2019 control.

To limit the phosphorus and thereby limit the phytoplankton potential for an algal bloom production, a phosphorus inactivation and water column stripping alum treatment is planned for the late spring to early summer of 2019. This will help limit the potential for an algal bloom and improve overall lake water quality.

6.0 Revisions to the Adaptive Plan

Currently, the data does not dictate any revisions to the adaptive plan.

7.0 References

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