CHAIN LAKE

REPORT DESCRIPTION

This report is an update on the health of Chain Lake based on water quality data collected from 1993 through 2016 by citizen volunteers or Snohomish County Surface Water Management (SWM) staff. For additional background on the information provided here or to find out more about Chain Lake, please visit www.lakes.surfacewater.info or call SWM at 425-388-3464.

LAKE DESCRIPTION

Chain Lake is a 39-acre lake located a few miles north of Monroe. The lake is fed by seasonal streams and drains west to French Creek. Chain Lake is relatively shallow, with a maximum depth of 6.5 meters (21 feet) based on a bathymetric map developed by SWM in 2003.

Chain Lake has a large watershed, which is the land area that drains to the lake. This means that there is a high potential for negative impacts to the lake from watershed pollution. Although there are only a few homes around the lake shore, there has been accelerating development of new residential subdivisions within the watershed in recent years.

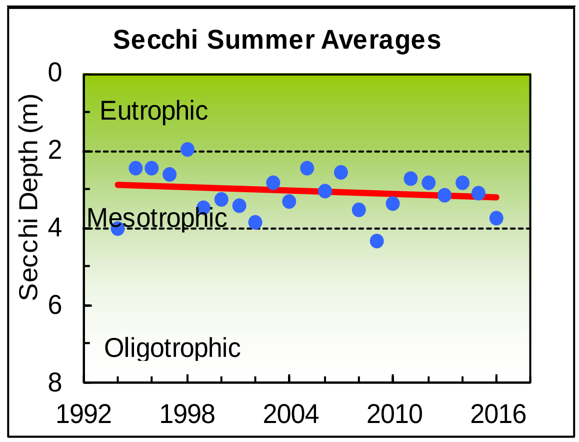
LAKE CONDITIONS

The following graphs illustrate the summer averages and trend lines (in red) for water clarity, total phosphorus, and chlorophyll *a* for Chain Lake. Please refer to the table at the end of the report for long-term averages and for averages and ranges for individual years.

Water Clarity

The water clarity of a lake, measured with a Secchi disk, is a reading of how far one can see into the water. Water clarity is affected by the amount of algae and sediment in the lake, as well as by water color. Lakes with high water clarity usually have low amounts of algae, while lakes with poor water clarity often have excessive amounts of algae.

Water clarity in Chain Lake is moderate, with a long-term 1993 to 2016 summer average of 3.1 meters (10 feet). Water clarity averages have been highly variable from year to year, ranging between 2.0 and 4.4 meters. Between 1993 and 2016, there has been no statistically significant trend in water clarity readings.



Water Color

The color of lake water affects water clarity and the depths at which algae and plants can grow. In many lakes, the water is naturally brown, orange, or yellow. This darker color comes from dissolved humic compounds from surrounding wetlands and does not harm water quality. Measurements of true water color provide clues to changes in water clarity. True water color is only the color from dissolved materials and not of the color of algae or sediment suspended in the water.

The water color of Chain Lake averaged 30 pcu (platinum-cobalt color units) in 2010 – 2011, which indicates a moderate amount of color in the lake water. This is similar to the water color in 1994 – 1995, when the average was 27 pcu. Moderately dark water color limits the amount of light in the lake, reducing the water clarity and suppressing some of the algae growth.

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Temperature

The temperature of lake water changes with the seasons and varies with depth. During spring and summer, the sun warms the upper waters. Because warmer water is less dense, it floats above the cooler, denser water below. The temperature and density differences create distinct layers of water in the lake, and these layers do not mix easily. This process is called stratification and occurs during the warm months. The warm, upper water layer is called the epilimnion. The colder, darker bottom zone is called the hypolimnion. These layers will stay separated until the fall when the upper waters cool, the temperature differences decrease, and the entire lake mixes, or turns over.

In June through September of 2016, temperatures were measured at each meter throughout the Chain Lake water column. The temperature data show that the lake was beginning to stratify thermally in June and maintained strong stratification through August (see graph). This means that there was a large temperature difference between the warm upper waters and the cool bottom waters, and mixing did not occur between these layers. By June the upper waters were already 14°F warmer than the lower waters. The surface waters reached a temperature peak in August of 75°F (24.3°C) and then began cooling down in September. At the same time, bottom water temperatures saw little change, from 53-68°F (11.5-14.5°C). Into the fall, the surface waters will continue to cool until the temperatures are almost equal from top to bottom. As the stratification weakens, the lake water will turn over or mix. The lake will stay mixed during the winter until springtime, when the upper waters begin to warm again.

Dissolved Oxygen

Oxygen dissolved in the water is essential for life in a lake. Most of the dissolved oxygen comes from the atmosphere. Like temperature, dissolved oxygen levels vary over time and with depth. During the warm months, the upper waters receive oxygen from the atmosphere, but the lower waters cannot be replenished with oxygen because of the separation between water layers. Meanwhile, bacteria in the lake bottom are consuming oxygen as they decompose organic matter. Eventually oxygen is depleted in the bottom waters. Low dissolved oxygen in the bottom waters can lead to a release of nutrients from the lake sediments.

In June through September of 2016, dissolved oxygen was measured at each meter throughout the Chain Lake water column (see graph). In June, oxygen levels in the lower waters were much lower than in the upper waters. By August, there was essentially no dissolved oxygen left in the lower waters. However, from August through September, there was actually an increase in dissolved oxygen around 12 feet deep. This indicates vigorous algae growth at that depth which added oxygen to the water. During the stratified summer period, oxygen in the lower waters is consumed by the decomposition of organic material within the lake. Since the lake is strongly stratified, the oxygen is not replenished by the overlying oxygen-rich upper waters or by the atmosphere. In the fall and winter, when the upper waters began to cool, dissolved oxygen from the atmosphere began to mix farther down into the lake. By mid-fall, the lake will be fully mixed and dissolved oxygen levels will again be nearly equal from the top to the bottom of the lake.

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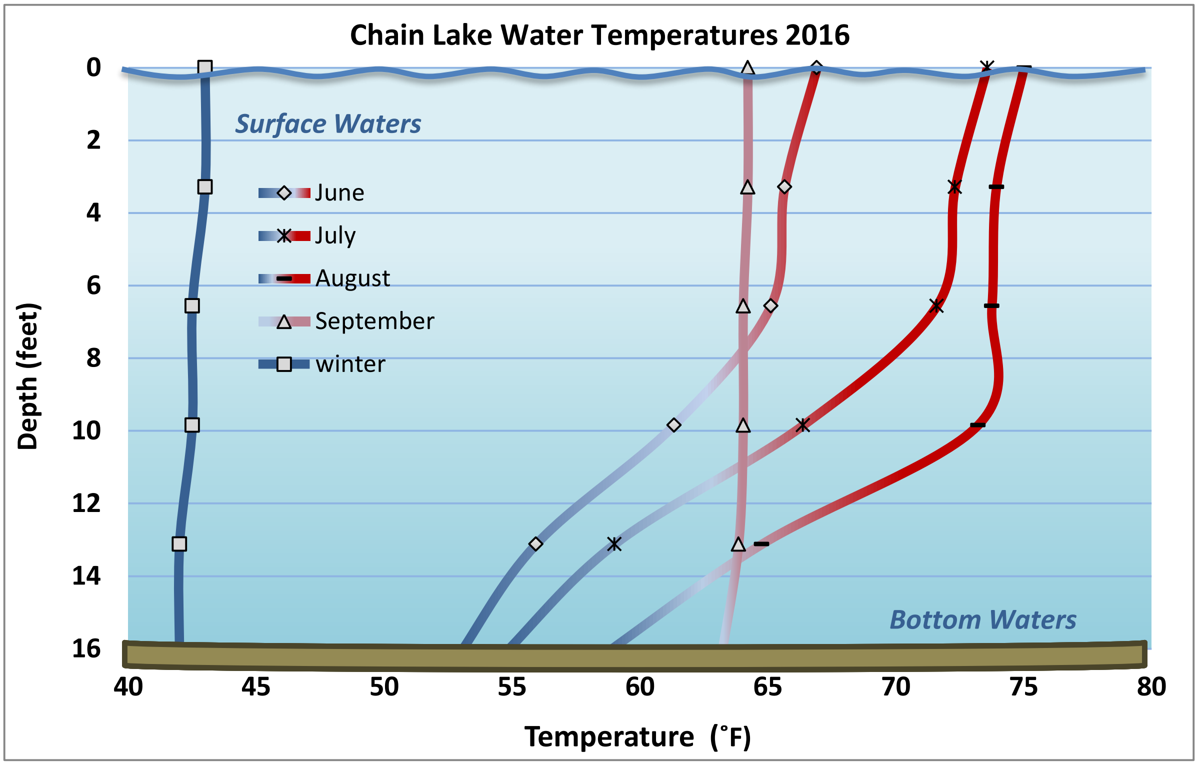
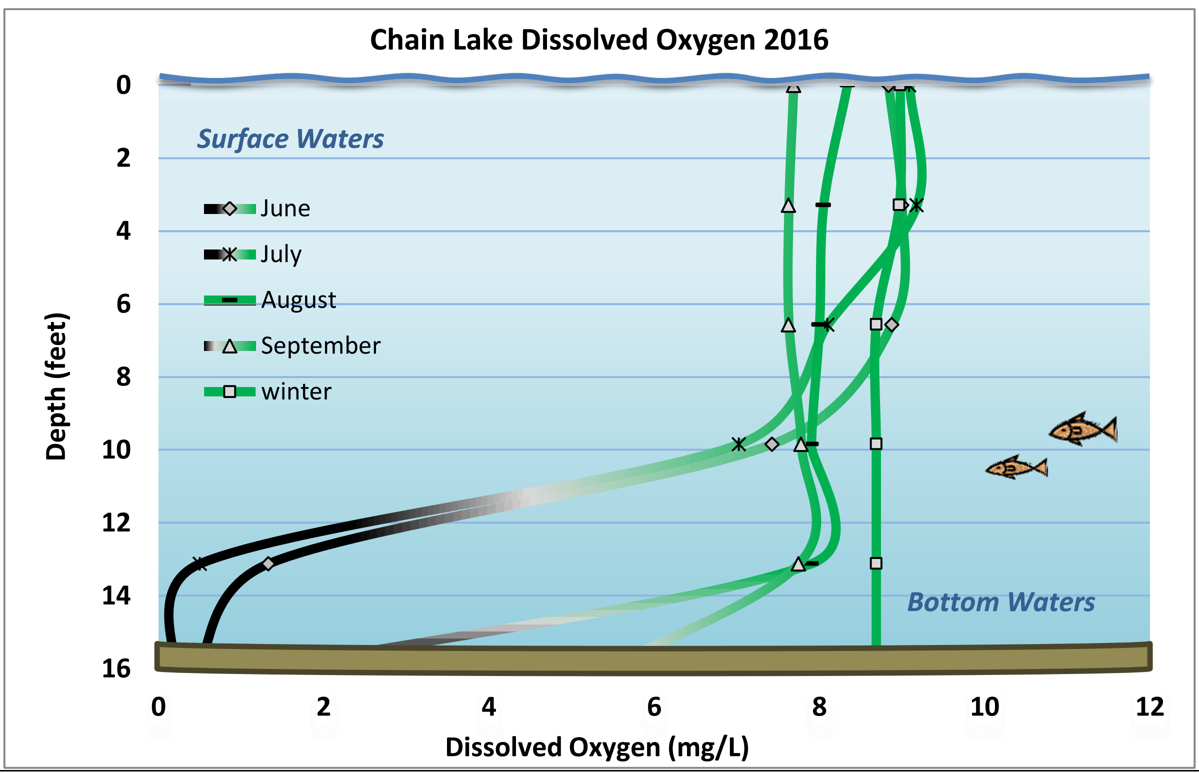

Chain Lake Water Temperatures 2016
Surface Waters
June
July
August
September
winter
Bottom Waters
Depth (feet)
0
2
4
6
8
10
12
14
16
40
45
50
55
60
65
70
75
80
Temperature (˚F)

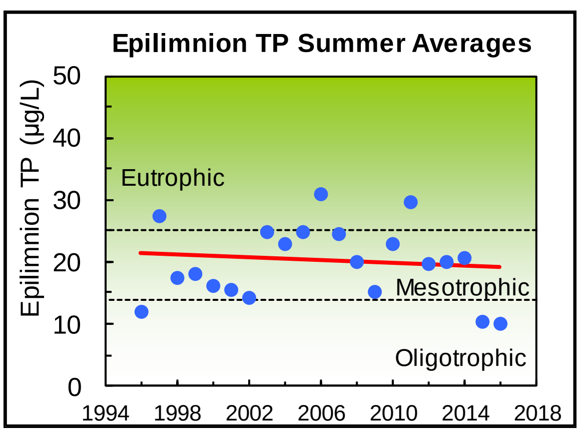

Chain Lake Dissolved Oxygen 2016
Surface Waters
June
July
August
September
winter
Bottom Waters
Depth (feet)
0
2
4
6
8
10
12
14
16
0
2
4
6
8
10
12
Dissolved Oxygen (mg/L)

CHAIN LAKE

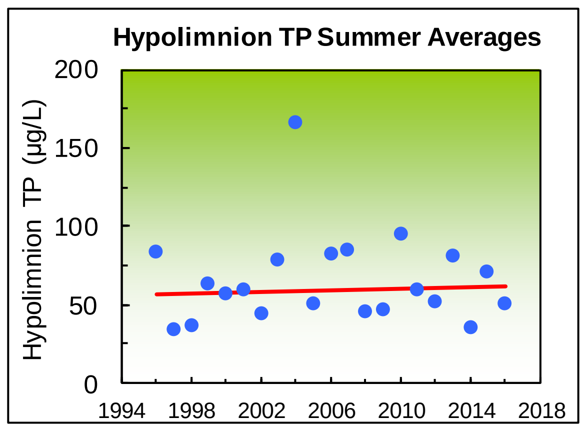
Phosphorus (key nutrient for algae)

Nutrients are essential for the growth of algae, fish, and aquatic plants in a lake. However, too many nutrients, especially phosphorus, can pollute a lake and lead to unpleasant algae growth. Nutrients enter the lake through stormwater runoff or from streams flowing into the lake. Sources of nutrients include fertilizers, pet and animal wastes, poorly-maintained septic systems and erosion from land clearing and construction. Monitoring of phosphorus levels over time helps to identify changes in nutrient pollution.

Total phosphorus concentrations in the epilimnion (upper waters) are moderate to high. The long-term summer average is 20 µg/L (micrograms per liter, which is equivalent to parts per billion). The summer averages have varied considerably from year to year. The 2012 through 2014 summer averages of 20 µg/L were closer to the long-term average. However the 2015 and 2016 summer averages were much lower than long term averages, both at 10 µg/L. Higher phosphorus levels can lead to excess algae growth in the lake. Because of annual variability, the changes between 1996 and 2016 are not considered statistically significant. The relatively high phosphorus levels are the reason that Chain Lake is listed as "impaired" in Washington State's official 2012 water quality assessment.



Summertime phosphorus levels in the hypolimnion (bottom waters) are moderate to high, with a long-term average of 66 µg/L. In 2004, the summer average jumped to more than twice previous averages. In other years the data are closer to the long-term average, but there appears to be a high degree of natural variability in total phosphorus from year to year. Overall, there is no statistically significant trend in phosphorus in the hypolimnion. Any increases in phosphorus in the hypolimnion could indicate that phosphorus is being released from the bottom sediments during periods of low dissolved oxygen and may be a sign of accelerating eutrophication.



Chlorophyll a (Algae)

Algae are tiny plant-like organisms that are essential for a healthy lake. Fish and other lake life depend on algae as the basis for their food supply. However, excessive growths of algae, called algae blooms, can cloud the water, form unsightly scums, and sometimes release toxins. Excess nutrients, such as phosphorus, are the main cause of nuisance algae growth in a lake. Chlorophyll *a* measurements are one method for tracking the amount of algae in a lake.

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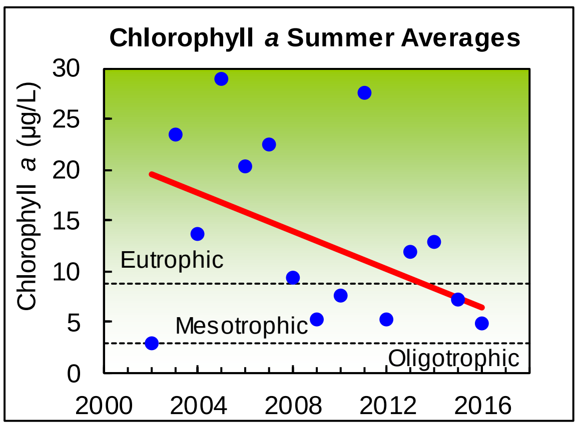
Chlorophyll *a* long-term, summer averages from 2002 through 2016 is 14 µg/L. This indicates abundant algae growth in Chain Lake and corresponds with the high phosphorus levels in the lake. The averages have also been quite variable, ranging from 3.0 µg/L in 2002 to 29 µg/L in 2005. From 2014 to 2016 the summer averages decreased from 13 µg/L to 4.8 µg/L. Overall there has been no statistically significant trend in chlorophyll *a* levels and the lake is capable of producing substantial amounts of algae.



Toxic Blue-Green Algae (Cyanobacteria)

Blue-green algae, also called cyanobacteria, are a group of algae capable of producing toxins during periods of high growth, known as blooms. The toxins can cause serious illness in people and pets that come into contact with affected water. Blooms often look like blue or green paint floating on the surface. Lake users should avoid contact with the water and keep pets away from the lake when it is experiencing a blue-green algae bloom. If a bloom has been identified as toxic, the lake will information posted at the public access site.

Chain Lake has had a history of blue-green algae blooms. Since 2005, SWM staff has screened algae at Chain Lake for potentially toxic blooms. However, since 2011, Chain Lake was not reported to have any noticeable surface accumulations or scums of blue-green algae during the summer. Neither microcystin (a liver toxin) nor anatoxin-a (a neurotoxin) were detected in any of the samples collected in 2009 or 2010. Three samples showed very slight levels of anatoxin-a in 2011, which were still below the Washington State Department of Health recreational guideline of 1 µg/L.

Screening for toxic algae will continue in 2017 as part of the regular lake monitoring program. Continued monitoring will help alert the public to any potential health risks as well as determine the frequency and severity of toxic algae blooms at Chain Lake.

Toxic Algae Testing Results

Date	Microcystin (µg/L)	Anatoxin (µg/L)
7/25/2011	0.00	0.03
8/8/2011	0.00	0.03
8/22/2011	0.00	0.02

**No values exceed the state recreational guidelines of 6 µg/l for Microcystin or 1 µg/L for Anatoxin*

CHAIN LAKE

SHORELINE CONDITION

The condition of the lake shoreline is important to understanding the overall lake health. Frequently, lake shorelines are modified through removal of natural vegetation, the installation of bulkheads or other hardening structures, and/or removal of partially submerged logs and branches. These types of alterations can be harmful to the lake ecosystem because natural shorelines protect the lake from harmful pollution, prevent bank erosion, and provide important habitat for fish and wildlife.

Chain Lake has one of the least developed shorelines in the county. The development around the lake appears to have changed little over the past few decades, with only 4 homes bordering the lake. The shoreline has been modified only at the boat launch, which comprises less than one percent of the 1.1 mile shoreline. In addition, there are no docks on the entire lake. There is only a small amount (about 15 pieces) of large wood, old logs and branches, still remaining in the lake to provide fish and wildlife habitat. However, Chain Lake is unique in that the vegetation immediately adjacent to the shoreline is 95% intact, and there are large wetlands with stands of floating aquatic plants bordering the majority of the lake. The natural state of the shoreline provides rich habitat for fish and wildlife and plays an important role in filtering out nutrients to protect the lake.

SUMMARY

Trophic State

All lakes go through a process of enrichment by nutrients and sediment. In this process, known as eutrophication, nutrients and sediment contribute to the ever-increasing growth of algae and aquatic plants. Over thousands of years, lakes will gradually fill up with organic matter and sediments.

Lakes can be classified by their degree of eutrophication, also known as their trophic state. There are three primary trophic states for lakes—oligotrophic, mesotrophic, and eutrophic—as well as intermediate states. Oligotrophic lakes are usually deep, with clear water, low nutrient concentrations, and few aquatic plants and algae. Mesotrophic lakes are richer in nutrients and produce more algae and aquatic plants. Eutrophic lakes are often shallow and characterized by abundant algae and plants, high nutrient concentrations, limited water clarity, and low dissolved oxygen in the bottom waters.

The trophic state classification of a lake does not necessarily indicate good or bad water quality because eutrophication is a natural process. However, human activities that contribute sediment and excess nutrients to a lake can dramatically accelerate the eutrophication process and result in declining water quality.

Based on the long-term monitoring data, Chain Lake may be classified as meso-eutrophic, with moderate water clarity, moderate to high phosphorus levels, and high algae levels. The lake also supports dense growths of aquatic plants.

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Condition and Trends

Chain Lake is meeting some, but not all, of its water quality targets set forth in the 2003 State of the Lakes Report. The long-term water clarity average has remained at 3.1 meters. Phosphorus levels have been highly variably through the years, although long-term averages indicate that Chain Lake is not meeting its water quality target for nutrient pollution. Long-term average phosphorus levels in the epilimnion (upper waters) have increased from 17 µg/L in 2003 to 20 µg/L in 2016. In the hypolimnion (bottom waters), there has been an increase from 55 µg/L in 2003 to 66 µg/L in 2016. There was no target Chlorophyll *a* level listed in the 2003 Report, and there are no statistically significant trends in algae levels since 2002. The State of Washington has listed Chain Lake as "impaired" because of high phosphorus concentrations.

Overall, Chain Lake appears to be at risk of future water quality declines because of potentially increasing phosphorus in the lake. The primary threat to lake water quality is an increase of nutrients entering the lake through new development and human activities in the watershed. Measures to control nutrients in the watershed should be taken now to prevent any future negative impacts to the lake. In addition, the shoreline should remain largely unaltered to protect the lake. To find out more about ways to preserve lake water quality and information on the causes and problems of elevated lake nutrient levels visit www.lakes.surfacewater.info.

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DATA SUMMARY FOR CHAIN LAKE						
		Water Clarity (Secchi depth	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Surface**	**Surface**
Bortleson, et al, 1976	**7/23/73**	1.8	33	30	-	-
Volunteer	**1993**	2.0 - 4.1 (3.0) *n = 6*	-	-	-	-
SWM Staff	**1994**	3.5 - 4.3 (4.0) *n = 3*	-	-	-	2.8 - 13 (7.9) *n = 2*
SWM Staff	**1995**	2.5	-	-	-	14
SWM Staff or Volunteer	**1996**	2.3 - 2.5 (2.4) *n = 4*	8 - 16 (12) *n = 2*	48 - 119 (84) *n = 2*	-	-
SWM Staff	**1997**	2.2 - 3.1 (2.6) *n = 2*	15 - 40 (28) *n =2*	21 - 49 (35) *n = 2*	-	-
SWM Staff or Volunteer	**1998**	1.4 - 2.6 (2.0) *n = 6*	10 - 24 (17) *n = 4*	33 - 46 (38) *n = 4*	-	-
SWM Staff or Volunteer	**1999**	2.8 - 4.3 (3.5) *n = 14*	11 - 25 (18) *n = 4*	48 - 76 (64) *n = 4*	-	-
SWM Staff or Volunteer	**2000**	2.3 - 4.3 (3.3) *n = 11*	11 - 22 (16) *n = 4*	26 - 111 (57) *n = 4*	-	-
SWM Staff	**2001**	2.9 - 3.8 (3.5) *n = 4*	12 - 19 (16) *n = 4*	26 - 92 (59) *n = 4*	-	-
SWM Staff	**2002**	3.4 - 4.3 (3.9) *n = 4*	10 - 21 (14) *n = 4*	25 - 85 (45) *n = 4*	-	1.9 - 5.1 (3.0) *n = 4*
SWM Staff	**2003**	2.1 - 3.9 (2.9) *n = 4*	16 - 41 (25) *n = 4*	60 - 102 (79) *n = 4*	-	2.4 - 69 (23) *n = 4*
SWM Staff	**2004**	1.5 - 4.0 (3.3) *n = 4*	14 - 31 (23) *n = 4*	30 - 395 (167) *n = 4*	-	2.1 - 39 (14) *n = 4*
SWM Staff	**2005**	1.5 - 3.5 (2.5) *n = 4*	18 - 36 (25) *n = 4*	42 - 61 (52) *n = 4*	-	3.5 - 93 (29) *n = 4*
SWM Staff	**2006**	2.3 - 4.3 (3.1) *n = 4*	16 - 37 (31) *n = 4*	27 - 176 (83) *n = 4*	-	4.8 - 48 (20) *n = 4*
SWM Staff	**2007**	1.3 - 3.7 (2.5) *n = 4*	20 - 28 (25) *n = 4*	29 - 146 (85) *n = 4*	-	8.5 - 36 (22) *n = 4*

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DATA SUMMARY FOR CHAIN LAKE						
Source	**Date**	**Water Clarity (Secchi depth in meters)**	**Total Phosphorus (µg/L) Surface**	**Total Phosphorus (µg/L) Bottom**	**Total Nitrogen (µg/L) Surface**	**Chlorophyll *a* (µg/L) Surface**
SWM Staff	**2008**	2.7 - 4.0 (3.5) *n = 4*	14 - 33 (20) *n = 4*	25 - 64 (46) *n = 3*	-	4.2 - 21 (9.3) *n = 4*
SWM Staff	**2009**	4.3 - 4.5 (4.4) *n = 4*	12 - 18 (15) *n = 4*	27 - 66 (48) *n = 4*	-	2.7 - 6.8 (5.2) *n = 4*
SWM Staff or Volunteer	**2010**	2.8 - 3.9 (3.4) *n = 4*	19 - 29 (23) *n = 4*	29 - 219 (95) *n = 4*	-	2.7 - 16 (7.6) *n = 4*
SWM Staff	**2011**	2.2 - 3.5 (2.7) *n = 12*	21 - 38 (30) *n = 4*	34 - 84 (60) *n = 4*	-	5.9 - 56 (27) *n = 4*
SWM Staff	**2012**	2.9 - 4.2 (2.8) *n = 4*	14 - 22 (20) *n = 4*	23 - 80 (52) *n = 4*	-	3.5 - 6.9 (5.2) *n = 4*
SWM Staff	**2013**	1.8 - 4.5 (3.1) *n = 4*	14 - 31 (20) *n = 4*	51 - 152 (82) *n = 4*	-	1.3 - 40 (12) *n = 4*
SWM Staff	**2014**	*1.8 - 3.6* *(2.8)* *n = 4*	*14 - 33* *(21)* *n = 3*	*21 - 52* *(35)* *n = 4*	*289 - 633* *(411)* *n = 4*	*0.80 - 41* *(13)* *n = 4*
SWM Staff	**2015**	*2.6 - 3.5* *(3.1)* *n = 4*	*8 - 12* *(10)* *n = 4*	*19 - 121* *(71)* *n = 4*	*249 - 466* *(353)* *n = 4*	*2.1 - 13* *(7.3)* *n = 4*
SWM Staff	**2016**	2.6 - 4.6 (3.8) *n = 4*	8 - 14 (10) *n = 4*	20 - 95 (51) *n = 4*	276 - 368 (323) *n = 4*	2.4 - 6.9 (4.8) *n = 4*
Long Term Avg		**3.1** **(1993-2016)**	**20** **(1996-2016)**	**66** **(1996-2016)**	**362** **(2014-2016)**	**14** **(2002-2016)**
TRENDS		**None**	**None**	**None**	**NA**	**None**

NOTES

- Table includes summer (May-Oct) data only.
- Each box shows the range on top, followed by summer average in ( ) and number of samples (*n*).
- Total phosphorus data are from samples taken at discrete depths only.
- "Surface" samples are from 1 meter depth and "bottom" samples are from 1-2 meters above the bottom.