

2018 Ward Lake Water Quality Report

Prepared by Thurston County Environmental Health Division

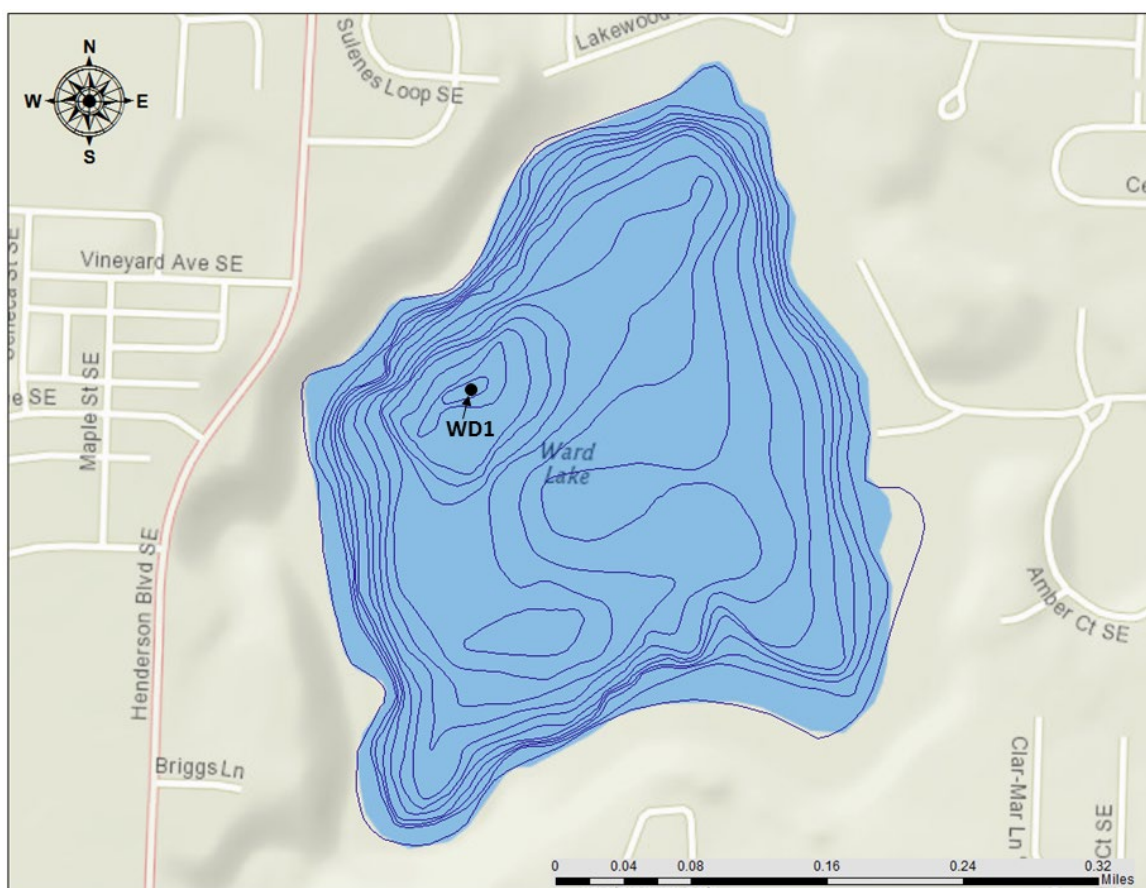


Figure 1. Ward Lake map showing location of sample site WD1.

PART OF DESCHUTES RIVER WATERSHED

- **SHORELINE LENGTH:** 1.4 miles
- **LAKE SIZE:** 0.1 square miles (65 acres)
- **BASIN SIZE:** 0.95 square miles
- **MEAN DEPTH:** 10 meters (33 feet)
- **MAXIMUM DEPTH:** 20 meters (67 feet)
- **VOLUME:** 2,590,308 cubic meters (2,100 acre-feet)

PRIMARY LAND USES:

Most of the basin is suburban with moderate to high density residential housing. Historically there was a large plant nursery on the west side, but that area is now being converted to an urban village.

PRIMARY LAKE USE:

Ward Lake is used for fishing, boating, and swimming.

PUBLIC ACCESS:

The Washington Department of Fish and Wildlife has one public boat launch. Four private access points exist for lakeside communities.

GENERAL TOPOGRAPHY:

The Ward Lake sub-basin is 313 acres. The lake is located at an altitude of 131 feet mean sea level. The topography of the basin is lowlands and rolling hills with occasional glacial depressions. Ward is a kettle lake, a deep glacial depression, that is fed by groundwater. There is no surface inlet or outlet.

GENERAL WATER QUALITY:

Good – Ward Lake is mesotrophic. The total phosphorus (TP) concentration was below the action level. Algal blooms have occurred, but toxins were not above the Washington State Advisory level in any of the sixteen samples collected since 2010.

DESCRIPTION

Ward Lake is a kettle lake located near the southwest boundary of Olympia, Washington. In the Puget Sound lowlands, many lakes occupy depressions in the surface of glacial drift. Ward Lake was formed by the melting of huge blocks of glacial ice. Kettle lakes like Ward often have a crenulated shoreline and undulating bathymetry. Ward Lake and the surrounding drainage area have Yelm fine sandy loam soils. Formed by volcanic ash and glacial outwash, these are deep, moderately drained soils on terraces (USDA, 1990).

Much of the eastern shoreline has been developed for residential use, with docks, bulkheads, and maintained lawns extending to the edge of water. Other shorelines are less developed, with more native riparian vegetation, wetlands, and large woody debris (Herrera, 2011).

Aquatic macrophytes in the littoral zone include: fragrant water lily (non-native and invasive), yellow water lily, Nuttall's waterweed, water moss, and big-leaf pondweed. Emergent plants on the shorelines include bull rush, cattails, and yellow flag iris (non-native and invasive).

Ward Lake is fed by groundwater; it has no surface inlet or outlet. Water quality has been generally good, except for in 2012 when higher concentrations of nutrients and fecal coliform degraded water quality and algal blooms interfered with recreation.

The Department of Fish and Wildlife manage the lake for rainbow trout and kokanee. Ward Lake also supports naturally reproducing largemouth bass, bluegill sunfish, cutthroat trout, and rock bass. Ward Lake is listed for persistent organic pollutants in fish: Category 5 (highest category for polluted waters) for Polychlorinated Biphenyls (PCBs) and Category 2 (water of concern) for 2, 3, 7, 8-Tetrachlordibenzo-*p*-dioxin (TCDD), which is the most toxic dioxin. Ward Lake was listed for these contaminants in 2006 as a result of a toxin study of tissue samples from bluegill, kokanee, and largemouth bass.

METHODS

In 2018, Thurston County Environmental Health (TCEH) conducted monthly monitoring at Ward Lake from May to October. Figure 1 shows the Ward Lake sample site (WD1) located in the deepest part of the lake. Table 1 lists the types of data collected (TCEH, 2009) and Appendix A provides the raw data. The Custer Color Strip (Figure 2) has been used as a reference for water color since the 1990s.

Table 1. List of parameters, units, method, and sampling locations.

Parameter	Units	Method	Sampling Location
Transparency	meters	Secchi Disk	Depth where disk is no longer visible
Color	#1 to #11	Custer Color Strip	Color of water on white portion of Secchi Disk
Vertical Water Quality Profile	<ul style="list-style-type: none"> • Water Temperature (°C) • Dissolved Oxygen (mg/L) • pH (standard units) • Specific Conductivity (µS/cm) 	YSI EXO1 Multi-parameter Sonde	~ 0.5 meter below the water surface to ~ 0.5 meter above the bottom sediments
Total Phosphorus	mg/L	Grab Samples with Kemmerer	Surface Sample: ~ 0.5 meter below the surface Bottom Sample: ~ 0.5 meter above the benthos
Total Nitrogen	mg/L	Grab Samples with Kemmerer	Surface Sample: ~ 0.5 meter below the surface Bottom Sample: ~ 0.5 meter above the benthos
Chlorophyll-a	µg/L	Composite of Multiple Grab Samples	Photic Zone
Phaeophytin-a	µg/L	Composite of Multiple Grab Samples	Photic Zone



Figure 2. TCEH compared water color to the Custer Color Strip.

Quality Assurance and Quality Control (QA/QC)

Each day TCEH collected 10% field replicates and daily trip blanks to assess total variation (3 to 4 lakes sampled each day). The calibration of the Yellow Springs Instrument (YSI) EXO1 was verified before and after each sampling day. See Appendix B for QA/QC data.

The Seasonal Kendall Test

TCEH used the Seasonal Kendall test, a highly robust, non-parametric test, to identify trends from 2008 to 2018 (Appendix C). This test compares the relationship between data points at separate time periods and determines if there is a trend (positive or negative). The Seasonal Kendall test statistic was computed by performing a Mann-Kendall calculation for each sample month (May to October) from 2008 to 2018. TCEH calculated the Z statistic to determine if the trend was statistically significant and Theil-Sen estimator, also called Sen Slope, to estimate the magnitude of the trend over time.

In 2017, the May sampling event was postponed until June 1. The June 1, 2017 data was included in the May trend analysis. Ward Lake was not sampled in May 2018 because the boat launch was closed.

RESULTS

Weather Conditions

Weather conditions during the 2018 sample season are provided in Table 2.

Table 2. Weather on sample days and the average, minimum, and maximum air temperatures for each month.

Month	Weather on Sample Day	Temperature (° C) Monthly Average (Low/High)
June	Mostly Cloudy (20°C); 0-3 mph S wind	31 (16/22)
July	Clear, (23°C); 5-10 mph S wind	34 (21/28)
August	Hazy from wildfire smoke, (22°C); 0-3 mph NNE wind	26 (18/36)
September	Sunny (19°C); 0-10 mph NNE wind	22 (17/29)
October	Fog (9°C); 0-5 mph S to SSW wind	16 (12/22)

Vertical Water Quality Profiles

During the summer, lakes often stratify into layers based on temperature and density differences.

- Epilimnion: upper warm, circulating strata in contact with the atmosphere
- Metalimnion: middle layer with steep thermal gradient (thermocline)
- Hypolimnion: deepest layer of colder, relatively stagnant water

The vertical water quality profiles illustrate how the water column at Ward Lake was thermally stratified for the duration of the sample season (Figures 3 to 5). Warmer, more oxygenated water existed on the surface in the epilimnion. Below this layer, the temperature and oxygen concentration declined with depth.

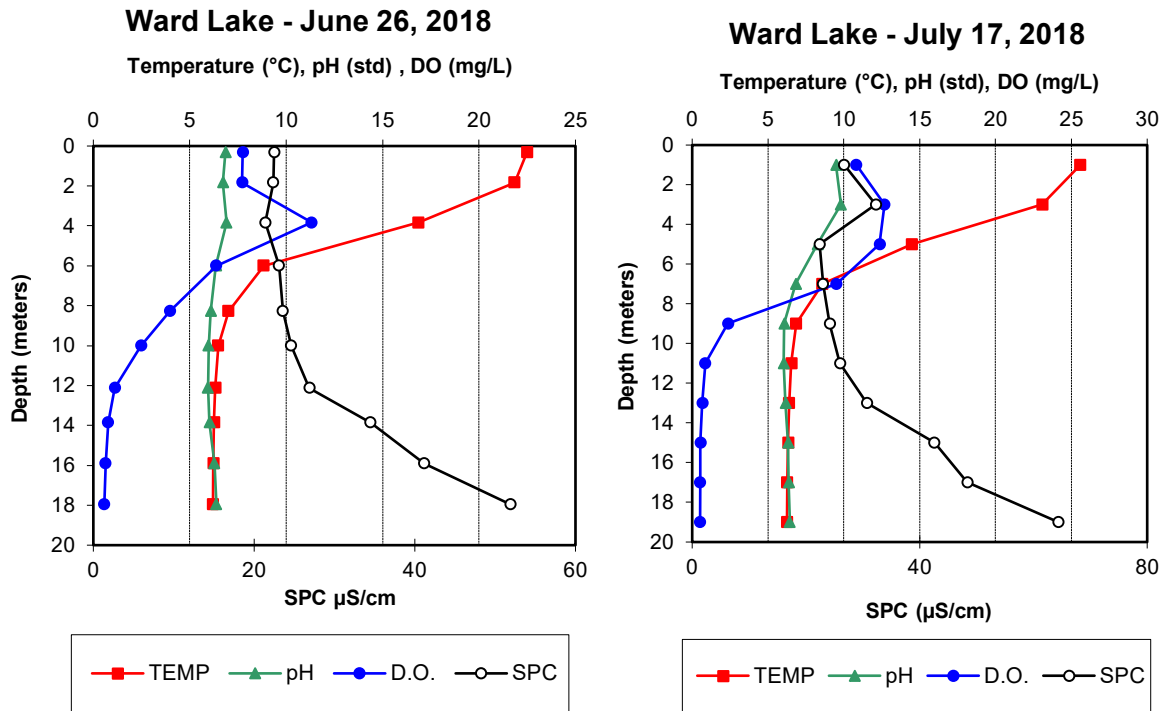


Figure 3. Vertical water quality profiles for Ward Lake collected during June and July 2018.

Ward Lake was thermally stratified in June. The summer sun heated the surface layer, the epilimnion. This heat was retained because the air temperature remained high (Table 2).

- June Epilimnion – Mean Temperature 22.16°C; Mean DO 7.73 mg/L
- June Hypolimnion – Mean Temperature 6.29°C; Mean DO 1.12 mg/L

In July, temperature increased in the epilimnion, as did the mean day and nighttime air temperatures. Productivity was high (Figure 10), which created higher DO. The hypolimnion, isolated from the oxygenated strata above, became more anoxic due to oxygen consuming processes or advection of low oxygen groundwater

- July Epilimnion – Mean Temperature 24.34°C; Mean DO 11.75 mg/L
- July Hypolimnion – Mean Temperature 6.35°C; Mean DO 0.63 mg/L

The Secchi depth was 2.6 to 4.7 meters from June to August (mean 3.4 meters), which allowed autotrophs to photosynthesize in the metalimnion. The DO positive heterograde curve was present all three months. When the water column is sufficiently transparent to permit photosynthesis in the metalimnion, excess oxygen accumulates there because thermal stratification prevents vertical mixing of the water column (Wetzel, 1983).

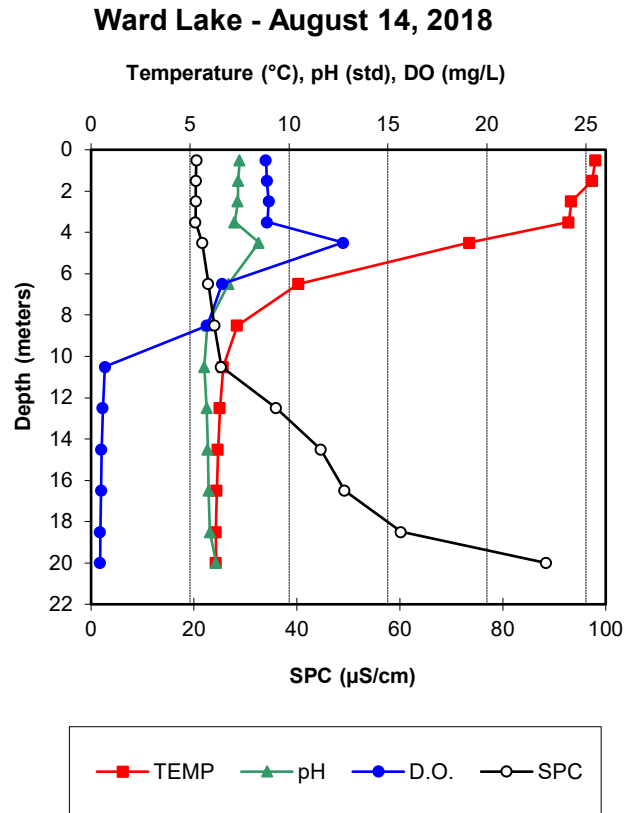


Figure 4. Vertical water quality profiles for Ward Lake collected during August 2018.

The epilimnion continued to warm in August. Compared to July, the oxygen supply diminished above and below the metalimnion. Secchi depth increased 0.25 meter in August from the previous month. Chlorophyll-a declined from its high in July of 7.5 µg/L to 4.3 µg/L in August (Figure 10).

- August Epilimnion – Mean Temperature 24.80°C; Mean DO 8.90 mg/L
- August Hypolimnion – Mean Temperature 6.42°C; Mean DO 0.54 mg/L

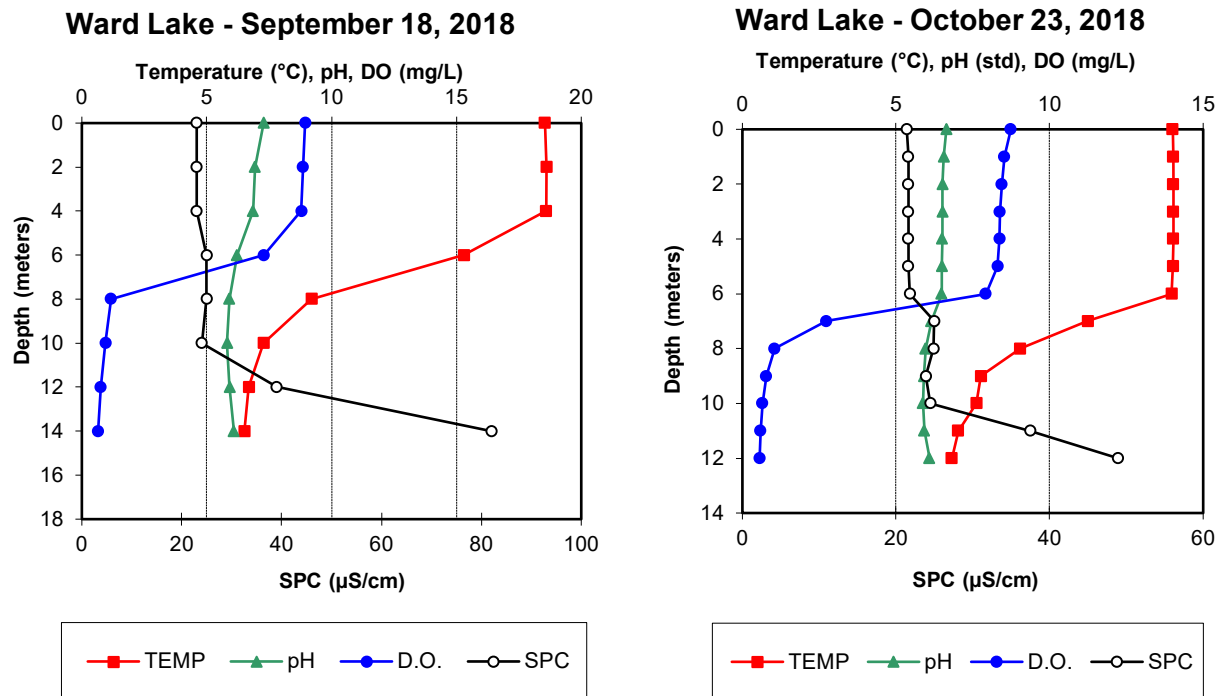


Figure 5. Vertical water quality profiles from Summit Lake collected during September and October 2018.

In September, the temperature of the epilimnion declined and this layer extended deeper. Also, the DO curve changed to clinograde in September and October; the metalimnion was no longer supersaturated with oxygen despite greater transparency. During these two months, there is evidence of lower productivity (Figure 10) and changes to the phytoplankton assemblage from the change of color and transparency (Figure 7).

- September Epilimnion – Mean Temperature 18.58°C; Mean DO 8.86 mg/L
- September Hypolimnion – Mean Temperature 6.60°C; Mean DO 0.70 mg/L

The epilimnion continued to cool and sink in October, but the lake had not yet turned over. Oxygen consuming processes or advection of low oxygen groundwater continued to produce anoxic conditions in the hypolimnion.

- October Epilimnion – Mean Temperature 14.02°C; Mean DO 8.46 mg/L
- October Hypolimnion – Mean Temperature 7.31°C; Mean DO 0.65 mg/L

Surface Water Temperature Trends

The Seasonal Kendall analysis for trends for 2008 to 2018 shows that surface temperature has significantly increased at WD1 from May to August (Figure 6). Increased temperatures have many effects on freshwater environments. Warmer temperatures prolong thermal stratification and prevent mixing, enabling algal blooms to grow thicker and faster (Wells et al., 2015). Higher temperatures and nutrient pollution may increase the frequency and intensity of harmful algal blooms. Cyanobacteria (commonly called blue green algae) have a higher temperature optimum than eukaryotic phytoplankton, giving them a competitive advantage in warmer water. For example, *Microcystis* have temperature-dependent gas vacuoles that increase buoyancy, allowing this type of cyanobacteria to rise to more favorable light and temperature conditions under quiescent conditions (Michalek et al, 2013). In contrast, surface water temperature has significantly declined over the last decade in September and October.

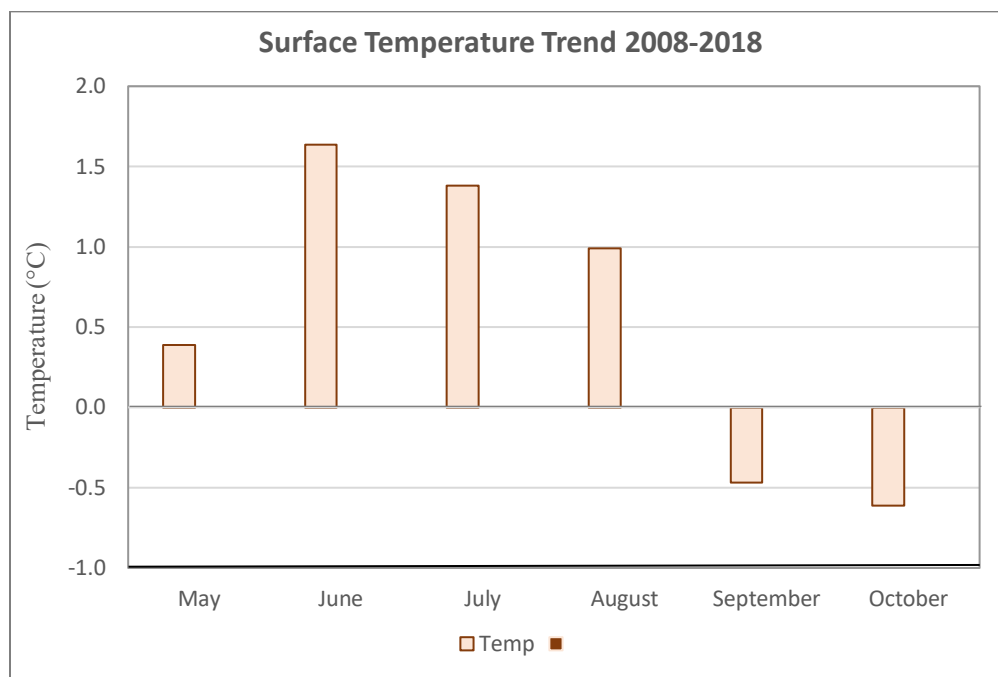


Figure 6. Surface temperature trend (+ or -) and magnitude of change (Theil-Sen estimator) for WD1 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p < 0.05$) for that time period.

Water Color and Transparency

Color can reveal information about a lake's nutrient load, algal growth, water quality and surrounding landscape. High concentrations of algae cause the water color to appear green, golden, or red. Weather, rocks and soil, land use practices, and types of trees and plants influence dissolved and suspended materials in the lake. Tannins and lignins, naturally occurring organic compounds from decomposition, can color the water yellow to brown.

Transparency of water to light has been used to approximate turbidity and phytoplankton populations. Secchi depth is closely correlated with the percentage of light transmission through water. The depth at which the Secchi disk is no longer visible approximates 10% of surface light, however suspended particles in the water affect accuracy. The health department recommends visibility of at least 1.2 meters, or four feet, at public swimming beaches.

Figure 7 shows the color and transparency for WD1 for 2018.

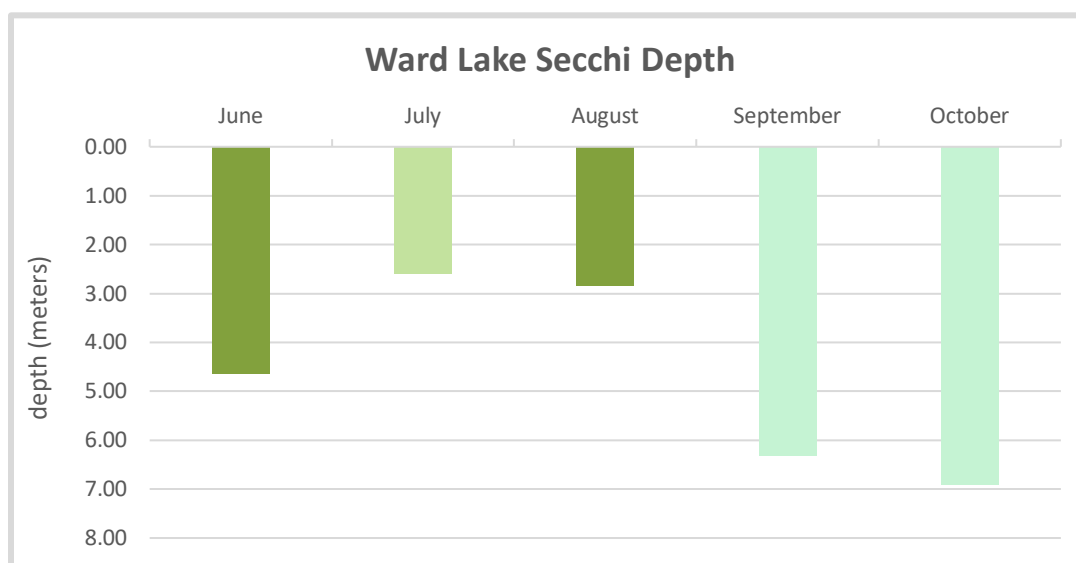


Figure 7. Water color and Secchi depths for 2018.

In 2018, transparency was lowest from July to August (2.6 to 2.9 meters) when the color was #3 and #6 and highest in September to October (6.3 to 6.9 meters) when the color was #2 (Figure 7). Changes in the algal community likely affected color and transparency.

Figure 8 shows the annual average transparency (Secchi depth) compared to the long-term average (LTA). Positive values reflect transparency better than the long-term average. In 2018, transparency at WD1 (mean 4.66 meters) was marginally lower (0.05 meter) than the long-term average.

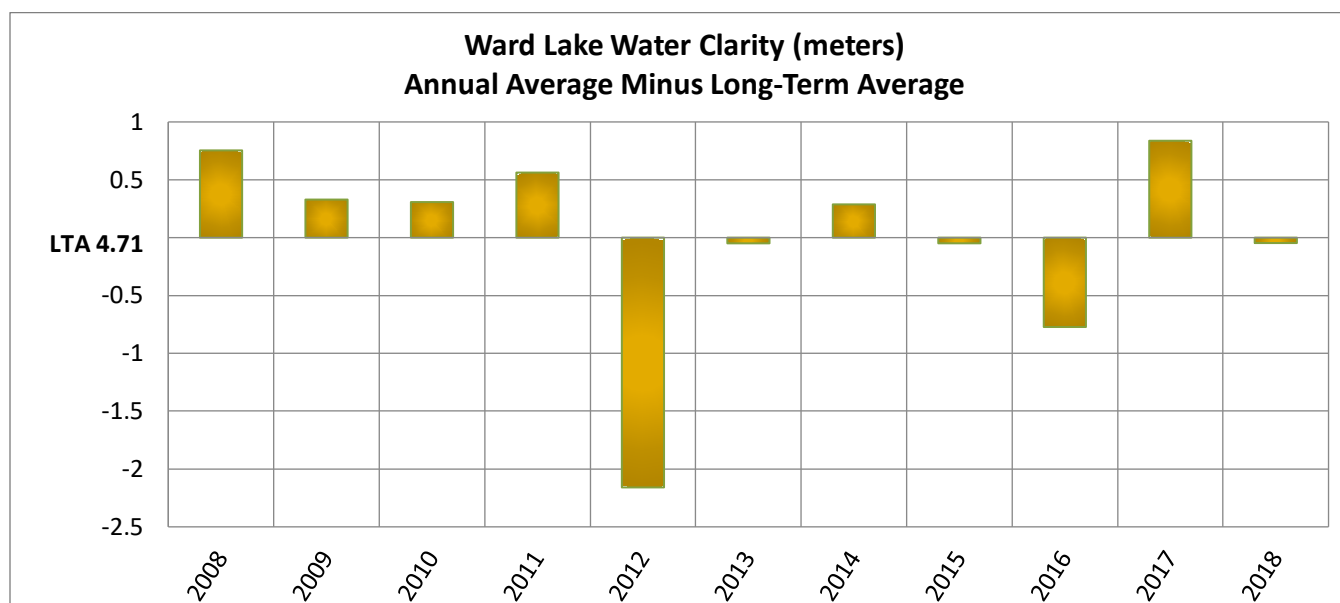


Figure 8. Transparency at WD1 compared to the long-term average (LTA).

The Seasonal Kendall test for 2008 to 2018 revealed a trend of reduced transparency (Figure 9) in July and August and increased water clarity in May. No significant ($p < 0.05$) trends existed in June and September to October.

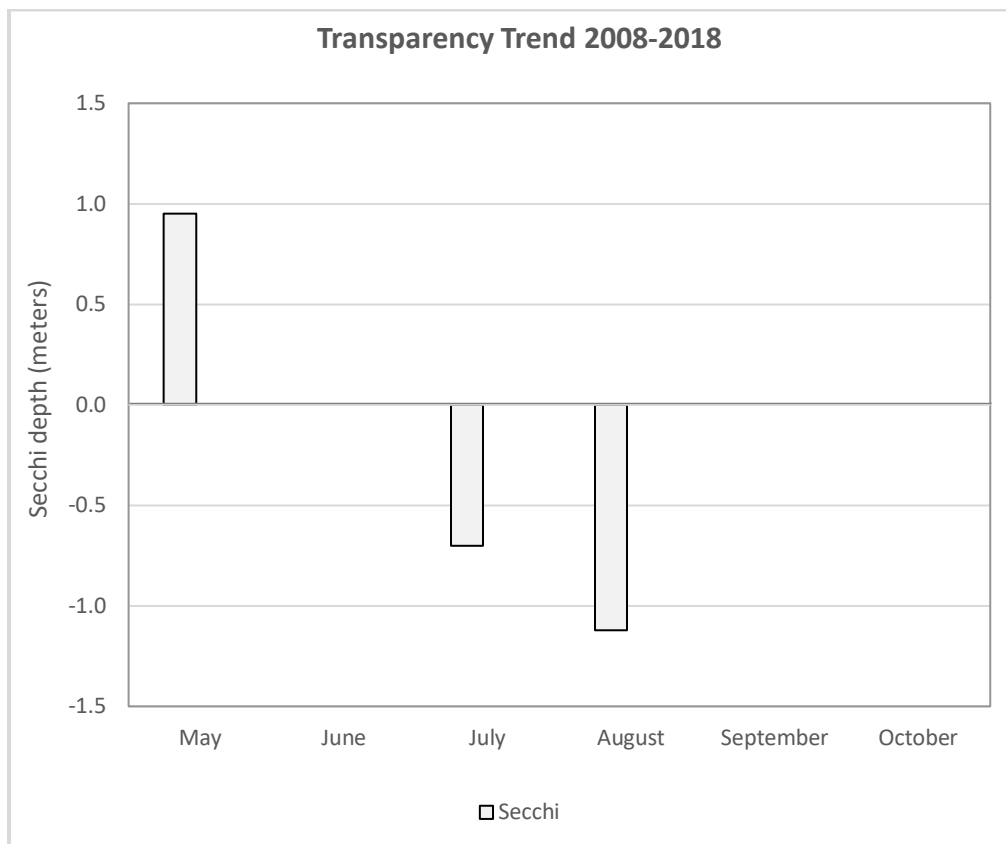


Figure 9. Transparency trend (+ or -) and magnitude of change (Theil-Sen estimator) for WDI from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p < 0.05$) for that time period.

Productivity

Pigments

Chlorophyll-a pigment is present in algae and cyanobacteria and is widely used to assess the abundance of phytoplankton in suspension. Phaeophytin is also a pigment, but it is not active in photosynthesis. It is a breakdown product of chlorophyll and is present in dead suspended material (Moss, 1967). Phaeophytin absorbs light in the same region of the spectrum as chlorophyll-a, and, if present can interfere with acquiring an accurate chlorophyll-a value. Phaeopigments have been reported to contribute 16 to 60% of the measured chlorophyll-a content (Marker et al., 1980). The ratio of chlorophyll-a to phaeophytin-a has been used as an indicator of the physiological condition of phytoplankton in the sample.

2018 Productivity Data

Figure 10 shows that the highest concentration of chlorophyll-a in 2018 occurred in July (7.5 $\mu\text{g/L}$), declining each successive month until October. The supply of oxygen in the epilimnion was highest in July (11.8 mg/L). The DO concentration was 8.9 mg/L in June and August and 8.5 in September and October. The ratio of chlorophyll-a to phaeophytin-a peaked in September.

Transparency was negatively correlated to productivity, as measured by the concentration of chlorophyll-a in the photic zone. Transparency was highest in June and again from September to October (Figure 7), when productivity was lower (Figure 10). Lake color was likely affected by changes in the algae and cyanobacteria communities; phytoplankton identification would provide more information about productivity and phytoplankton assemblages.

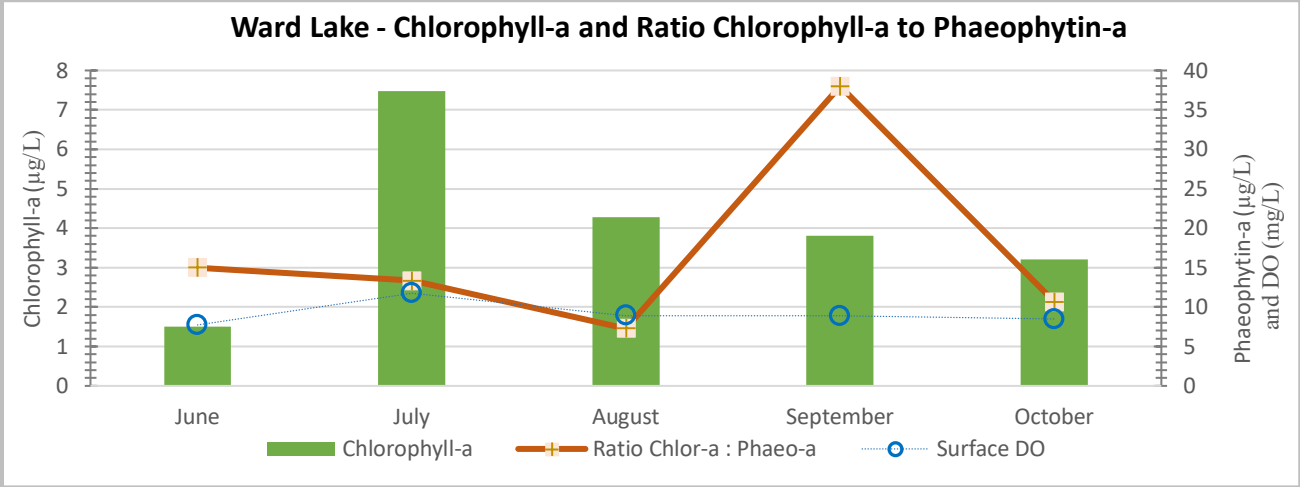


Figure 10. Chlorophyll-a concentration and ratio of chlorophyll-a to phaeophytin-a pigments in samples collected at WD1.

The Seasonal Kendall test for trends from 2008 to 2018 for chlorophyll-a concentration indicates a significant ($p < 0.05$) increase in chlorophyll-a concentration in August and decrease in June. No trends for chlorophyll-a concentration were detected for the remainder of the sampling season. Figure 11 shows the magnitude of change for all significant trends.

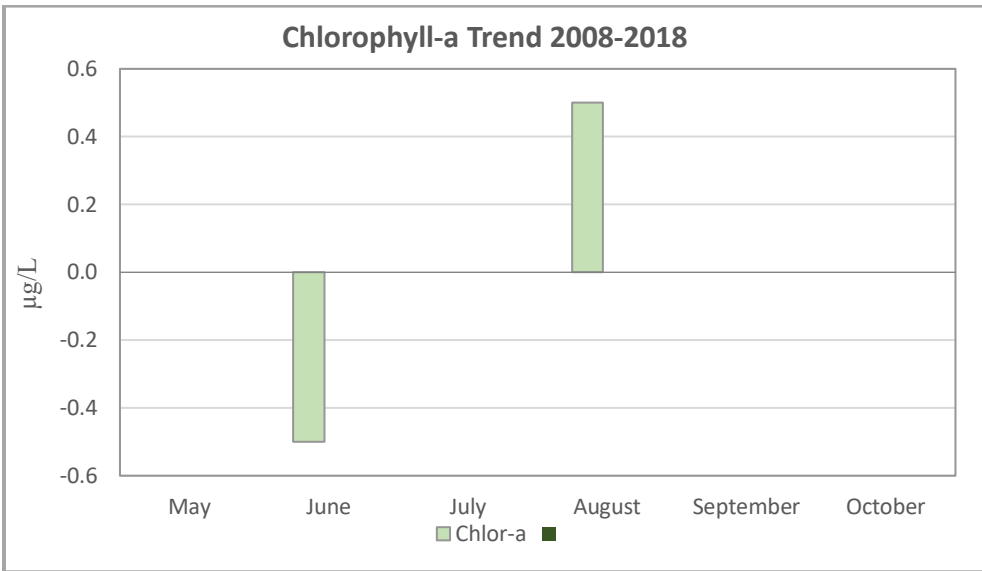


Figure 11. Chlorophyll-a trend (+ or -) and magnitude of change (Theil-Sen estimator) for WD1 from 2008 to 2018.

Nutrients

Surface Nutrients

Inorganic nutrients, particularly the elements phosphorus and nitrogen, are vital for algal nutrition and cellular constituents. Over-enrichment of surface waters leads to excessive production of autotrophs, especially algae and cyanobacteria (Correll, 1998). Figure 12 shows the total phosphorus (TP) and total nitrogen (TN) present in the surface waters at WD1.

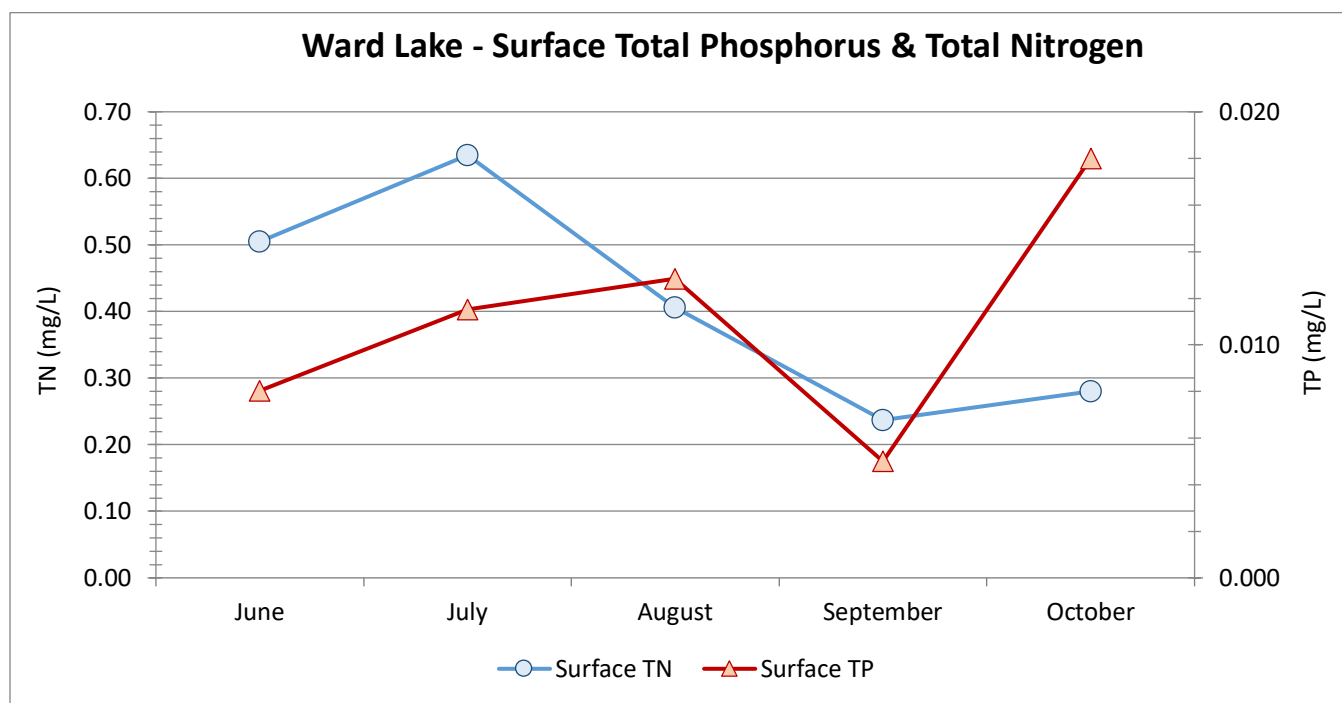


Figure 12. 2018 surface concentration of TP and TN at WD1 at Ward Lake.

The concentration of TP in surface waters was highest in August and October. TN was highest early in the summer, in June and July. The concentration of both nutrients was lowest at the surface in September. Thermal stratification reduced internal loading to surface waters from May to October; changes in the phytoplankton community and external sources likely affect nutrient levels during stratification.

Total Phosphorus

Compared to the rich supply of other elements required for nutrition or structure, phosphorus is the least abundant and most commonly limits biological productivity. Lakes in this region experience undesirable algae growth when the annual average surface phosphorus level reaches 0.030 mg/L (Gilliom, 1983). Washington adopted numeric action values in the state water quality standards to protect lakes. The action level for the Puget Lowlands ecoregion is 0.020 mg/L (WAC, 2019). Figure 13 displays the TP concentration at WD1.

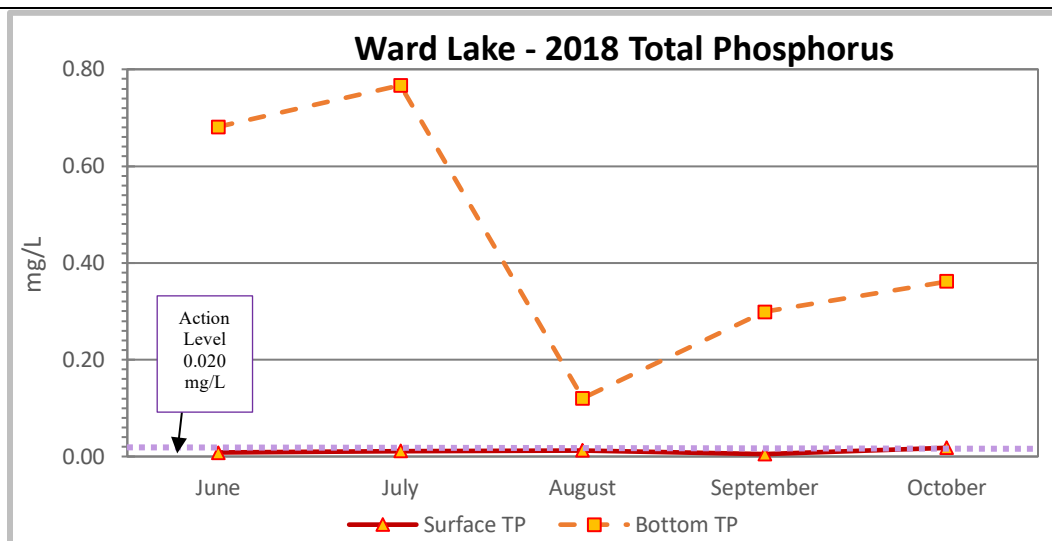


Figure 13. Concentration of Total Phosphorus at the surface and bottom of Ward Lake in 2018.

At WD1, the 2018 TP concentration was:

- TP Surface Mean 0.011 mg/L
- TP Surface Median 0.012 mg/L
- TP Surface Std Dev 0.004 mg/L
- TP Bottom Mean 0.446 mg/L
- TP Bottom Median 0.362 mg/L
- TP Bottom Std Dev 0.242 mg/L

The concentration was higher at the bottom because Ward Lake was thermally stratified during the summer. During stratification, the hypolimnion was mostly stagnant, not mixing with the oxygenated water above. At the same time, oxygen in the hypolimnion was consumed by redox processes like decomposition. Due to the lack of oxygen near the bottom, phosphorus stored in the sediments was released into the water column. This phosphorus accumulated in the hypolimnion, until turn-over later in the fall.

Figure 14 displays the average annual concentration of total phosphorus at the Ward Lake site from 2008 to 2018. The surface samples for total phosphorus have been below the state action level (purple line at 0.020 mg/L) every sample season except 2017. TP samples from the hypolimnion have been higher since 2017.

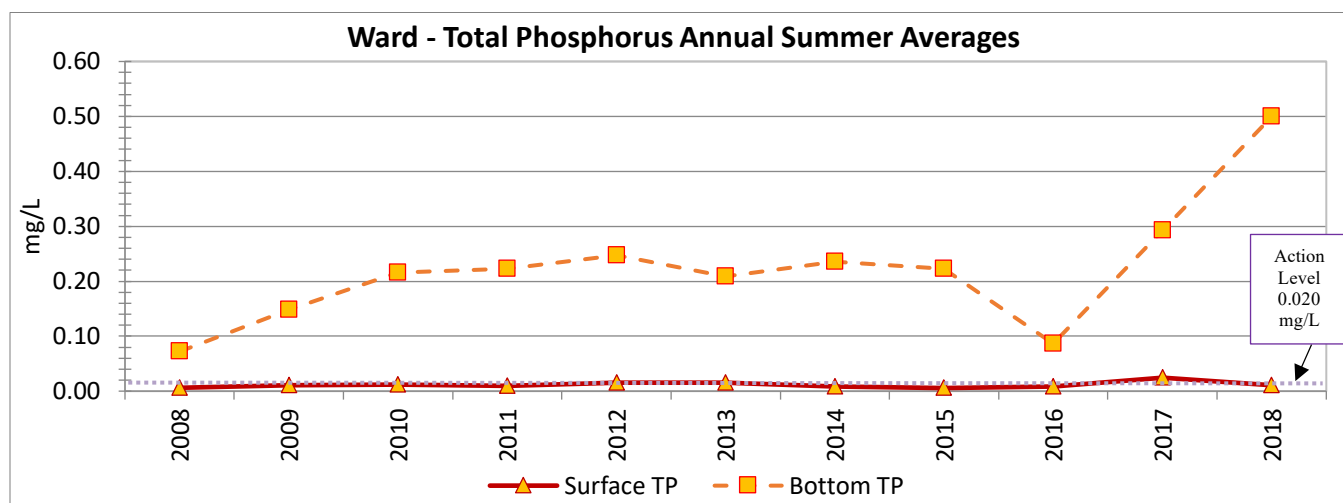


Figure 14. Average Annual Total Phosphorus at WD1 from 2008 to 2018.

At WD1, the TP concentration from 2008 to 2018 was:

- TP Surface Mean 0.012 mg/L
- TP Surface Median 0.011 mg/L
- TP Surface Std Dev 0.005 mg/L
- TP Bottom Mean 0.223 mg/L
- TP Bottom Median 0.223 mg/L
- TP Bottom Std Dev 0.108 mg/L

The Seasonal Kendall test (2008 to 2018) revealed significant trends (Figure 15) in surface water at WD1:

- Increase in July and August (0.001 mg/L)
- Decrease in June and September (0.001 mg/L)

No trends for TP concentration were detected for the remainder of the sampling season.

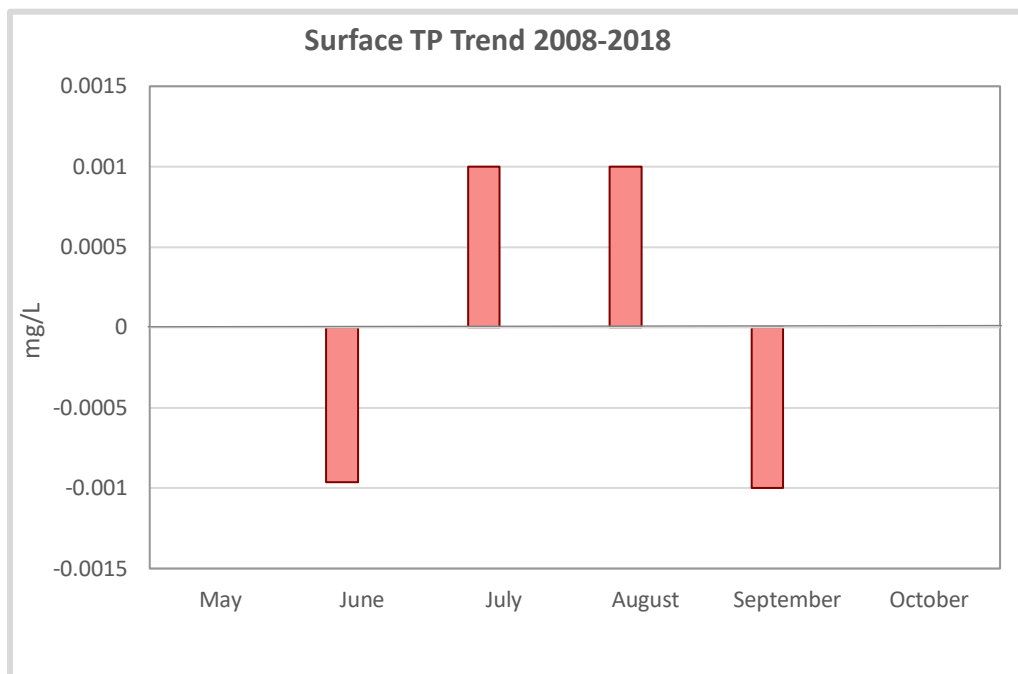


Figure 15. Surface TP trend (+ or -) and magnitude of change (Theil-Sen estimator) for WD1 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p < 0.05$) for that time period.

Nitrogen

Nitrogen is also limiting to lake productivity, but supplies are more readily augmented by inputs from external sources. The State of Washington does not have established action or cleanup levels for surface total nitrogen. In 2018, the TN concentration was:

- TN Surface Mean 0.413 mg/L
- TN Surface Median 0.406 mg/L
- TN Surface Std Dev 0.146 mg/L
- TN Bottom Mean 1.746 mg/L
- TN Bottom Median 1.760 mg/L
- TN Bottom Std Dev 0.730 mg/L

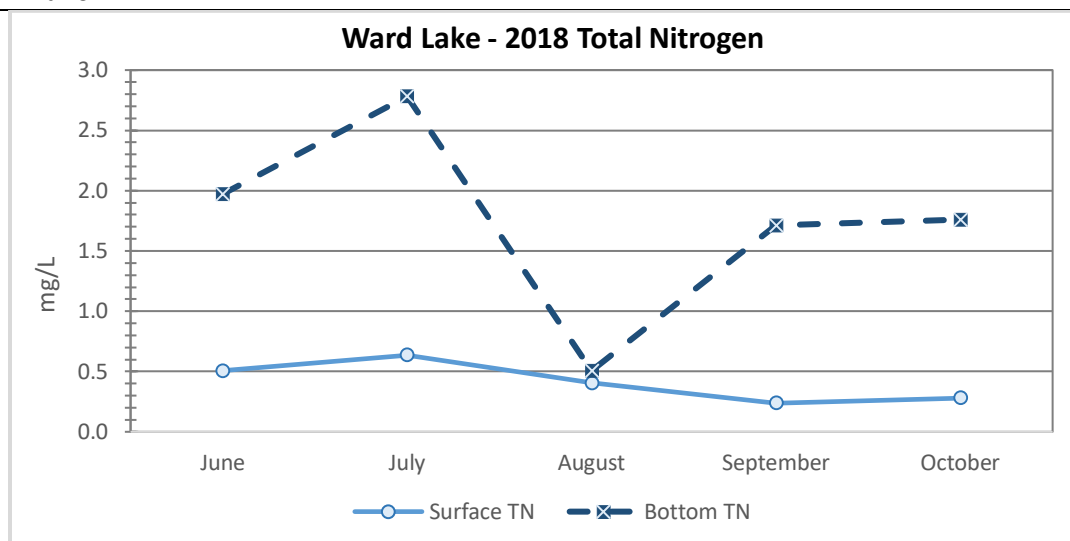


Figure 16. Concentration of Total Nitrogen at the surface and bottom at the Ward Lake site WDI in 2018.

The TN concentration was higher at the bottom because the hypolimnion was hypoxic during stratification; ammonia-nitrogen was released from the bottom sediments and accumulated in the hypolimnion. Figure 16 shows the 2018 TN concentrations for the Ward Lake site.

Figure 17 displays the average annual concentrations for total nitrogen from 2008 to 2018. The mean/median TN concentration for the period of record was:

- TN Surface Mean 0.371 mg/L
- TN Surface Median 0.313 mg/L
- TN Surface Std Dev 0.169 mg/L
- TN Bottom Mean 1.182 mg/L
- TN Bottom Median 1.197 mg/L
- TN Bottom Std Dev 0.342 mg/L

The surface TN concentration exceeded the mean in 2012 and 2018. The bottom concentration exceeded the mean 2010 to 2013 and 2017 to 2018.

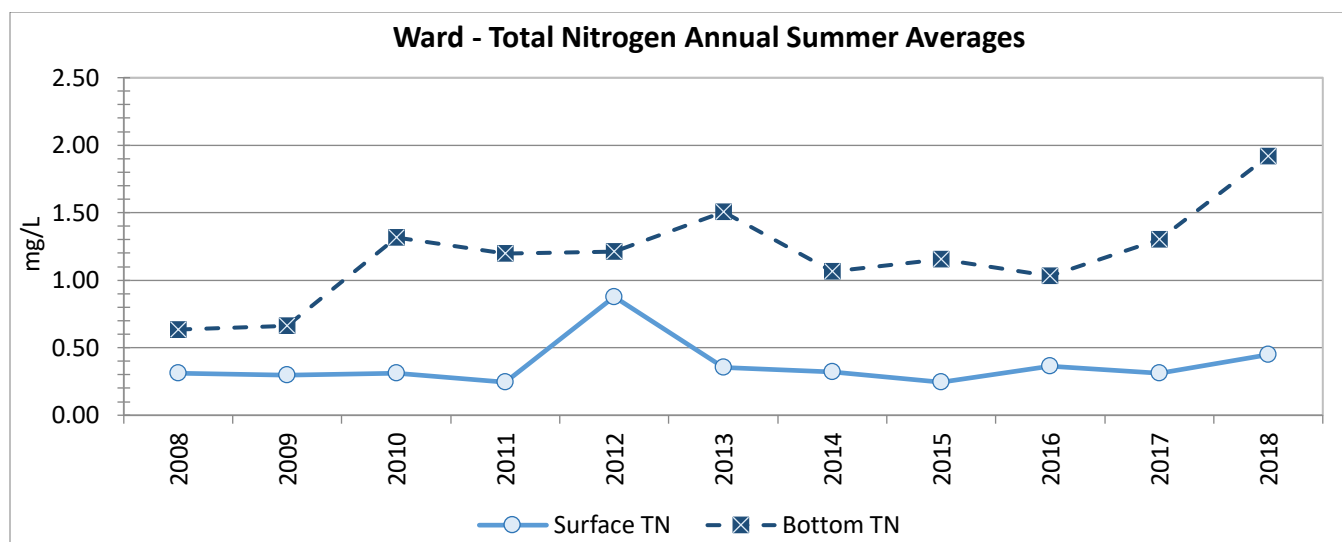


Figure 17. Average Annual Total Nitrogen at WDI from 2008 to 2018.

The Seasonal Kendall test shows a significant ($p < 0.05$) trend of surface TN concentrations (Figure 18):

- Downward trend in May (0.065 mg/L)
- Upward trend in June (0.018 mg/L), July (0.066 mg/L) and August (0.033 mg/L)

No significant trend was detected for September and October.

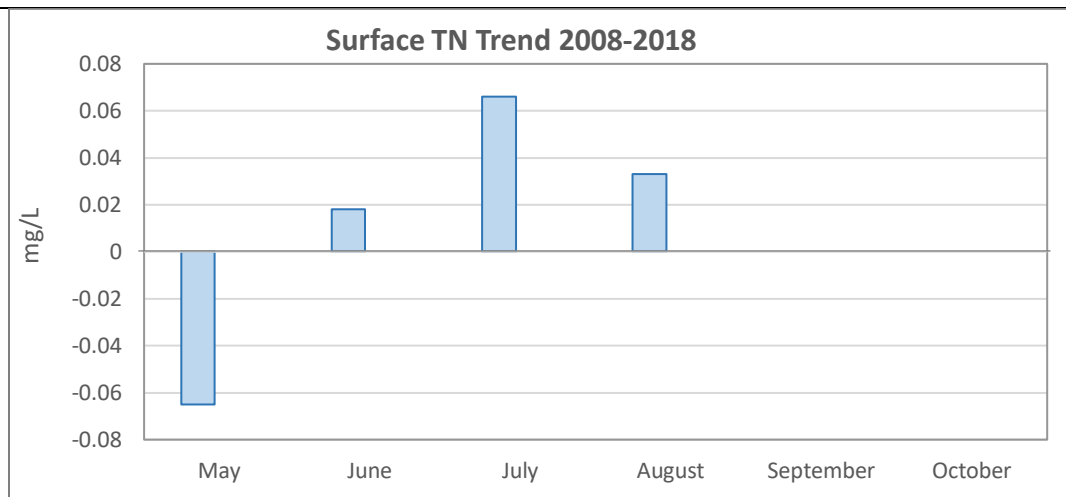


Figure 18. Surface TN trend (+ or -) and magnitude of change (Theil-Sen estimator) for WD1 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p < 0.05$) for that time period.

Nitrogen to Phosphorus Ratios

To prevent dominance by cyanobacteria (blue-green algae), the TN to TP ratio (TN:TP) should be above 10:1 (Moore and Hicks, 2004). Figure 19 shows the TN to TP ratio at WD1. Ward Lake has been phosphorus limited since 2008.

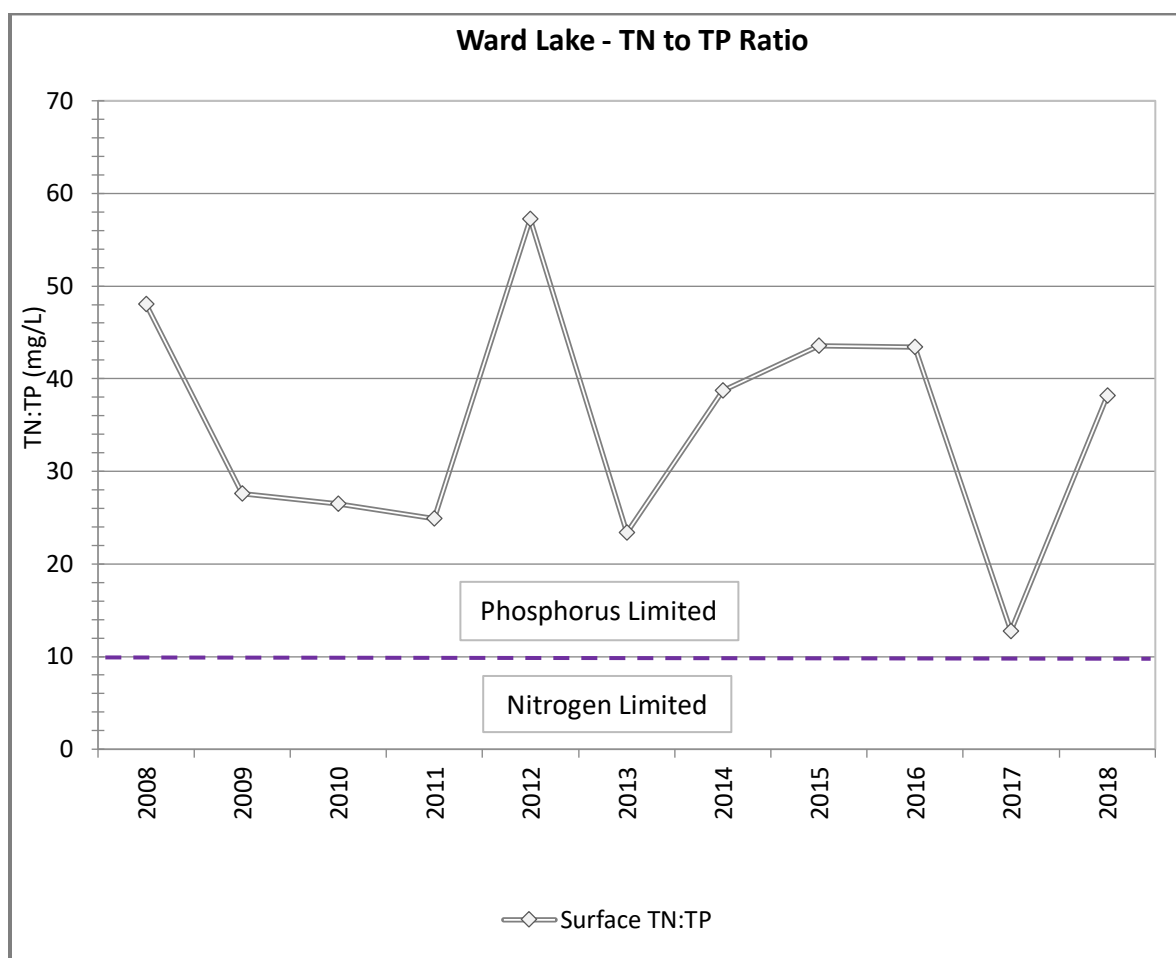


Figure 19. TN:TP at the Ward Lake site WD1 from 2008 to 2018.

Trophic State Indices (TSI)

The most commonly used method to classify lakes is called the Carlson's Trophic State Index (Carlson, 1977). Based on the productivity, this method uses three index variables: transparency (Secchi disk depth), chlorophyll-a (productivity), and phosphorus concentrations (nutrient enrichment). Table 3 provides the index values for each trophic classification.

Table 3. Trophic State Index variables.

TSI Value	Trophic State	Productivity
0 to 40	oligotrophic	Low
41 to 50	mesotrophic	Medium
> 50	eutrophic	High

For the Ward Lake site, the 2018 TSI results were:

- Chlorophyll-a: 46 mesotrophic
- Total Phosphorus: 39 oligotrophic
- Secchi Disk: 38 oligotrophic

The average of the three TSI variables is 41, which categorizes the Ward Lake site as mesotrophic in 2018. Based on the chlorophyll-a concentration, Ward Lake has been mesotrophic 91% of sample seasons -- every year since 2009. The TSI value for total phosphorus classified the Ward Lake site as mesotrophic 27% of sample seasons -- in 2011, 2012, and 2017. For water transparency, the Ward Lake site was classified as oligotrophic 91% of sample seasons; this site was classified as mesotrophic once in 2012 based on reduced water clarity.

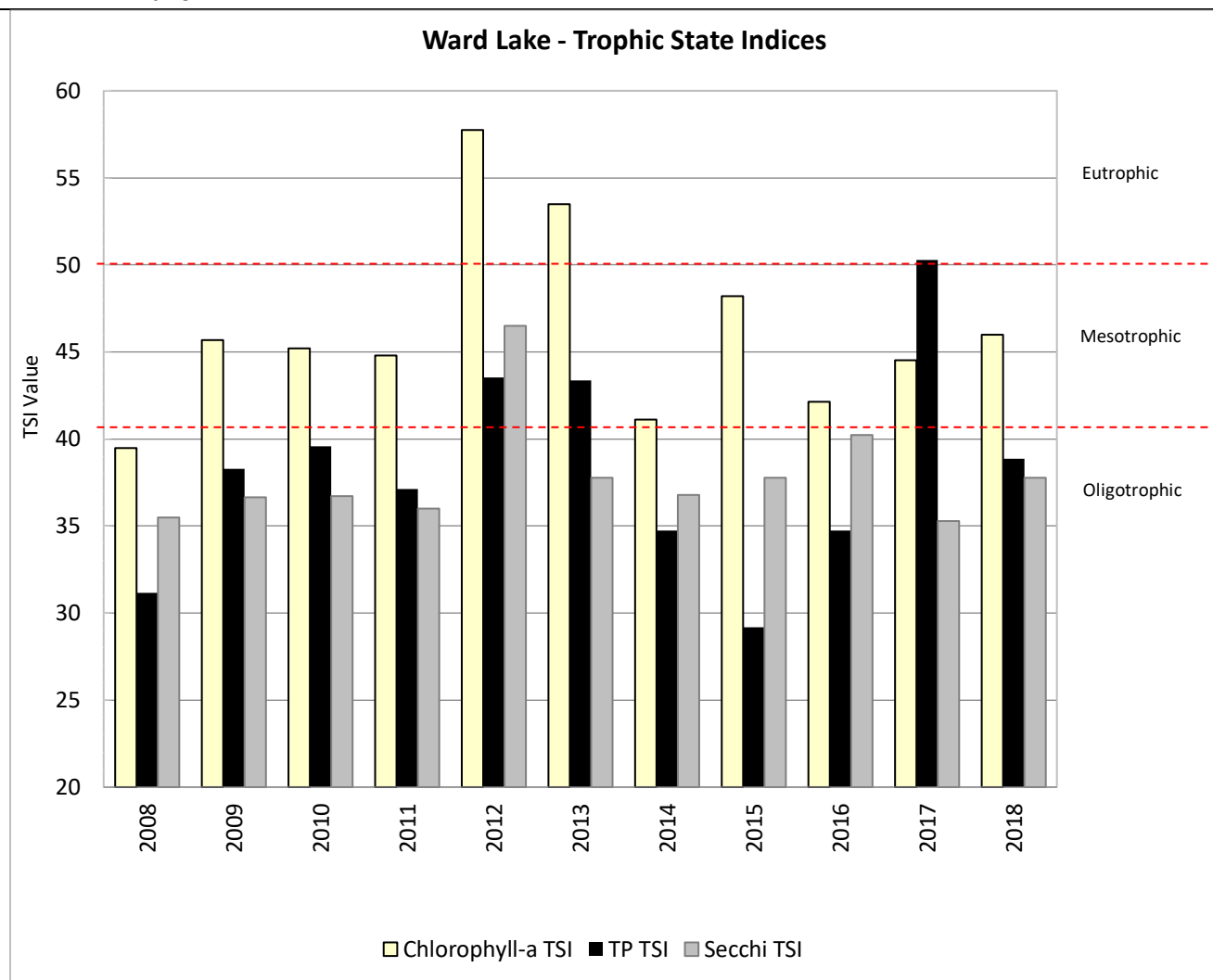


Figure 20. Ward Lake Trophic State Index from 2008 to 2018.

The Mann Kendall test (2008 to 2018) reveals significant increasing trend ($p < 0.05$) for the Secchi depth TSI value (Sen slope 1.01). The upward trend of the Secchi depth TSI indicates a reduction in water clarity over the last decade. No trend was found for chlorophyll-a or TP concentration TSI scores (Appendix C).

SUMMARY

Thermal Stratification and Increased Temperature Trends

In 2018, the water column at Ward Lake was thermally stratified from June to October. The trend from 2008 to 2018 was increased temperature in surface water at WD1 from May to August. In September and October, the trend changed to a significant downward trend toward lower temperatures.

Water Clarity and Transparency Trends

In 2018, the mean transparency was 4.7 meters, marginally lower (0.05 meter) than the long-term average. Transparency was inversely related to the concentration of chlorophyll-a. Transparency in 2018 was highest in October (6.9 meters) and September (6.3 meters) and lowest in July and August (2.6 to 2.8 meters). The trend from 2008 to 2018 was increased transparency in May and reduced water clarity in July and August.

Chlorophyll-a and Lower Productivity Trends

In 2018, the mean concentration of chlorophyll-a was 4.1 $\mu\text{g/L}$. The highest productivity (7.5 $\mu\text{g/L}$) was in July and August (4.3 $\mu\text{g/L}$) and the lowest was in June (1.5 $\mu\text{g/L}$). The DO concentration was highest (11.8 mg/L) in

Ward Lake 2018

July, when productivity peaked. Trend analysis indicates a significant downward trend in June and upward trend in August. The magnitude of the trends was $\pm 0.5 \mu\text{g/L}$ for the decade.

Volunteers reported algal blooms with surface scum from May until June 2018. TCEH sampled Ward Lake on four dates during this period and had samples analyzed for algal toxins. None of the samples had toxin concentrations over the Washington State advisory levels. Since 2010, sixteen algae samples have been collected at Ward Lake. No samples have had anatoxin-a, microcystin, saxitoxin, or cylindrospermopsin above Washington State advisory levels.

Nutrients and Trends

The average TP concentration was 0.011 mg/L at the surface, below the action level (0.020 mg/L) for lower mesotrophic lakes in the Puget Sound Lowlands ecoregion. TP at the surface was highest in October (0.018 mg/L) and August (0.013 mg/L) and lowest in September (0.005 mg/L). The Seasonal Kendall test (2008 to 2018) reveals significant trends (Sen slope 0.001 mg/L) for TP in surface water:

- Increased TP concentration in July and August
- Decreased TP concentration in June and September

No significant trends were identified in May and October.

The average surface TN concentration was 0.413 mg/L in 2018. The highest concentration occurred in July (0.635 mg/L) and the lowest in September (0.237 mg/L). The Seasonal Kendall test indicates a significant ($p < 0.05$) trends of surface TN concentrations:

- Decreased TN concentration in May (0.065 mg/L)
- Increased TN concentrations in June (0.018 mg/L), July (0.066 mg/L), and August (0.033 mg/L)

No significant trend was detected at WD1 in September and October.

Classified as Mesotrophic

In 2018, the Ward Lake site WD1 was classified as mesotrophic based on an average of the three TSI variables. Since 2008, the TSI value has been in the mesotrophic range: 91% of sample seasons for chlorophyll-a, 27% for TP, and 9% for Secchi depth. Ward was classified as eutrophic twice for chlorophyll-a (2011-2012) and once for TP (2017). The trend for Secchi depth TSI from 2008 to 2018 was up (1 TSI value), which indicates a decline in water clarity. There was no trend for chlorophyll-a and TP TSI scores.

CONTACTS AND DATA SOURCES:

Thurston County Community Planning and Economic Development
(360) 786-5549 or
<https://www.thurstoncountywa.gov/planning/Pages/water-gateway.aspx>

Thurston County Environmental Health
(360) 867-2626 or
<https://www.co.thurston.wa.us/health/ehrp/annualreport.html>
For digital data contact the main telephone number or sarah.ashworth@co.thurston.wa.us

For questions, corrections, and/or suggestions, contact the author of the 2018 report:
renee.fields@co.thurston.wa.us

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Appendices

Appendix A. Raw Data

Appendix B. Quality Assurance/Quality Control

Appendix C. Trends

Appendix D. Toxic Algae

Appendix A. Raw data

Table A-1 Raw data collected at the Ward Lake site WD1.

Date	Time	Bottom Depth (meters)	Secchi (meters)	Water Color	Bottom Sample Depth (meters)	Surface TP (mg/L)	Bottom TP (mg/L)	Surface TN (mg/L)	Bottom TN (mg/L)	Chl a (µg/L)	Phae a (µg/L)	Lake Notes
5/1/2018	-	-	-	-	-	-	-	-	-	-	-	Ward Lake not sampled 5/2018 due to boat ramp repairs
6/26/2018	15:30	18.80	4.65	3	18.3	0.008	0.681	0.505	1.972	1.5	<0.1	
7/17/2018	15:13	19.35	2.60	6	18.8	0.012	0.749	0.689	2.644	7.5	0.4	
7/17/2018	-	-	-	-		0.011	0.785	0.580	2.919	7.5	0.7	QA
8/14/2018	15:50	20.10	2.85	3	19.6	0.013	0.121	0.406	0.506	4.3	0.6	
9/18/2018	9:35	16.00	6.32	2	-	0.005	0.299	0.237	1.710	3.8	<0.1	
10/23/2018	9:41	14.55	6.90	2	14.5	0.018	0.362	0.280	1.760	3.2	0.3	

Appendix B. Quality Assurance/Quality Control

Table B-1 provides the amount of instrument drift for specific conductivity, dissolved oxygen (collected with optical sensor), and pH. The temperature thermistor was checked against a NIST thermometer on May 31, 2018 and difference was 0.04° C.

Table B-1. Instrument drift for Ward Lake sample days in 2018.

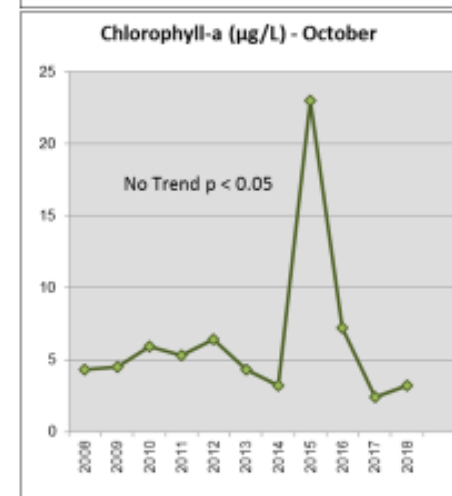
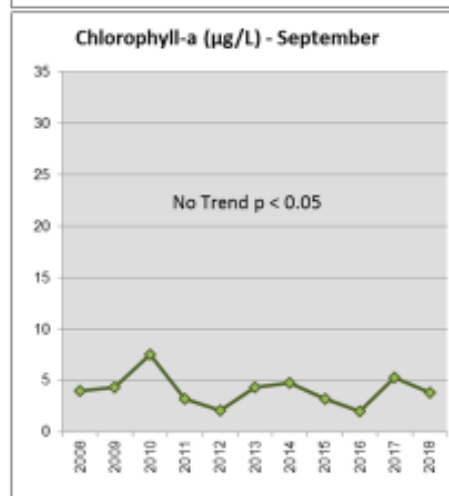
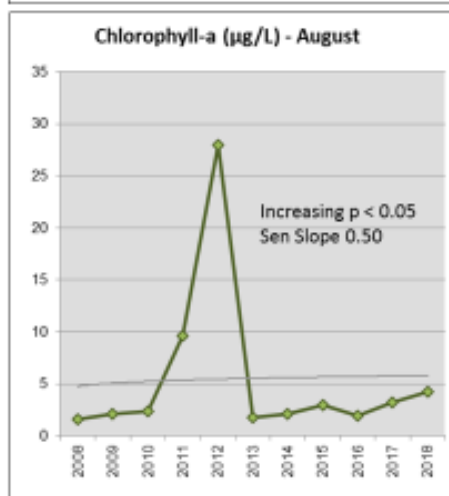
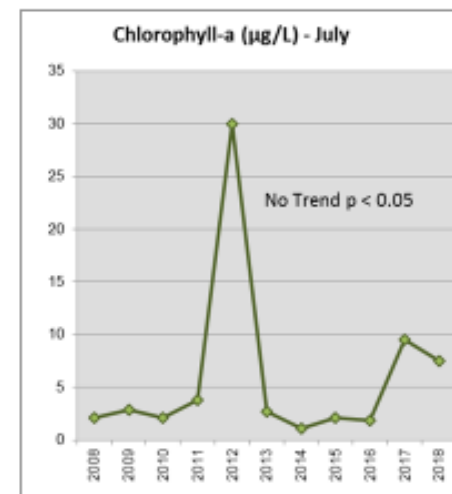
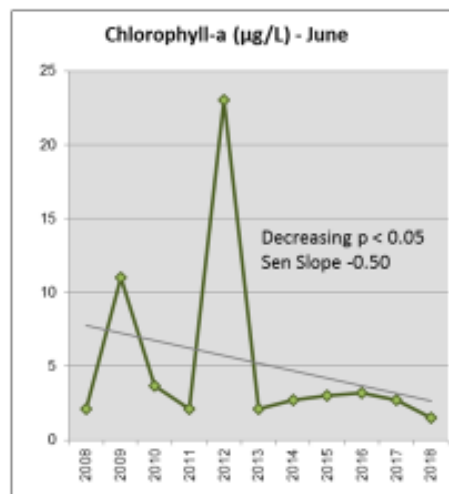
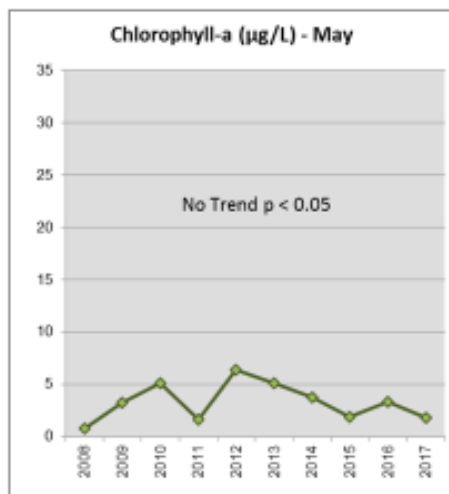
Post-Check Date	SPC (μS/cm)	ODO (% sat)	pH (std units)
6/27/2018 7:28	-3.3	-0.85	0.07
7/18/2018 7:45	2.2	-0.82	0.11
8/15/2018 15:40	1.5	-0.01	0.17
9/19/2018 8:20	0.1	-0.29	-0.05
10/24/2018 7:40	-0.1	-0.03	0.01
Mean Percent Difference	0.01	-0.36	0.78

Table B-2. Precision of field replicates.

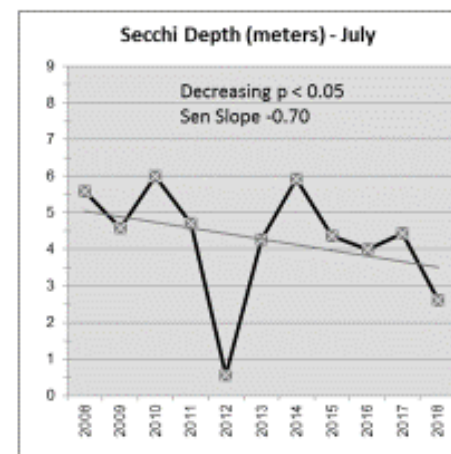
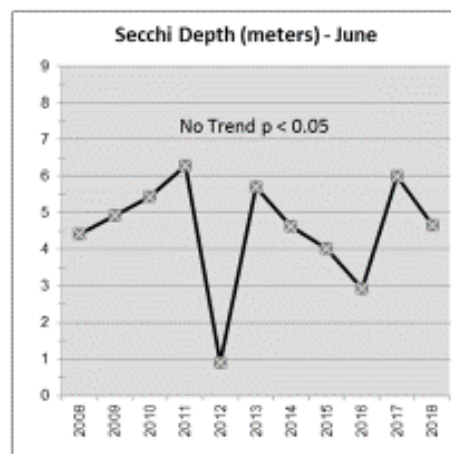
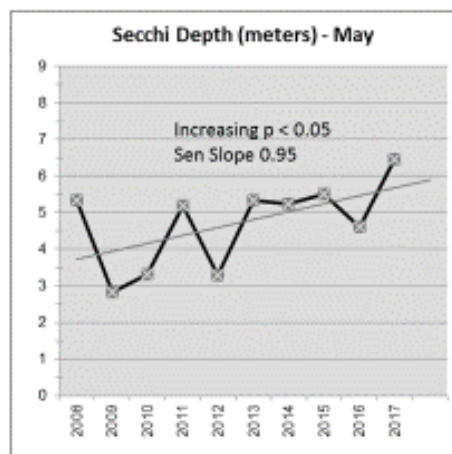
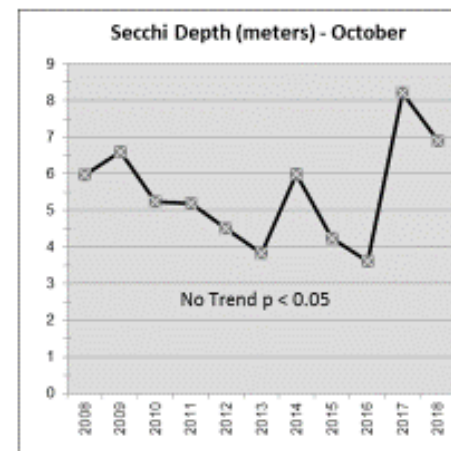
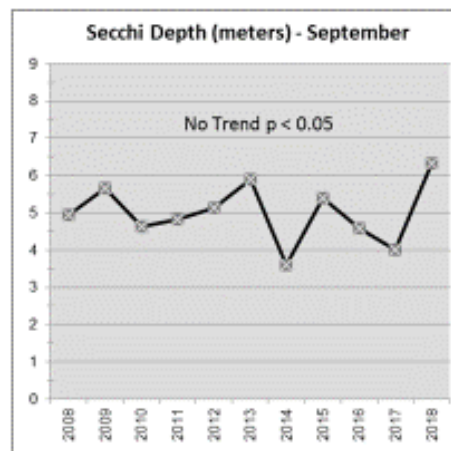
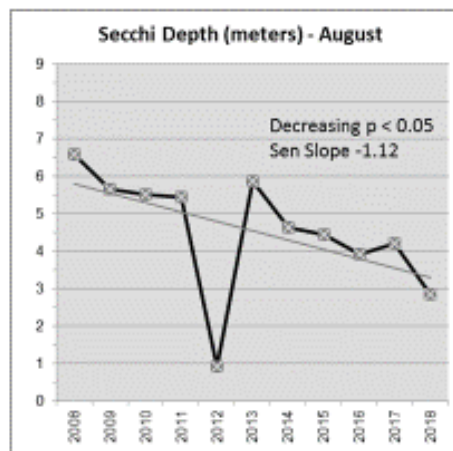
Site	Date/Time	sample	field replicate	Relative Percent Difference
WD1 Surface TP	7/17/2018 15:13:00 PM	0.012	0.011	1.280
WD1 Bottom TP	7/17/2018 15:13:00 PM	0.749	0.785	4.724
WD1 Surface TN	7/17/2018 15:13:00 PM	0.689	0.580	17.164
WD1 Bottom TN	7/17/2018 15:13:00 PM	2.644	2.919	9.896
WD1 Chlor-a	7/17/2018 15:13:00 PM	7.48	7.48	0.000
WD1 Phae-a	7/17/2018 15:13:00 PM	0.37	0.75	66.667

Appendix C. Trends

Ward Lake

2008-2018
TrendsChlorophyll-a
($\mu\text{g/L}$)

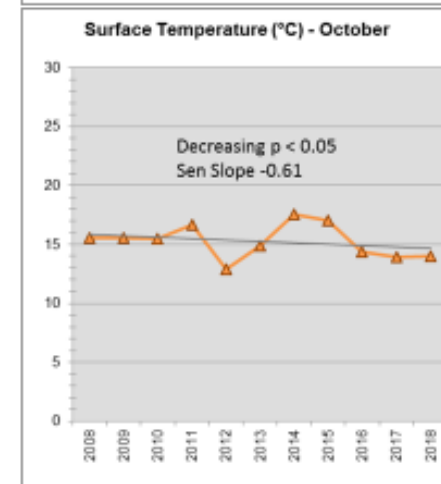
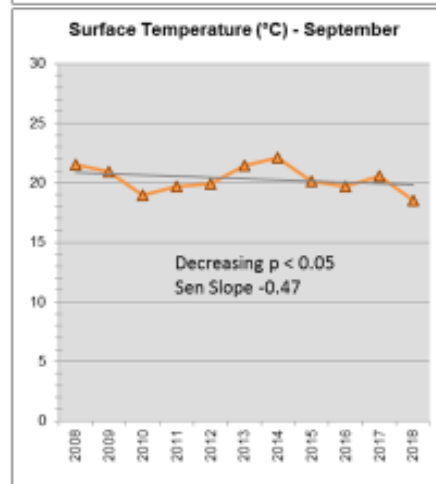
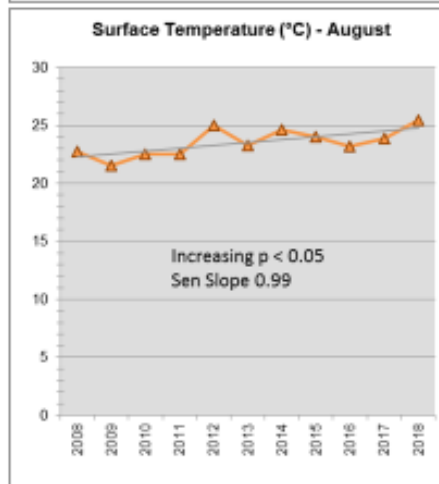
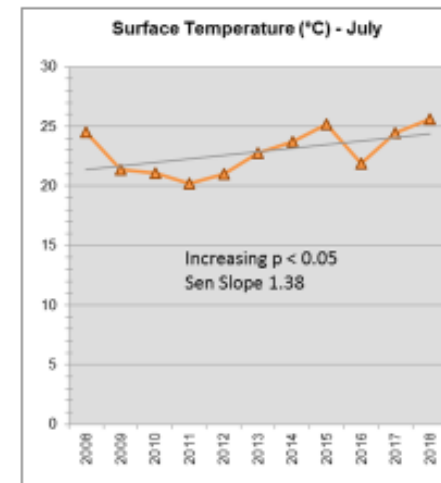
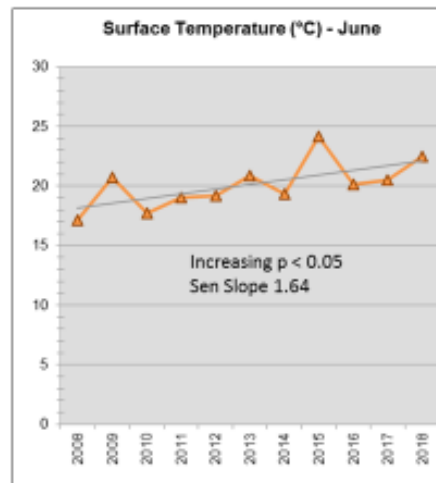
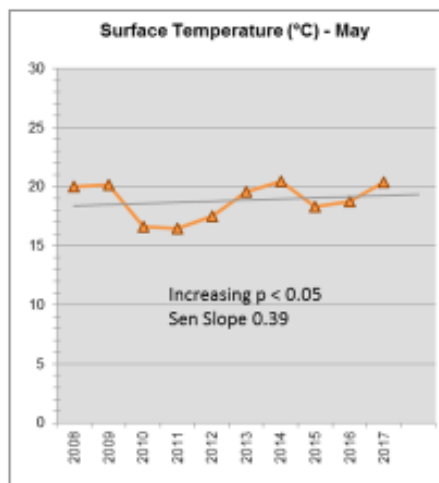
Ward Lake

2008-2018
Trends

Secchi Depth
(meters)


Ward Lake

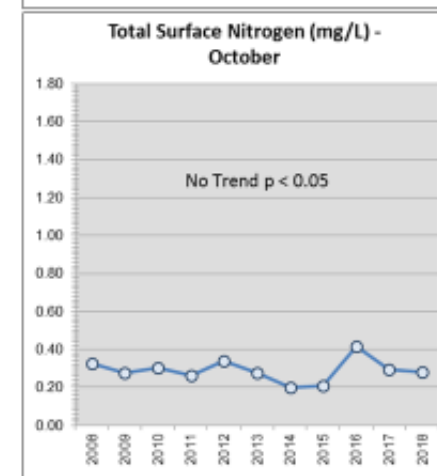
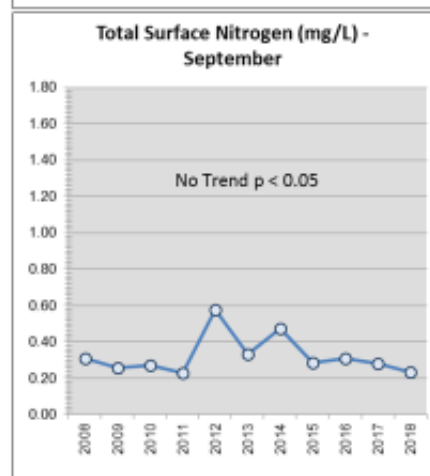
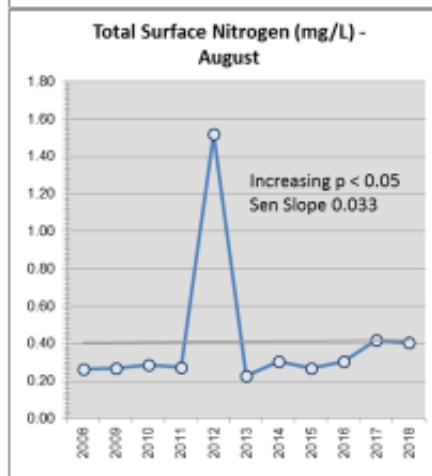
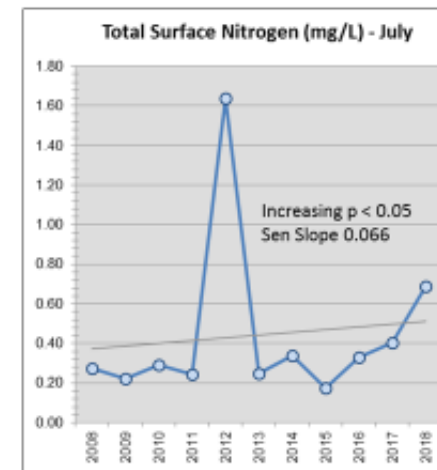
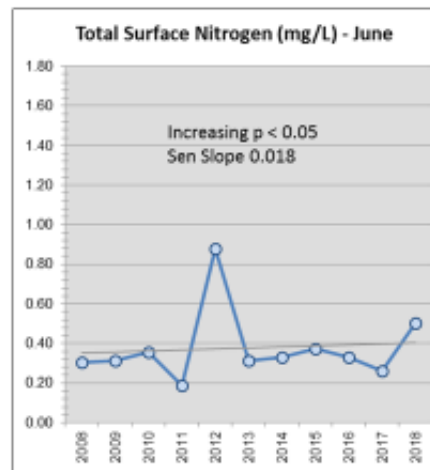
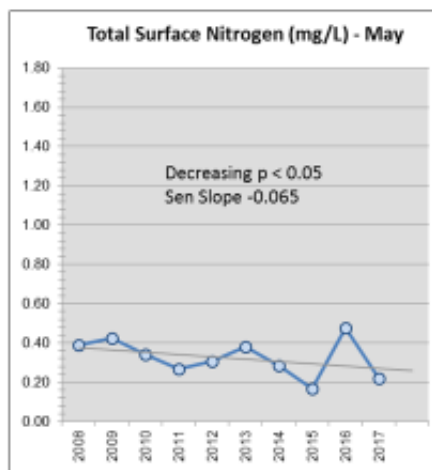
2008-2018
Trends

Surface Water
Temperature
(°C)



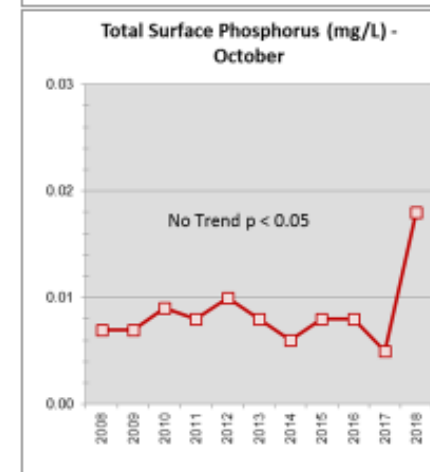
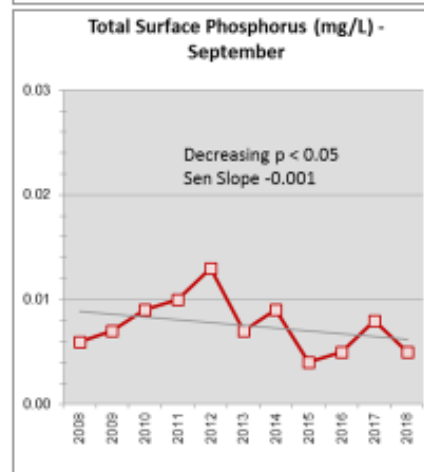
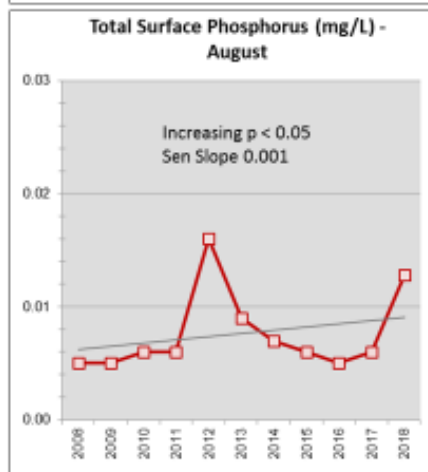
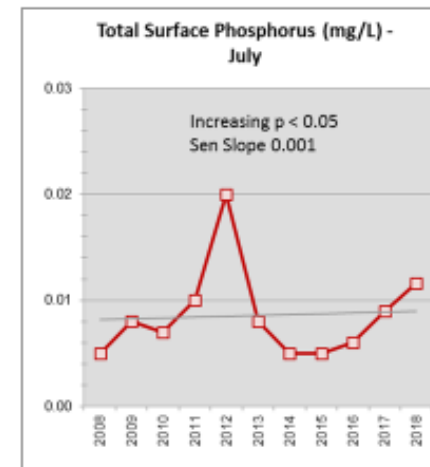
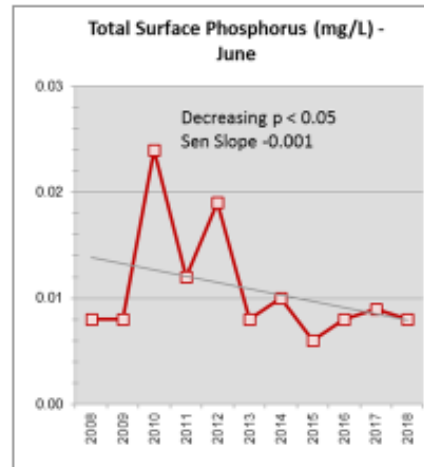
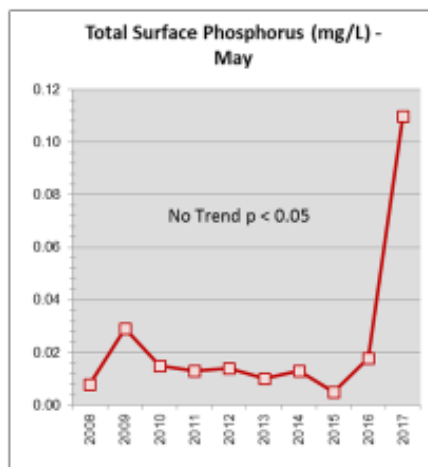
Ward Lake

2008-2018
Trends

Surface Total
Nitrogen
(mg/L)


Ward Lake

2008-2018
Trends

Surface Total
Phosphorus
(mg/L)


Ward Lake

2008-2018
Trends

TSI values

