2016 STATE OF THE LAKES UPDATE

LAKE GOODWIN

REPORT DESCRIPTION

This report is an update on the health of Lake Goodwin based on water quality data collected from 1992 through 2016 by local volunteers and Snohomish County Surface Water Management (SWM) staff. For additional background on the information provided here or to find out more about Lake Goodwin, visit www.lakes.surfacewater.info or call SWM at 425-388-3464.

LAKE DESCRIPTION

Lake Goodwin is the second largest natural lake in Snohomish County, covering 539 acres. The lake is relatively shallow for its size, with a maximum depth of 15.2 meters (50 feet) and an average depth of 7.0 meters (23 feet). It is located in the Seven Lakes area north of the Tulalip Reservation. Lake Goodwin is fed by Lake Loma and Lake Crabapple and drains to Lake Shoecraft. The total watershed, which is the land area that drains to the lake, including the drainage from Lake Loma and Lake Crabapple, is small—only 6.1 times the size of the lake. However, the lake shore is fully developed with homes, and more development is occurring throughout the watershed. These activities could have future water quality impacts.

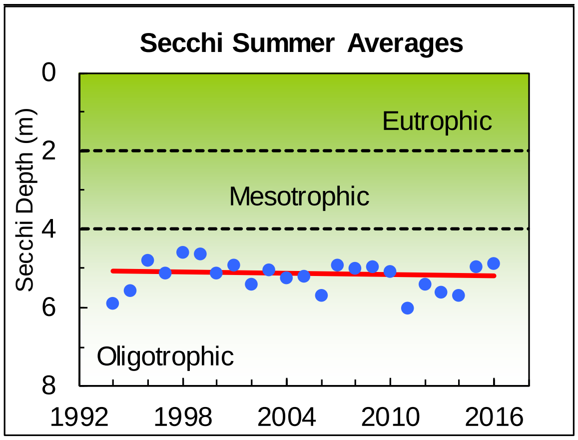
LAKE CONDITIONS

The following graphs illustrate the summer averages and trend lines (shown in red) for water clarity, total phosphorus, and chlorophyll *a* for Lake Goodwin. 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.

The water clarity in Lake Goodwin is high, with a 1992 to 2016 long-term summer average of 5.2 meters (over 17 feet). Water clarity averages have been relatively stable over time, except for better water clarity in 1993-95 and in 2011. Overall, between 1992 and 2016, there has been no significant change in water clarity in Lake Goodwin.



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 Lake Goodwin averaged 15 pcu (platinum-cobalt color units) in 2010, which indicates a slight amount of color in the lake water. However, the 2011 average was only 5 pcu, similar to the average in 1994-1995. Less natural color in the lake water in 2011 may be a factor in the greater water clarity that year.

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 was collected monthly throughout the water column at Lake Goodwin. The temperature profiles (see graph) show that the lake was already thermally stratified in May, with about a 16˚F temperature difference between surface and bottom waters. Stratification continued to be strong through August. Bottom water temperatures changed very little throughout the summer, and remained between 49-52˚F (9-11˚C). Because of the difference in temperatures and the fact that warm water is lighter, mixing did not occur between these layers. By October, the upper waters began to cool down until the temperatures were eventually equal from top to bottom. As stratification weakened, the lake water turned over (or mixed). 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.

The depth profiles of dissolved oxygen measured in 2016 are similar to the temperature profiles seen during that time period. Oxygen levels were relatively high in the upper waters in May, while the bottom waters contained low to moderate amounts of oxygen. Then, by June, the upper waters still contained plenty of dissolved oxygen, but the bottom waters had little or no oxygen below about 33 feet. This situation continued into September. In May and June, there was a small increase in dissolved oxygen levels about 22 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. When the lake is stratified, the oxygen is not replenished by the overlying oxygen-rich upper waters or the atmosphere. The bottom of the lake will remain devoid of oxygen until the lake mixes (usually in late October/early November). The lake then remains mixed until springtime when the upper waters begin to warm and dissolved oxygen begins to decline again in the bottom.

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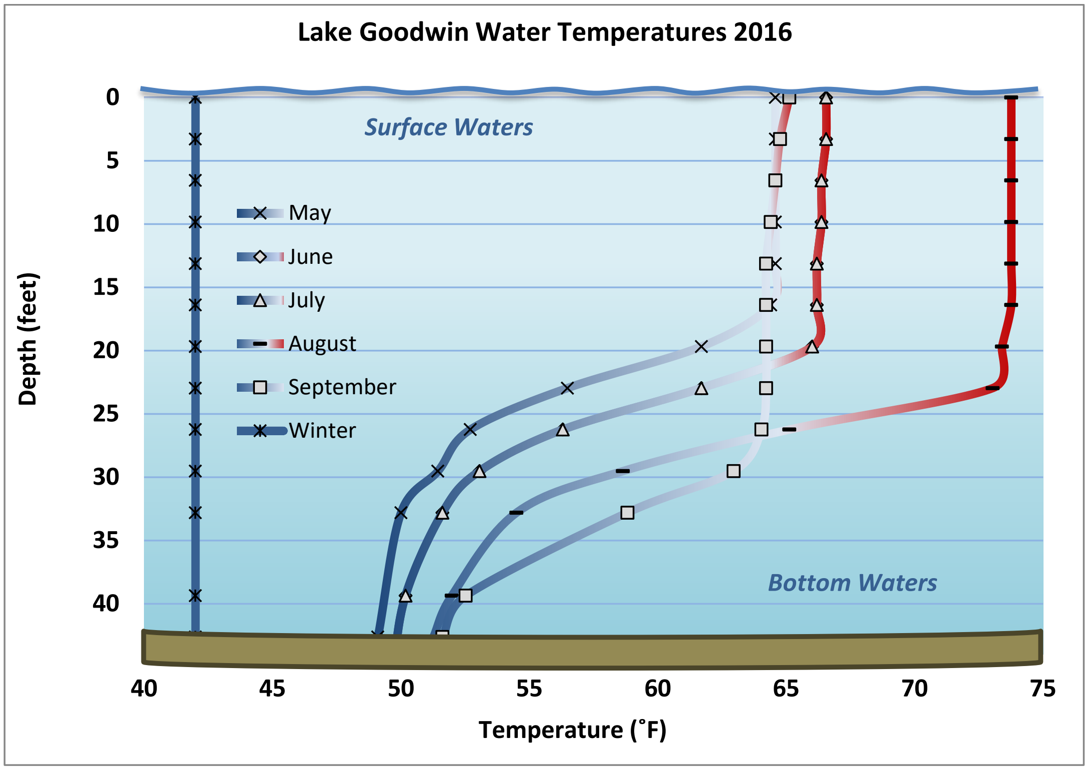
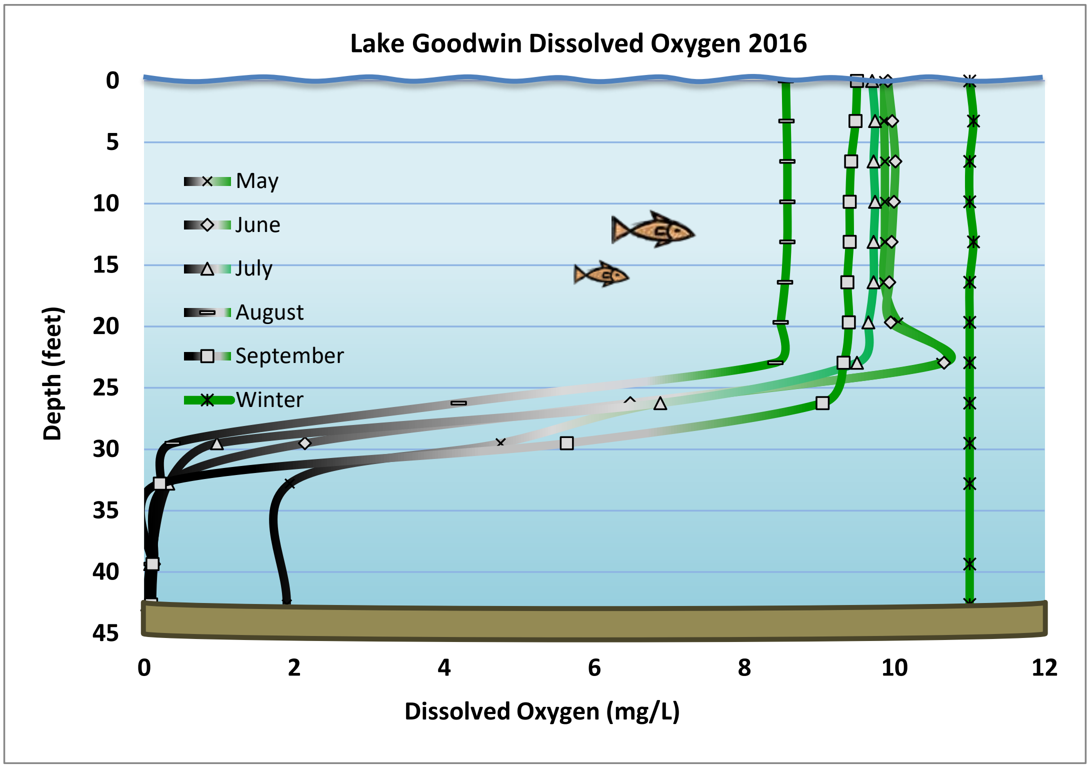
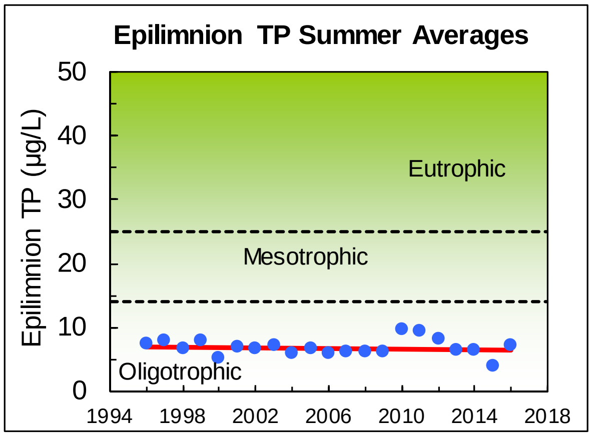




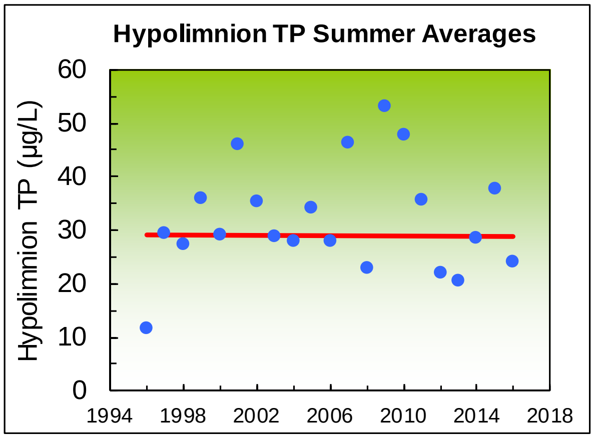
Phosphorus (key nutrient for algae)

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 7 µg/L (micrograms per liter, which is equivalent to parts per billion). Overall, phosphorus has shown little year-to-year variability. For several years, there appeared to be a very small trend toward declining total phosphorus levels in the epilimnion. However, that apparent trend is no longer evident. Instead, the 2010-2011 summer averages of 10 µg/L, though quite low, were the highest on record. Any increase in phosphorus levels can lead to the growth of 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 in the hypolimnion is 32 µg/L, which is relatively low compared to other Snohomish County lakes. In 2009, the summer hypolimnetic phosphorus average jumped to 53 µg/L, the highest level on record. The 2010 average was also high at 48 µg/L. High phosphorus levels in the bottom waters can lead to more algae growth in future years. Fortunately, the summer average value has declined since 2010. The higher averages in 2009 and 2010, as well as spikes in 2001 and 2007, could be warning signs of eutrophication. However, between 1996 and 2016, there has been no statistically significant trend toward increasing total phosphorus values in the bottom waters of Lake Goodwin.



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 and nitrogen, 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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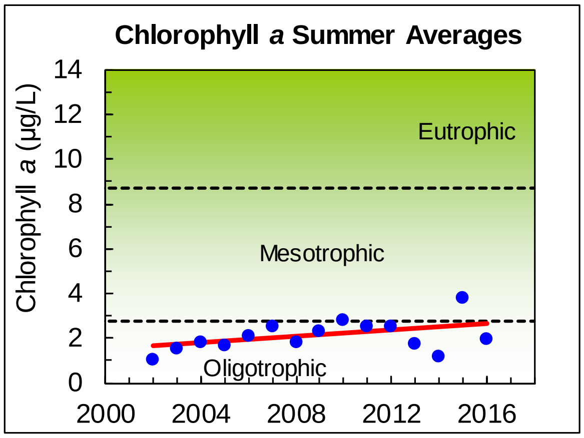
Chlorophyll *a* measurements showed low algae levels in the summers of 2002 through 2016, with a long-term summer average of 2.1 µg/L. The 2015 summer average of 3.8 µg/L is the highest observed. In 2015 there was a small, but statistically significant small trend towards increasing chlorophyll *a* in Lake Goodwin, although this trend disappeared in 2016.

Increases in chlorophyll *a* are a sign of more algae growth and, as noted, typically correspond with higher levels of phosphorus in the lake. Because there is no clear evidence of long-term increases in phosphorus levels in Lake Goodwin, the risk of nuisance algae levels in the near future is low. Furthermore, there have been only limited observations of dense algae blooms in the lake, although there have been reports of occasional nuisance blooms in localized areas. If phosphorus levels do start to increase in Lake Goodwin, more frequent algae blooms may occur.



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, Lake Goodwin had relatively low levels of total nitrogen (summer average of 363 µg/L). This is consistent with the limited algae growth and low 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. Lake Goodwin had a high average N:P ratio of 60, and nuisance blue green algae blooms were not observed in 2016.

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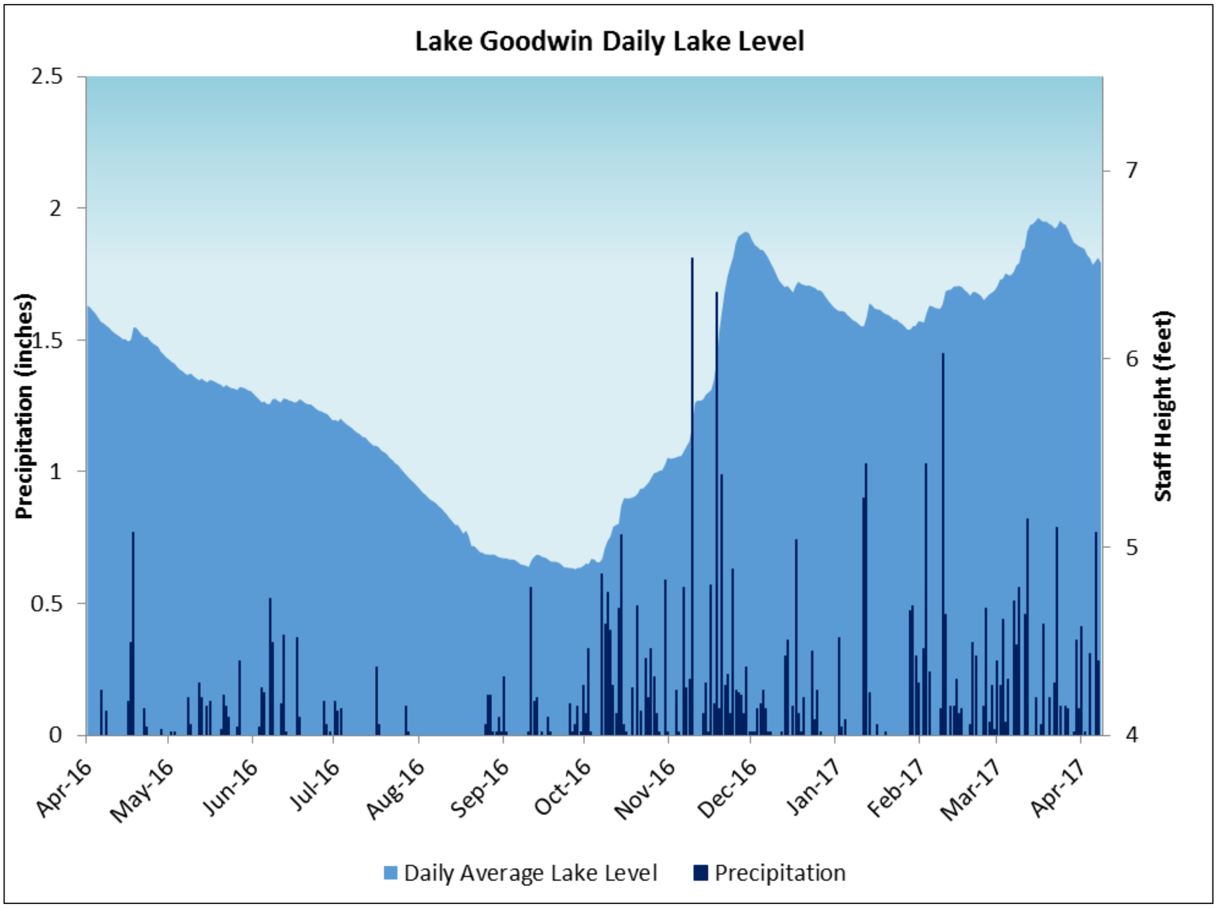
Lake Level

Lake level data tracks the amount of water in the lake and the balance between water coming in by streams, precipitation, groundwater and water leaving by evaporation or outflow. Lake levels in our region are highest in early spring and lowest in late summer and fall. The importance of lake level is to indicate the seasonal effects of the water balance in the lake. In addition to rainfall, lake levels can be affected by sedimentation, surrounding topography, beaver activity, plugged outlets, and the ratio of developed to undeveloped land in the watershed. Paved or impervious surfaces will create faster runoff and quickly rising lake levels during large rain events, while forests, wetlands, and pastures will slow down runoff and limit large rises in lake level

Lake Levels for Lake Goodwin and Lake Shoecraft are managed by the Tulalip Tribes and lake residents with a weir and removable boards at the outlet of Lake Shoecraft. Boards are removed in the winter months to alleviate rising lake levels and are re-installed in the summer months to retain water. SWM installed a continuous gage at the Lake Goodwin Community Park dock in April 2016 to monitor lake levels year round. Lake data is recorded hourly as elevation in feet. The graph below shows the daily average lake level and daily total rainfall for Lake Goodwin from the time of installation through mid-April 2017. The precipitation data used for graph was recorded at the Lake Goodwin Community Park. The lake levels fluctuated 1.9 feet in 2016. The summer of 2016 was fairly dry and the lake level dropped quite low. Heavy rains in in the fall resulted in large rises in the lake level.



Aquatic Plants

Aquatic plants are also important in a lake ecosystem. Plants provide food and shelter for fish and other aquatic animals, stabilize the shoreline and bottom sediments, and in some cases increase water clarity by out-competing algae for nutrients. Some plants grow entirely submersed under the water (like elodea), some have leaves that float on the surface (like lilies), and others have roots under the water with most of the plant standing above the water (like cattails).

Although aquatic plants are essential for lake health, excess growth of aquatic plants can interfere with swimming, boating, fishing, and wildlife habitat. In addition, invasion by non-native plant species can seriously damage a lake ecosystem. Non-native aquatic plants choke out native plants and form dense stands that are a nuisance to humans and wildlife.

Lake Goodwin continues to have localized infestations of Eurasian watermilfoil, an invasive aquatic plant. There are scattered locations with one to several individual milfoil plants and a few locations with small, dense patches. These existing milfoil plants put the whole lake at risk of infestation because small fragments of milfoil can break off and potentially spread the plants to other areas of the lake. In 2008, one small area of milfoil plants near the outlet channel to Lake Shoecraft expanded into a dense patch with hundreds of plants. By the end of August 2009, most of the plants in this patch had been removed. However, more small patches of milfoil were found in recent years in other parts of Lake Goodwin that likely came from this source, and Lake Shoecraft became re-infested by milfoil fragments from Lake Goodwin.

In 2013, Snohomish County secured a State permit to allow herbicide treatments to control the growth of milfoil. A contractor applied herbicides to 12 acres of milfoil in Lake Goodwin in July 2013. Diving surveys from 2014 to 2016 showed that the herbicides were effective in the treated areas. However, patches of milfoil were found in several other areas of the lake. Snohomish County and lake residents will continue to work on controlling and eliminating this plant using funds collected from the property owners around the lake.

SHORELINE CONDITION

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

Lake Goodwin has the second most densely developed lake shoreline in the county. Surveys conducted in the mid-90s identified 381 homes bordering the lake with an average of 13.2 homes per 1000 feet of shoreline. There are also 367 docks present, covering nearly 5 acres of the lake. Seventy percent of the 5.7 miles of shoreline has been modified, with bulkheads comprising the majority of the modifications (62%) and rock or log revetments accounting for 6.6%. The zone of native vegetation immediately adjacent to the shoreline has also been dramatically altered, with only 4% now being classified as still intact. In addition, there is almost no large wood remaining in Lake Goodwin. These old logs and branches are valuable for fish and wildlife habitat.

The high level of shoreline modification leaves the lake susceptible to pollution inputs from the watershed, eliminates the buffer of vegetation that can filter out pollution, and limits the amount of aquatic habitat available to fish and wildlife. The loss of native vegetation along the shoreline could also lead to shoreline erosion.

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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, Lake Goodwin may be classified as oligotrophic with high water clarity, low phosphorus concentrations, and low amounts of algae.

Condition and Trends

Overall, Lake Goodwin appears to be in good condition. The water quality targets for the lake are to maintain long-term averages of 5.0 meters for water clarity and phosphorus averages of 7 µg/L in the upper waters and 31 µg/L in the bottom waters.

The target for water clarity is being met because the long-term average has improved to 5.3 meters. The phosphorus target for the epilimnion is also being met because the long-term average is unchanged. However, the long-term phosphorus average in the bottom waters is now slightly higher at 33 µg/L. In addition, the higher chlorophyll *a* values from 2002 through 2012, and in 2015 may be an early warning sign of future water quality problems and will need to be carefully tracked.

The primary threat to Lake Goodwin's water quality is the possibility of increases in nutrients from future development or from human activities in the surrounding watershed. The lake is particularly susceptible to watershed inputs given the high degree of shoreline modification and lack of natural vegetation bordering the lakeshore. In order to protect the healthy condition of the lake, measures to control nutrients in the watershed should be taken. To find out more about the causes and problems of nutrient pollution and tips to improve lake water quality visit www.lakes.surfacewater.info.

DATA SUMMARY FOR LAKE GOODWIN

		Water Clarity (Secchi depth in meters)	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**		**Surface**	**Bottom**	**Surface**	**Surface**
Bortleson, et al, 1976	**7/27/72**	4.0	5	16	-	-
Entranco, 1986	**1983**	4.1 - 6.0 (5.3) *n = 5*	<5 (<5) *n = 5*	7 - 20 (13) *n = 5*	-	1.1 - 2.3 (1.5) *n = 5*
DOE	**1989**	4.2 - 6.9 (5.0) *n = 8*	-	-	-	-
Volunteer	**1992**	3.6 - 6.8 (4.8) *n = 7*	-	-	-	-
Volunteer	**1993**	5.3 - 7.1 (6.0) *n = 5*	-	-	-	-
SWM Staff	**1994**	5.7 - 6.2 (5.9) *n = 2*	-	-	-	0.5 - 2.7 (1.6) *n = 2*
SWM Staff	**1995**	5.6	-	-	-	1.9
Volunteer	**1996**	4.0 - 6.5 (4.8) *n = 10*	<2 - 13 (8) *n = 2*	9 - 14 (12) *n = 2*	-	-
SWM Staff or Volunteer	**1997**	3.4 - 7.7 (5.2) *n = 14*	7 - 9 (8) *n = 2*	23 - 36 (30) *n = 2*	-	-
Volunteer	**1998**	3.4 - 7.2 (4.6) *n = 15*	4 - 8 (7) *n = 4*	20 - 39 (28) *n = 4*	-	-
SWM Staff or Volunteer	**1999**	3.4 - 5.9 (4.7) *n = 12*	5 - 14 (8) *n = 4*	16 - 44 (36) *n = 4*	-	-
SWM Staff or Volunteer	**2000**	3.3 - 7.0 (5.1) *n = 11*	3 - 7 (5) *n = 4*	2 - 47 (29) *n = 4*	-	-
Volunteer	**2001**	3.8 - 6.0 (5.0) *n = 12*	6 - 8 (7) *n = 4*	26 - 68 (46) *n = 4*	-	-
Volunteer	**2002**	4.2 - 6.5 (5.5) *n = 10*	5 - 8 (7) *n = 4*	20 - 48 (36) *n = 4*	-	0.5 - 1.9 (1.0) *n = 4*
Volunteer	**2003**	4.0 - 7.0 (5.1) *n = 13*	6 - 9 (7) *n = 4*	14 - 42 (29) *n = 4*	-	1.1 - 1.9 (1.6) *n = 4*
Volunteer	**2004**	4.3 - 6.7 (5.3) *n = 10*	5 - 7 (6) *n = 4*	19 - 37 (28) *n = 4*	-	1.3 - 2.7 (1.8) *n = 4*
Volunteer	**2005**	3.0 - 6.7 (5.2) *n = 13*	5 - 8 (7) *n = 4*	20 - 45 (34) *n = 4*	-	1.1 - 2.4 (1.7) *n = 4*

DATA SUMMARY FOR LAKE GOODWIN

Source	Date	Water Clarity (Secchi depth in meters)	Total Phosphorus (µg/L)		Total Nitrogen (µg/L)	Chlorophyll *a* (µg/L)
			Surface	Bottom	Surface	Surface
Volunteer	**2006**	3.6 - 7.6 (5.7) *n = 14*	4 - 8 (6) *n = 4*	14 - 44 (28) *n = 4*	-	1.6 - 3.2 (2.1) *n = 4*
Volunteer	**2007**	4.3 - 6.2 (5.0) *n = 11*	5 - 8 (6) *n = 4*	32 - 59 (46) *n = 4*	-	2.1 - 2.7 (2.6) *n = 4*
Volunteer	**2008**	4.1 - 6.7 (5.0) *n = 11*	4 - 10 (6) *n = 4*	13 - 38 (23) *n = 4*	-	1.6 - 2.1 (1.8) *n = 4*
Volunteer	**2009**	3.7 - 6.0 (5.0) *n = 10*	5 - 7 (6) *n = 4*	32 - 69 (53) *n = 4*	-	1.5 - 3.2 (2.3) *n = 4*
Volunteer	**2010**	4.3 - 5.6 (5.1) *n = 10*	6 - 13 (10) *n = 4*	27 - 82 (48) *n = 4*	-	2.0 - 4.5 (2.8) *n = 4*
SWM Staff	**2011**	5.3 - 7.0 (6.1) *n = 6*	8 - 11 (10) *n = 4*	15 - 51 (36) *n = 4*	-	1.1 - 3.5 (2.5) *n = 4*
SWM Staff	**2012**	3.9 - 7.2 (5.4) *n = 5*	7 - 11 (8) *n = 4*	8 - 44 (22) *n = 4*	-	1.6 - 4.0 (2.5) *n = 4*
Volunteer	**2013**	4.7 - 7.4 (5.6) *n = 5*	5 - 8 (7) *n = 4*	5 - 28 (21) *n = 4*	-	1.6 - 2.1 (1.8) *n = 5*
Volunteer	**2014**	*4.0 - 9.6* *(5.7)* *n = 13*	*5 - 7* *(7)* *n = 4*	*12 - 66* *(29)* *n = 4*	*339 - 398* *(364)* *n = 4*	*0.50 - 2.1* *(1.2)* *n = 4*
Volunteer	**2015**	*3.3 - 7.4* *(5.0)* *n = 13*	*2 - 5* *(4)* *n = 4*	*26 - 58* *(38)* *n = 4*	*300 - 470* *(362)* *n = 4*	*1.5 - 10* *(3.8)* *n = 4*
Volunteer	**2016**	3.2 - 6.6 (4.9) *n = 12*	4 - 13 (7) *n = 4*	12 - 34 (24) *n = 4*	274 - 419 (363) *n = 4*	0.80 - 3.3 (1.9) *n = 4*
Long Term Avg		**5.2** **(1992-2016)**	**7** **(1996-2016)**	**32** **(1996-2016)**	**363** **(2014-2016)**	**2.1** **(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.
- DOE = Washington Department of Ecology
- "Surface" samples are from 1 meter depth and "bottom" samples are from 1-2 meters above the bottom.