STORM LAKE

REPORT DESCRIPTION

This report is an update on the health of Storm Lake based on water quality data collected from 1990 through 2016 by citizen volunteers and Snohomish County Surface Water Management (SWM) staff. For additional background on the information provided here or to find out more about Storm Lake, please visit www.lakes.surfacewater.info or call SWM at 425-388-3464.

LAKE DESCRIPTION

Storm Lake is a 76-acre lake located six miles north of Monroe. It sits at the upper end of a three-lake chain. Storm Lake is fed by groundwater and drains into Flowing Lake, which in turn discharges into Panther Lake. Storm Lake has a maximum depth of 14 meters (46 feet) and an average depth of 6.7 meters (22 feet). The watershed, which is the land area that drains to the lake, is very small—less than three times the size of the lake. This means that there is less potential for pollution from activities in the watershed affecting the lake water quality compared to other lakes. Also, there is only scattered development in the watershed, except around the shoreline. Most of the lake shore is developed with single family homes.

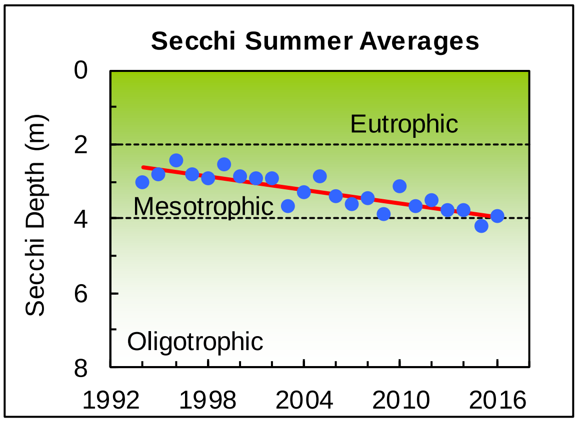
LAKE CONDITIONS

The following graphs illustrate the summer averages and trend lines (shown in red) for water clarity, total phosphorus, and chlorophyll *a* for Storm 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 Storm Lake is moderate, with a 1990 – 2016 long-term summer average of 3.2 meters (10.2 feet). The water clarity has been steadily improving through the years. Between 1990 and 2016, there has been a statistically significant trend toward improving water clarity (p=0.00). This is at odds with the potential increases in phosphorus and algae growth described below. However, changes in lake water color may be affecting water clarity. In any case, better water clarity is a good sign for the lake.



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 Storm Lake averaged 26 pcu (platinum-cobalt color units) in 2010 – 2011, which indicates a moderate amount of color in the lake water. This is a slight decrease in color from the 1994 – 1995 average of 32 pcu. This reduction in natural water color is likely a factor in the improvement in water clarity over the same time period.

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.

From May through September 2016, temperature data were collected at each meter throughout the Storm Lake water column (see graph). Temperature profiles for 2016 show that throughout the sampling season the lake was strongly thermally stratified. 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. In May the upper waters measured about 67˚F (19.3°C) in temperature, and by August had reached their peak at 78°F (25.3°C). At the same time, bottom water temperatures changed only a little and remained around 45-46°F (7.4-7.6°C). By October, the surface waters had begun to cool. This cooling will continue through the fall until the temperatures are almost equal from top to bottom. As stratification weakens, the lake water will turn over (or mix). The lake will stay mixed during the winter until springtime, when the upper waters began to warm again.

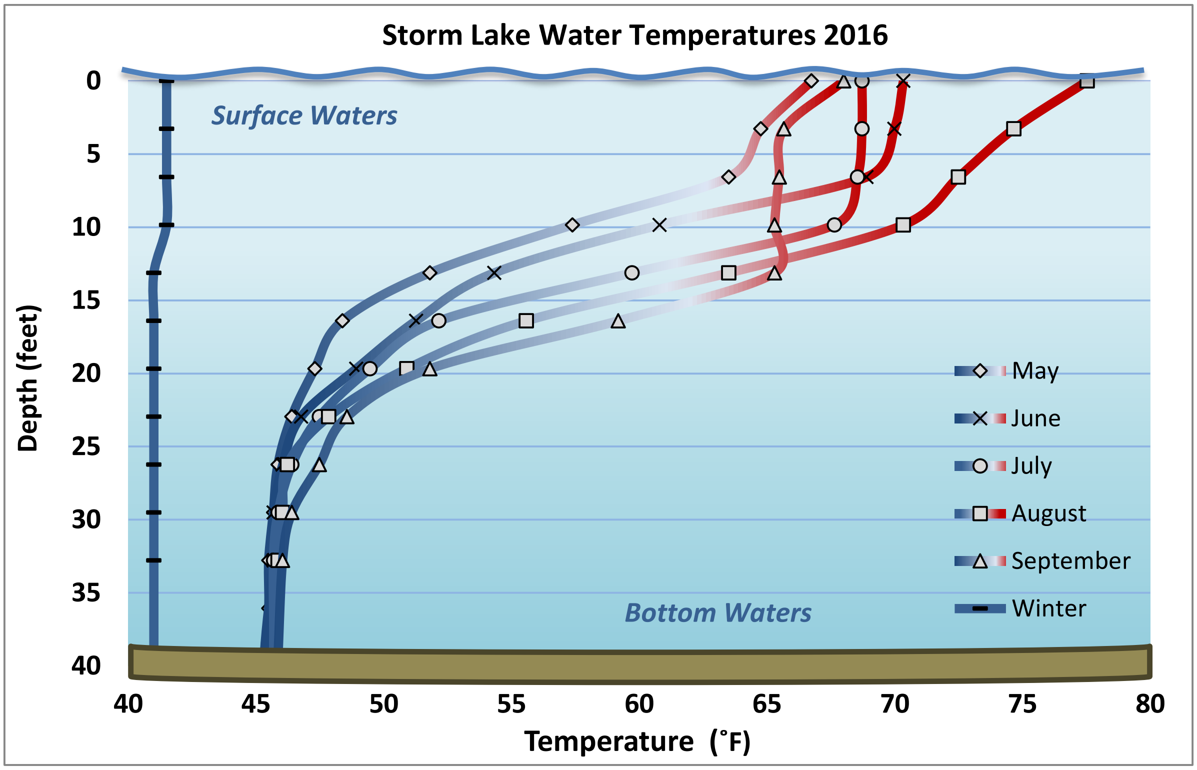
Dissolved Oxygen

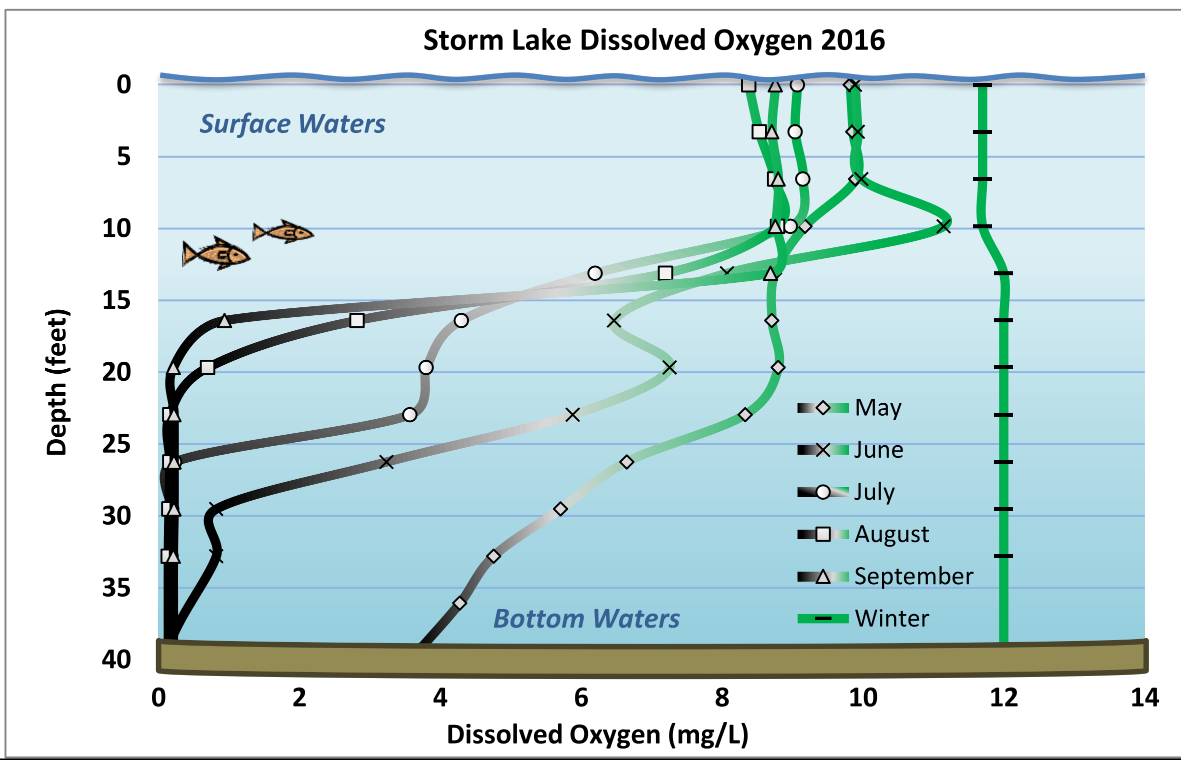
Oxygen dissolved in the water is essential for life in a lake. Most of the dissolved oxygen comes from the atmosphere. Like temperature, dissolved oxygen levels vary over time and with depth. During the warm months, the upper waters receive oxygen from the atmosphere, but the lower waters cannot be replenished 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.

Dissolved oxygen was also measured at every meter throughout the Storm Lake water column from May to September 2016 (see graph). Dissolved oxygen patterns from the upper waters to bottom waters were more variable than temperatures in the lake. Oxygen levels were relatively high in the upper waters from May through September. In June there was a small increase in dissolved oxygen levels about 10 and 20 feet down in the lake. This indicates vigorous algae growth at that depth which added oxygen to the water.

Meanwhile, by June dissolved oxygen levels were dropping in the bottom waters, and by July the bottom waters contained little to no dissolved oxygen. From July through September, the zone of no dissolved oxygen in the lake began at about 15 to 20 feet deep. During the summer period, oxygen in the lower waters is consumed by the decomposition of organic material within the lake. When the lake is stratified, the oxygen is not replenished by the overlying oxygen-rich upper waters or the atmosphere. The lack of oxygen in the lower waters can allow phosphorus in the bottom sediments to be released into the overlying lake water where it can fuel algae growth in the late summer or the following spring. The bottom of the lake will remain devoid of oxygen until the lake mixes (typically in late October/early November). The lake then remains mixed through the winter until springtime when the upper waters begin to warm and dissolved oxygen begins to decline in the bottom.

STORM LAKE


Storm Lake Water Temperatures 2016
Surface Waters
Bottom Waters
Depth (feet)
0
5
10
15
20
25
30
35
40
40
45
50
55
60
65
70
75
80
Temperature (˚F)
May
June
July
August
September
Winter

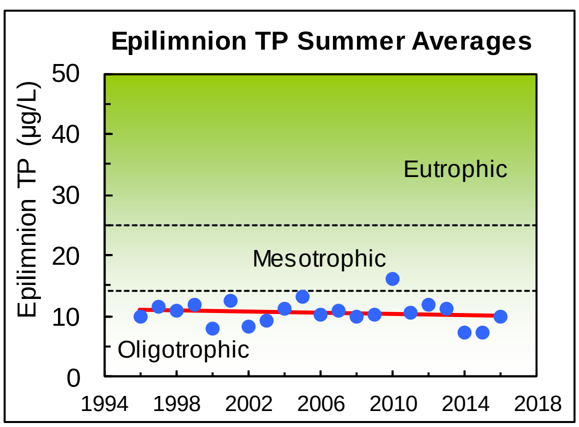

Storm Lake Dissolved Oxygen 2016
Surface Waters
Bottom Waters
Depth (feet)
0
5
10
15
20
25
30
35
40
0
2
4
6
8
10
12
14
Dissolved Oxygen (mg/L)
May
June
July
August
September
Winter

STORM LAKE

Phosphorus (key nutrient for algae)

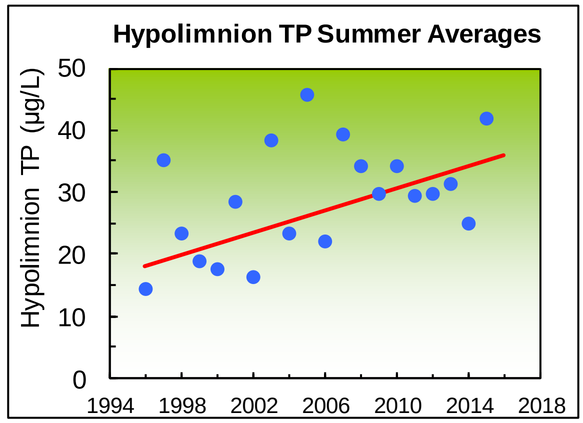
Nutrients are essential for the growth of algae, fish, and aquatic plants in a lake. However, too many nutrients, especially phosphorus, can pollute a lake and lead to unpleasant algae growth. Nutrients enter the lake through stormwater runoff or from streams flowing into the lake. Sources of nutrients 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 low, with a 1996 - 2016 long-term summer average of 11 µg/L (micrograms per liter, which is equivalent to parts per billion). Summer phosphorus averages have varied only slightly from year to year. There is no evidence of a long-term trend in phosphorus concentrations in the epilimnion, but the summer average for 2010 (16 µg/L) was the highest on record. Higher phosphorus levels can lead to more algae in the lake.



Phosphorus values in the hypolimnion (bottom waters) are higher and much more variable than in the epilimnion. The 1996 – 2016 long-term summer average is 30 µg/L. In recent years, phosphorus averages have been higher than in the 1990s, which indicates more release of phosphorus from bottom sediments during periods of low dissolved oxygen.

Between 1996 and 2016, there has been a statistically significant trend toward increasing phosphorus in the bottom waters (p=0.03). High phosphorus levels in the bottom waters may also be a sign of accelerating eutrophication and may lead to increases in algae growth in future years.



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.

Chlorophyll *a* values indicate moderate levels of algae in the lake. The long-term 2002 - 2016 summer chlorophyll *a* average is 3.9 µg/L. The chlorophyll *a* averages are variable from year to year, and from 2002 to 2014 there was a statistically significant increasing trend. The increasing trend was lost in 2015. Increases in chlorophyll *a* indicates that more algae are growing in the lake. More algae may be a response to more phosphorus in the bottom waters that becomes available when the lake turns over and mixes in the fall.

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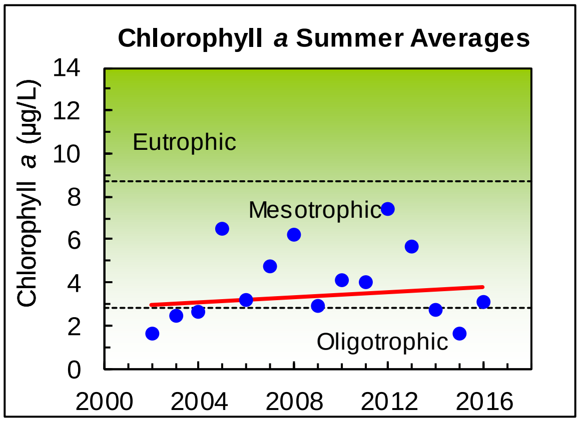

Nitrogen (another essential nutrient for algae)

Nitrogen is another important nutrient for plant and algae growth. Similar to phosphorus, lakes with high levels of nitrogen typically have more aquatic plants and algae. From 2014 to 2016, Storm Lake had relatively low levels of total nitrogen (summer average of 302 µg/L). This is consistent with the moderate chlorophyll *a* concentrations measured in the lake.

The relative abundance of nitrogen and phosphorus can also be a useful indicator of lake conditions. This is referred to as the nitrogen to phosphorus ratio or N:P ratio. When lakes have low N:P ratios (typically less than 20), algae growth is often high and harmful blue-green algae blooms may be a problem. Low N:P ratios may also indicate that fertilizers, septic systems, polluted runoff from developed areas, and release of phosphorus from the lake bottom sediments are contributing most of the nutrients to the lake.

In contrast, when lakes have higher N:P ratios (greater than 20), algae growth will be limited by the amount of phosphorus available, and blue-green algae are usually less of a problem. Storm Lake had a moderate to high average N:P ratio of 39, and blue green algae blooms were not observed in 2015.

SHORELINE AND WATERSHED CONDITION

The condition of the lake shoreline is important to understanding overall lake health. As development on a lake increases, the shorelines typically are modified either through removal of natural vegetation, the installation of bulkheads or other hardening structures, and/or the removal of large 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.

The Storm Lake shoreline is moderately developed. There were 26 homes or cabins around the lake in 1973. By the mid-90s, there were 38 homes bordering the lake. There are also 41 docks present on the lake. Fortunately, there have been limited modifications to the shoreline through the years. Only 7% of the shoreline has been armored with bulkheads, rock or log revetments, or fill. A sizeable portion (69%) of the shore immediately adjacent to the lake still contains a zone of intact native vegetation. On the other hand, this does mean that 31% of the vegetation has been altered. There is also a moderate amount of large wood (about 71 pieces) still remaining in the lake. These old logs and branches are valuable for fish and wildlife habitat.

These various forms of shoreline modification leave the lake susceptible to pollution from the watershed, eliminate the buffer of native vegetation that can filter out pollution, and limit the amount of habitat available for fish and wildlife. The loss of native vegetation along the shoreline could also lead to shoreline erosion.

In addition, during 2013 there was a large logging operation southeast of Storm Lake that harvested timber from approximately 175 acres. About 80 acres of the logged area is within the watershed of Storm Lake. Fortunately, the timber harvest did not extend to the shoreline of the lake. However, until the forest is re-established, there is potential for additional runoff and erosion from the cleared areas that can carry nutrients to 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, Storm Lake may be classified as mesotrophic, with moderate water clarity and low to moderate levels of phosphorus and algae. There are sparse populations of aquatic plants in the lake, partly because the colored water and steep shoreline limit the amount of light and the area available for plant growth.

Condition and Trends

The water quality targets for Storm Lake are to maintain stable water clarity and phosphorus levels. The lake is exceeding the water clarity target. There has been a statistically significant trend toward improving water clarity between 1990 and 2016. Part of the reason for this improvement may be less natural color in the water.

The lake is also meeting the phosphorus target for the upper waters. Levels of phosphorus in the epilimnion appear to be stable. However, there is a statistically significant increasing trend in phosphorus in the bottom waters, which may point to more nutrients entering the lake and more phosphorus being released from the bottom sediments. There has also been a corresponding increases in algae growth.

Overall, Storm Lake is still in healthy condition. However, there is some concern about potentially increasing phosphorus levels in the bottom waters and increasing algae levels. The primary threat to lake water quality is the possibility of rapid development, more widespread logging, or other human activities that would increase the inflow of nutrients from the watershed. Measures to control nutrients should be taken now to prevent any future negative impacts to the lake. To find out more about the causes and problems of elevated lake nutrient levels and learn about steps to improve lake water quality, please visit www.lakes.surfacewater.info.

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DATA SUMMARY FOR STORM 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**	2.1	13	37	-	-
DOE	**1990**	1.8 - 3.1 (2.4) *n = 6*	-	-	-	-
Volunteer	**1993**	1.7 - 3.1 (2.4) *n = 9*	-	-	-	-
SWM Staff or Volunteer	**1994**	2.2 - 4.5 (3.0) *n = 14*	-	-	-	1.9 - 9.8 (5.9) *n = 2*
SWM Staff or Volunteer	**1995**	2.0 - 3.9 (2.8) *n = 13*	-	-	-	6.7
Volunteer or DOE	**1996**	1.8 - 3.3 (2.4) *n = 14*	5 - 15 (10) *n = 2*	10 - 19 (15) *n = 2*	-	4.4 - 6.3 (5.4) *n = 2*
SWM Staff or Volunteer	**1997**	2.5 - 3.5 (2.8) *n = 15*	9 - 14 (12) *n = 2*	27 - 43 (35) *n = 2*	-	-
Volunteer	**1998**	2.3 - 3.9 (2.9) *n = 13*	7 - 20 (11) *n = 4*	20 - 28 (24) *n = 4*	-	-
Volunteer	**1999**	1.3 - 3.7 (2.6) *n = 14*	8 - 17 (12) *n = 4*	14 - 23 (19) *n = 4*	-	-
SWM Staff or Volunteer	**2000**	2.2 - 3.5 (2.9) *n = 12*	4 - 13 (8) *n = 4*	3 - 27 (18) *n = 4*	-	-
Volunteer	**2001**	2.4 - 3.5 (2.9) *n = 12*	9 - 19 (13) *n = 4*	26 - 30 (29) *n = 4*	-	-
Volunteer	**2002**	2.3 - 3.6 (2.9) *n = 13*	4 - 11 (8) *n = 4*	15 - 19 (16) *n = 4*	-	0.1 - 3.7 (1.6) *n = 4*
Volunteer	**2003**	2.4 - 5.2 (3.7) *n = 4*	6 - 12 (9) *n = 4*	29 - 54 (38) *n = 4*	-	1.6 - 4.3 (2.4) *n = 4*
Volunteer	**2004**	2.1 - 4.4 (3.3) *n = 4*	7 - 13 (11) *n = 4*	8 - 35 (24) *n = 4*	-	0.8 - 4.5 (2.7) *n = 4*
SWM Staff	**2005**	2.3 - 3.3 (2.9) *n = 4*	10 - 17 (13) *n = 4*	26 - 65 (46) *n = 4*	-	4.3 - 9.1 (6.5) *n = 4*
Volunteer	**2006**	2.8 - 4.4 (3.4) *n = 10*	8 - 12 (10) *n = 4*	20 - 25 (22) *n = 4*	-	1.6 - 5.3 (3.2) *n = 4*

STORM LAKE

DATA SUMMARY FOR STORM LAKE						
		Water Clarity (Secchi depth in meters)	Total Phosphorus (µg/L)		Total Nitrogen (µg/L)	Chlorophyll *a* (µg/L)
Source	**Date**		**Surface**	**Bottom**	**Surface**	**Surface**
Volunteer	**2007**	3.2 - 4.0 (3.6) *n = 9*	8 - 13 (11) *n = 4*	23 - 54 (39) *n = 4*	-	3.2 - 7.2 (4.7) *n = 4*
Volunteer	**2008**	2.6 - 4.3 (3.5) *n = 11*	7 - 13 (10) *n = 3*	23 - 47 (34) *n =3*	-	2.4 - 16 (6.2) *n = 4*
Volunteer	**2009**	3.0 - 4.5 (3.9) *n = 12*	8 - 12 (10) *n = 4*	23 - 34 (30) *n = 4*	-	1.6 - 5.1 (3.0) *n = 4*
Volunteer	**2010**	2.2 - 3.8 (3.2) *n = 10*	9 - 34 (16) *n = 4*	27 - 47 (34) *n = 4*	-	2.7 - 6.4 (4.1) *n = 4*
Volunteer	**2011**	2.5 - 4.7 (3.7) *n = 9*	7 - 13 (11) *n = 4*	20 - 40 (30) *n = 4*	-	1.3 - 6.4 (4.1) *n = 4*
Volunteer	**2012**	2.9 - 4.4 (3.5) *n = 6*	7 - 17 (12) *n = 4*	23 - 41 (30) *n = 4*	-	1.5 - 17 (7.4) *n = 4*
Volunteer	**2013**	3.4 - 4.4 (3.8) *n = 7*	7 - 15 (11) *n = 4*	22 - 38 (31) *n = 4*	-	1.6 - 15 (5.6) *n = 4*
Volunteer	**2014**	2.1 - 4.6 (3.8) *n = 11*	6 - 11 (7) *n = 5*	22 - 27 (25) *n = 5*	340 - 399 (382) *n = 4*	1.5 - 4.8 (2.7) *n = 5*
Volunteer	**2015**	*3.0 - 5.0* *(4.2)* *n = 11*	*4 - 10* *(7)* *n = 4*	*27 - 53* *(42)* *n = 4*	*192 - 292* *(239)* *n = 4*	*1.1 - 2.1* *(1.6)* *n = 4*
Volunteer	**2016**	3.1 - 4.7 (3.9) *n = 12*	8 - 11 (10) *n = 4*	14 - 105 (58) *n = 4*	229 - 312 (284) *n = 3*	1.5 - 4.4 (3.1) *n = 4*
Long Term Avg		**3.2** **(1990-2016)**	**11** **(1996-2016)**	**30** **(1996-2016)**	**303** **(2014-2016)**	**3.9** **(2002-2016)**
TRENDS		**Increasing**	**None**	**Increasing**	**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.
- DOE = Washington Department of Ecology
- "Surface" samples are from 1 meter depth and "bottom" samples are from 1-2 meters above the bottom.