CLMP+ Report on Aerie Lake
(St. Louis County)

Lake ID# 69-0701-00
2014-2015 CLMP+ Data Summary

Minnesota Pollution Control Agency

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Introduction

The Minnesota Pollution Control Agency (MPCA) conducts and supports lake monitoring activities to determine if water quality supports recreational uses (swimming, wading, boating, etc.) of lakes, and to measure and compare regional differences and trends in water quality with lakes from all over the state. MPCA staff, local partners (soil and water conservation districts, watershed districts, tribal entities, etc.), and citizens all play a role in sampling lake water quality.

As part of the MPCA's Advanced Citizen Lake Monitoring Program (CLMP+), Bob Francis, John Wolvin, and Len Kucza measured water quality in Aerie Lake from May-September in 2014 and 2015. Aerie Lake is located in St. Louis County, approximately 3.4 miles northwest of Alborn, Minnesota. It is 143 acres in size and has a maximum depth of 37 feet (11 meters). CLMP+ volunteers measured water transparency, collected temperature and dissolved oxygen (DO) profiles weekly, and collected water chemistry samples monthly. This report provides a summary of the water quality data and of other physical and ecological characteristics of the lake (Figures 1 and 2).

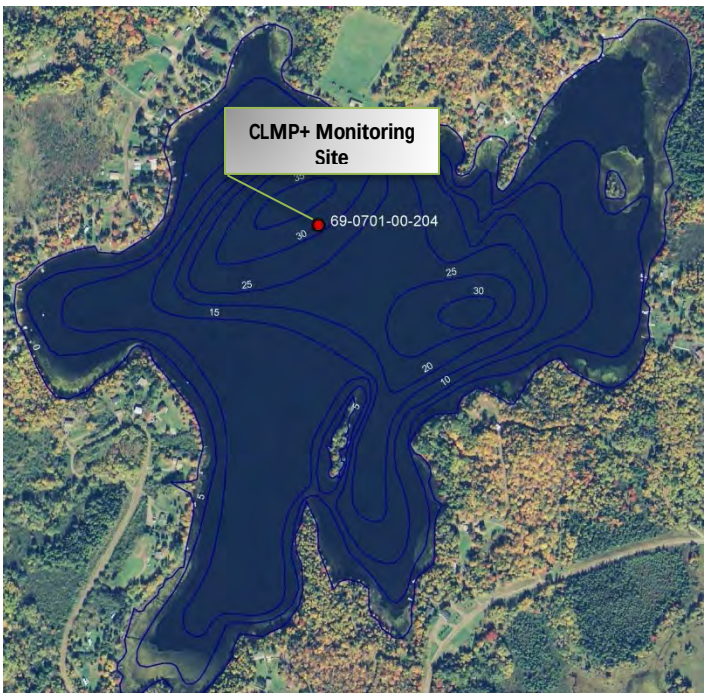

Figure 1. Aerial photo of Aerie Lake

Ecoregion and land use characteristics

When investigating lake water quality, it is important to consider how land within the lake's catchment (the area of land surrounding the lake that drains water directly to it) is used. Certain uses of the land increase pollutant loading to the lake. For instance, phosphorus in animal waste can runoff from feedlots to surface waters during heavy rain events. Likewise, manure and commercial fertilizers can be washed from cultivated fields over land or through tiling systems to lakes. Additionally, phosphorus binds tightly to soil, so eroded soil from developed lakeshore or stream banks is often a large source of phosphorus to lakes and streams. Conversely, forested areas, undeveloped land, and wetlands are important features that preserve good water quality by serving as a buffer to filter water that flows across the catchment and into the lake.

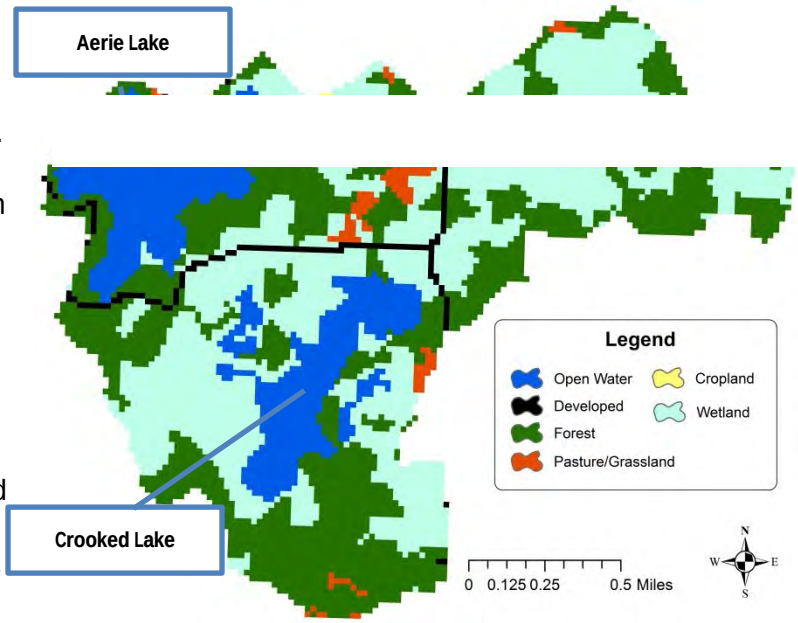

Figure 2. Aerie Lake catchment

Minnesota is divided into seven ecoregions, as defined by soils, land surface form, natural vegetation, and current land use. Aerie Lake is located in the Northern Lakes and Forest (NLF) ecoregion. Throughout this report, Aerie Lake characteristics are compared to the typical range of values from reference lakes within the NLF ecoregion. Aerie Lake has a catchment area of 1,552 acres. This is a small-sized watershed relative to the size of the lake (11:1 watershed: lake area ratio). Lakes with small watersheds relative to lake area often receive low water and nutrient loads; in contrast, those with large watersheds often receive high water and nutrient loads. In general, land use in the Aerie Lake catchment is very similar to the typical land uses found in the NLF ecoregion. Watersheds dominated by forest and wetland typically deliver low amounts of nutrients to lakes.

Table 1. Land use composition

Land use	Aerie Lake catchment land use percentage	NLF typical land use percentage
Developed	2	0 – 7
Cultivated (Ag)	0.1	< 1
Pasture and open	2	0 – 6
Forest	37	54 – 81
Water and wetland	59	14 – 31
Feedlots (#)	0	

Lake mixing and stratification

Lake size, depth, and the shape of the basin affect whether a lake stratifies (forms distinct temperature layers) and how it mixes, which have a significant influence on water quality. Deep lakes that stratify during the summer months fully mix, or turn over, twice per year; typically in spring and fall. Shallow lakes (maximum depths of six meters or less), in contrast, typically do not stratify and mix continuously. Lakes with moderate depths may stratify intermittently during calm periods, but mix during heavy winds and during spring and fall. Mixing events allow nutrient-rich lake sediments to be re-suspended, which introduces phosphorus into the water where it may encourage the growth of algae, so lakes that continuously mix are at more risk of developing algal blooms than deeper lakes that stratify. Lakes that strongly stratify often have little or no oxygen near the lake bottom. Low oxygen can allow phosphorus to be released from the lake sediments, which is another way nutrients are introduced to the water and can stimulate the growth of algae. To determine if a lake stratifies or not, water temperature and DO are measured throughout the water column (surface to bottom) at selected intervals (e.g. every meter) several times during the open-water season. These measurements, called “profiles”, will reveal specific patterns if the lake stratifies and will also show how oxygen changes with depth.

Weekly temperature and DO profile measurements taken on Aerie Lake were used to create isopleth graphs for the entire summer. The isopleth graph uses colored “bands” to depict changes in temperature and DO from the surface to the bottom of the lake (Figures 3-6). When a lake stratifies, isopleth graphs show distinct horizontal bands of color with depth, which suggests the different “layers”. Horizontal bands are clearly evident in both temperature profile isopleth graphs, indicating that Aerie Lake did stratify in 2014 and 2015 (Figures 3 and 5). Aerie Lake is a dimictic lake, meaning that it has annual spring and fall mixing periods. Lake stratification occurs between these mixing cycles, although the timing each year is highly dependent upon local weather conditions. The temperature isopleth graphs show gradients beginning to appear on the lake in mid-May, after the spring mix, when waters begin to slowly warm. By mid-May in 2014 and mid-June in 2015, several distinct bands of color become

visible on the temperature isopleths (Figures 3 and 5). Stratification generally continues until mid to late September, although data gathered for 2014 and 2015 were not able to fully capture the event, with stratification still clearly visible with multiple bands of color at the end of each data collection season.

The 2014 and 2015, DO profile isopleths depict seasonal changes typical of a stratified lake (Figures 4 and 6). In May and June, with ice recently off, a greater percentage of Aerie Lake has cool, oxygen rich water as compared with later in the summer as the lake begins to stratify and DO declines as the water warms (oxygen dissolves more readily in cooler water). Additionally, the bacterial break down of decaying organic matter (i.e. algae, fish droppings and other vegetation) depletes oxygen levels even further at the lake bottom. Higher levels of DO exist near the surface, even though the water is warmer, because of the photosynthetic activity of plants and algae.

Overall, temperature and DO levels are typical of a lake the size and depth of Aerie. In order for a lake to support cool and warm water game fish, a DO concentration of five milligrams per liter (mg/L) is necessary. As is typical in stratified lakes, the DO concentrations in Aerie Lake remained regularly well above 5 mg/L in the well-mixed waters of the upper surface of the lake, but declined rapidly to well below 5 mg/L toward the lake bottom (Figures 4 and 6). This is not concerning, as the layer of oxygen-rich water appears to be ample to support a healthy fishery and is typical of stratified lakes.

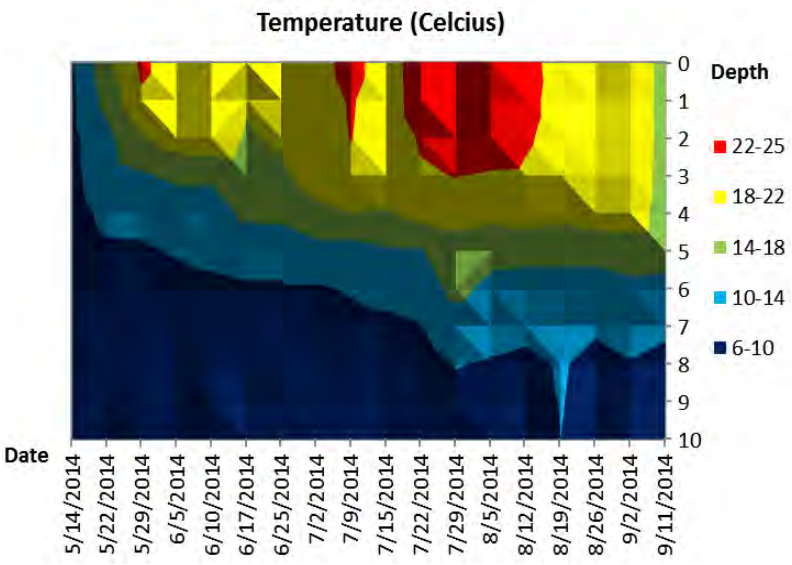

Figure 3. 2014 temperature profile

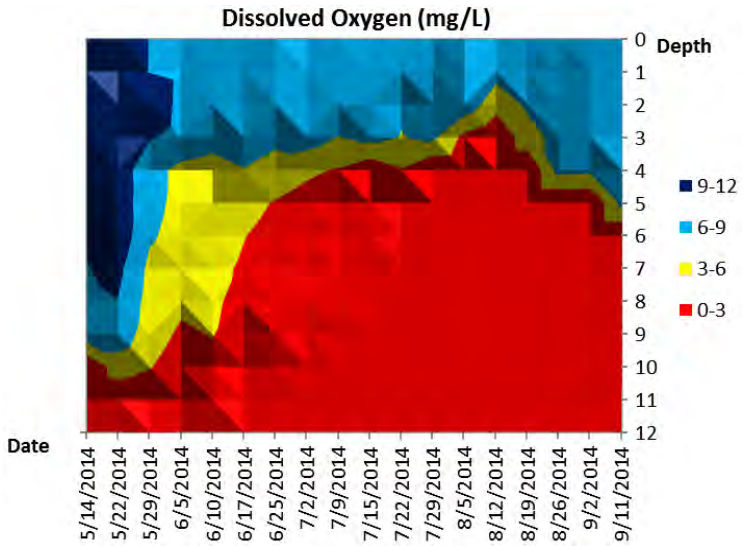

Figure 4. 2014 dissolved oxygen profile

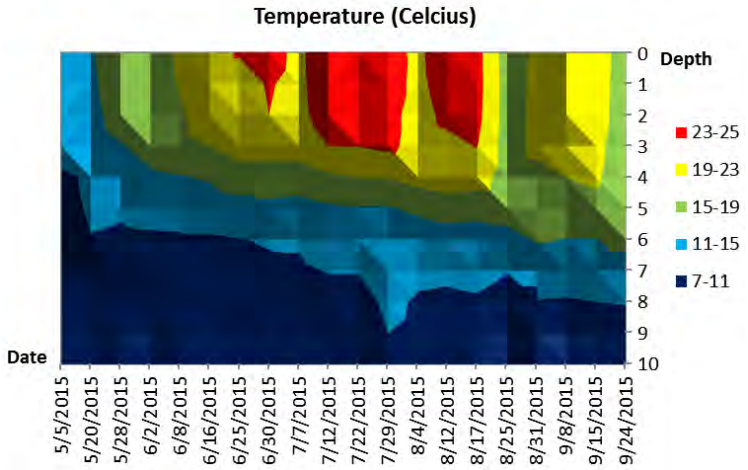

Figure 5. 2015 temperature profile

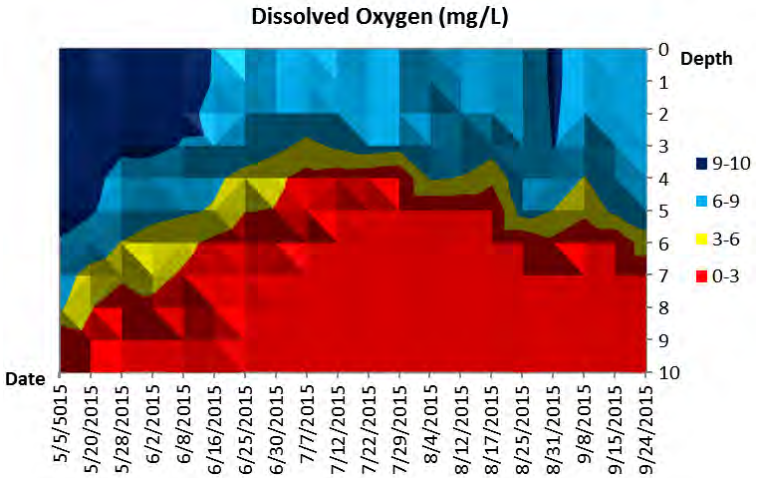

Figure 6. 2015 dissolved oxygen profile

Water quality

Nutrients, typically phosphorus and nitrogen, are the primary drivers of algal productivity in lakes. In general, high nutrient levels increase the likelihood that nuisance algal blooms will grow and that lakes will not support aquatic recreational uses; however, there are sometimes other factors at play that also must be considered. For this reason, it's important to collect information on suspended solids, temperature, DO, and a number of other parameters. All June-September water chemistry data for Aerie Lake gathered in 2014 and 2015 were averaged and compared to minimally impacted reference lakes in the NLF ecoregion (Table 2). References to lakes included in the last column in Table 2 include those selected to be typical of the ecoregion and minimally impacted, and allow for comparison to Aerie Lake.

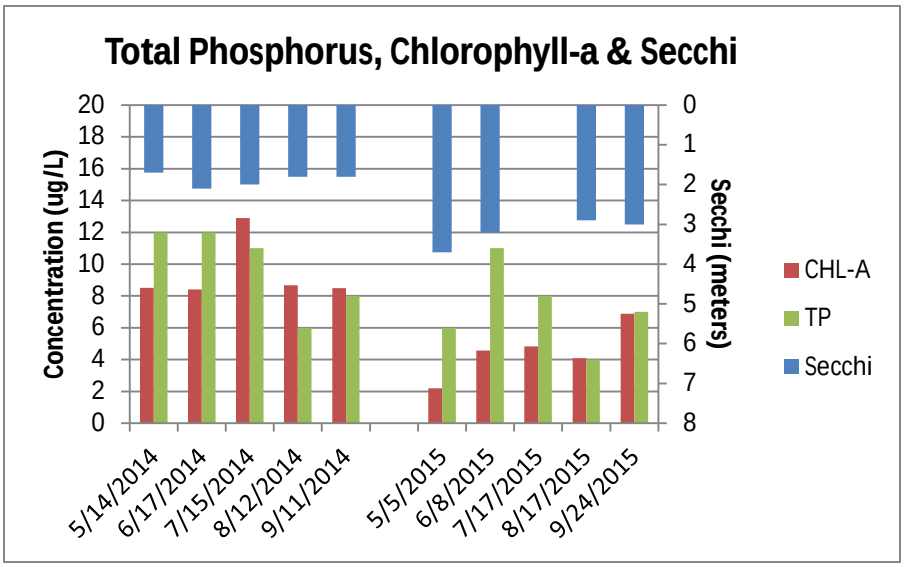

Figure 7. 2014 and 2015 phosphorus, chlorophyll-a, and Secchi

Total phosphorus (TP) is often considered the nutrient that "limits" algal growth in lakes. This is because it is essential to algal growth and it is typically in the shortest supply. Aerie Lake's summer average TP, 10 ug/L, is much better than typical range for NLF lakes, which is 14-27 ug/L (Table 2). Samples collected near the bottom of the lake had only slightly higher concentrations of phosphorus than surface readings, with bottom samples ranging from 10 ug/L to 22 ug/L. Bottom sample results were not included when calculating summer averages for Aerie Lake, rather they were gathered to help gauge lake turnover (when the lake mixes, bottom, and surface phosphorus readings are near equal) and determine the amount of phosphorus diffusing out of the sediment during anoxic conditions at the lake bottom during stratification.

Nitrogen, while also an essential nutrient for algal growth is typically not the "limiting nutrient" in most Minnesota lakes. Total Kjeldahl nitrogen is a measure of organic nitrogen (i.e., nitrogen found in algae) and ammonia- nitrogen. When combined with inorganic nitrogen, this represents total nitrogen (TN). Since inorganic nitrogen is often at or below detection in lakes, we often use total Kjeldahl alone to represent TN. The ratio of TN to TP is used as a simple basis for discerning which nutrient, TN or TP, is the limiting nutrient. Lakes are often considered "nitrogen-limited" when the TN:TP ratio falls below about 10:1. In the case of Aerie Lake its 67:1 TN:TP ratio is high, over the typical range for NLF lakes, indicating that phosphorus is the nutrient controlling algal growth in this lake. The addition of phosphorus to the lake could increase the production of algae and aquatic plants.

Chlorophyll-*a* (Chl-*a*) (a pigment found in algae) is used to estimate the amount of algal production in a lake and, therefore, the lake's response to nutrients. As would be anticipated with the low TP results found in Aerie Lake, its Chl-*a* summer average of 7 ug/L was also low. With concentrations from 10-20 ug/L indicating a mild algal bloom and concentrations greater than 30 ug/L indicating severe nuisance conditions, an algal bloom on Aerie Lake in 2013 or 2014 would have been possible, but extremely mild.

Table 2. Aerie Lake 2014-2015 as compared to typical range for NLF ecoregion reference lakes[1]

Parameter	Aerie Lake 2014 Average	Aerie Lake 2015 Average	Aerie Lake 2-year summer Average	Typical range for minimally impacted lakes in NLF
Number of reference lakes	1	1	1	32
Total phosphorus (µg/L)	10	10	10	14 – 27
Chlorophyll (µg/L)	9	5	7	4 – 10
Transparency **(feet)** **(meters)**	 6.2 1.9	 10.5 3.2	 8.2 2.5	 8 – 15 2.4 – 4.6
Total Kjeldahl Nitrogen (mg/L)	0.68	0.57	0.62	0.4 – 0.75
Alkalinity (mg/L)	10*	10*	10*	40 – 140
Chloride (mg/L)	3.7	3.7	3.7	0.6 – 1.2
Total Suspended Solids (mg/L)	2.3	1.5	1.8	< 1 – 2
Total Suspended Inorganic Solids (mg/L)	0.2	0.2	0.2	< 1 – 2
TN:TP ratio	73:1	62:1	67:1	25:1 – 35:1

1. Concentrations shown are the mean of samples taken June-September (i.e., summer means)
ug/L = micrograms per liter; mg/L = milligrams per liter

* Several readings were below detectable lab limits. For the purposes of summarizing data, all non-detect samples were rounded up to the lowest detectable limit.

Chloride (Cl) for Aerie Lake was slightly higher than the typical range for NLF lakes (Table 2). The primary source of Cl to Minnesota lakes is winter application of road de-icing (road salt) compounds; however, other potential sources include water softeners, treated wastewater effluent, and seepage from septic systems. As noted in all lakes with development, Cl levels will likely continue to increase in the years to come since it is a conservative pollutant, meaning that it does not break down or leave the lake system over time. Chloride levels found in Aerie Lake are very low and impacts to aquatic life are not found unless concentrations are consistently above 200 mg/L.

Secchi transparency measures the depth of water clarity. Aerie Lake's two year transparency average falls within the typical range for NLF lakes (Table 2 and Figure 8), however it is slightly lower than the long-term transparency average of 8.9 feet (2.7 meters) due to low transparency readings in 2014. In fact, 2014's Secchi average is tied for the second worst yearly average for Secchi transparency since records began for Aerie Lake in 1975 (Figure 9). In some lakes, high total suspended sediment or high color may also limit transparency. High total suspended sediment may arise from suspended sediments (e.g. from runoff or wind mixing), but this doesn't appear to be a concern for Aerie Lake.

CLMP+ data collected for Aerie Lake show that in terms of TP, chlorophyll, and Secchi disk transparency, the water quality of the lake is equal to or better than minimally impacted (reference) lakes in the ecoregion. Moderately productive lakes such as Aerie are termed 'mesotrophic'.

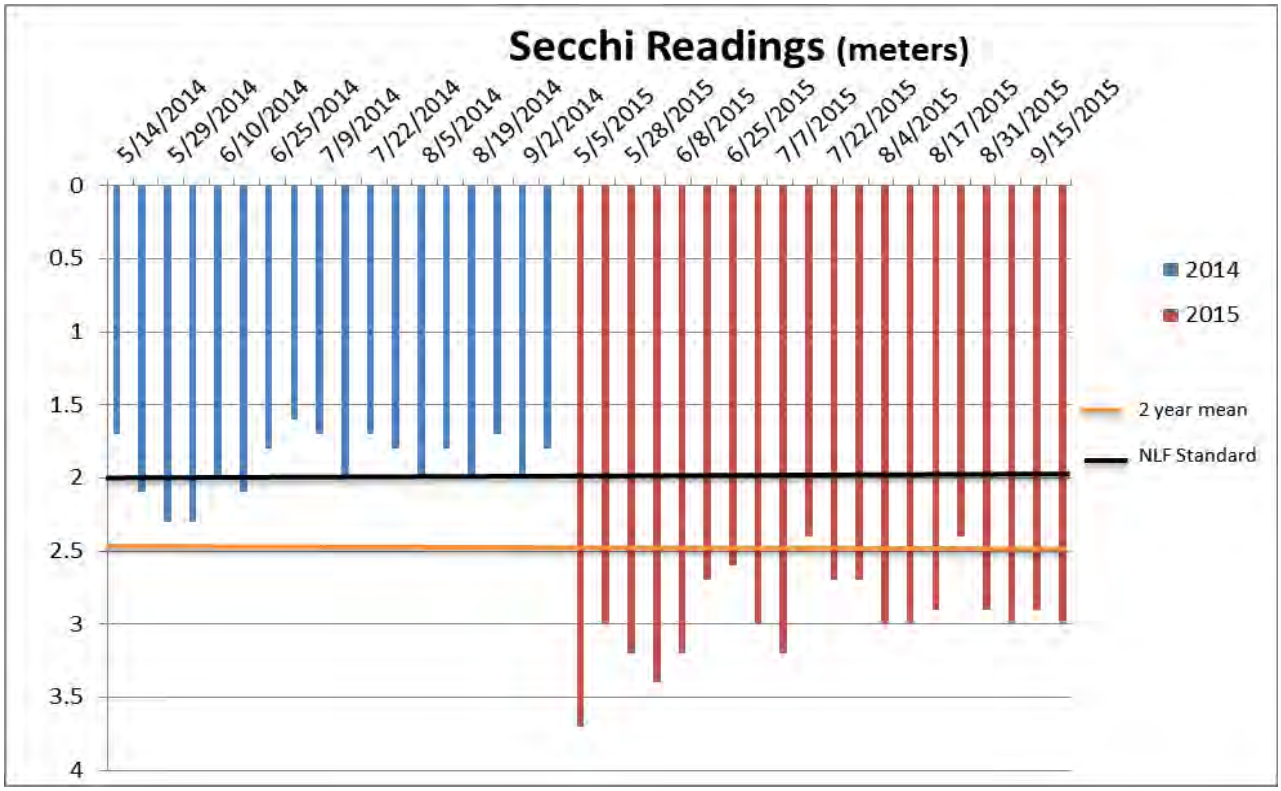

Figure 8. 2014 and 2015 Secchi readings

Trends

As part of the CLMP, citizens have monitored Aerie Lake for 16 years. The primary purpose of CLMP monitoring is to gather water clarity information for as many lakes as possible over a long period of time to determine if the water clarity trend for the lake over time is increasing, declining or remaining stable. At least 20 data points spread over eight years are required for a basic trend analysis, and more data are often needed to see an actual increasing or declining trend.

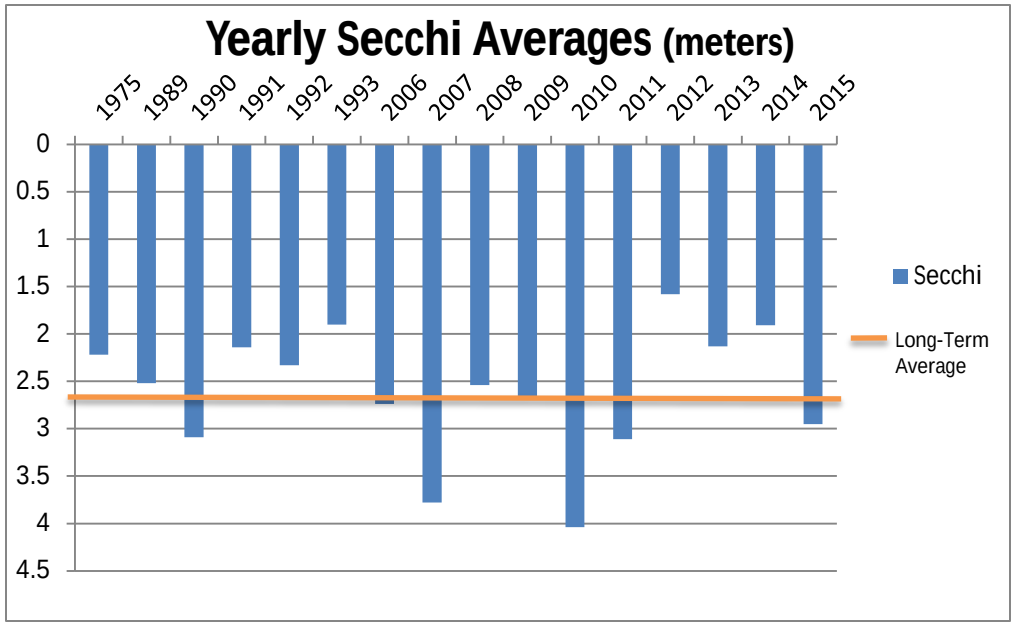

Figure 9. Long-term Secchi averages

Sufficient Secchi readings were collected on the Aerie Lake between 1975 and 2015 to run the trend analysis; however, given the variability of the readings over these years, there is no evidence yet of a long-term trend in either direction. Continued participation in the CLMP program would help gather the data necessary to determine if a trend transparency trend will emerge in the future.

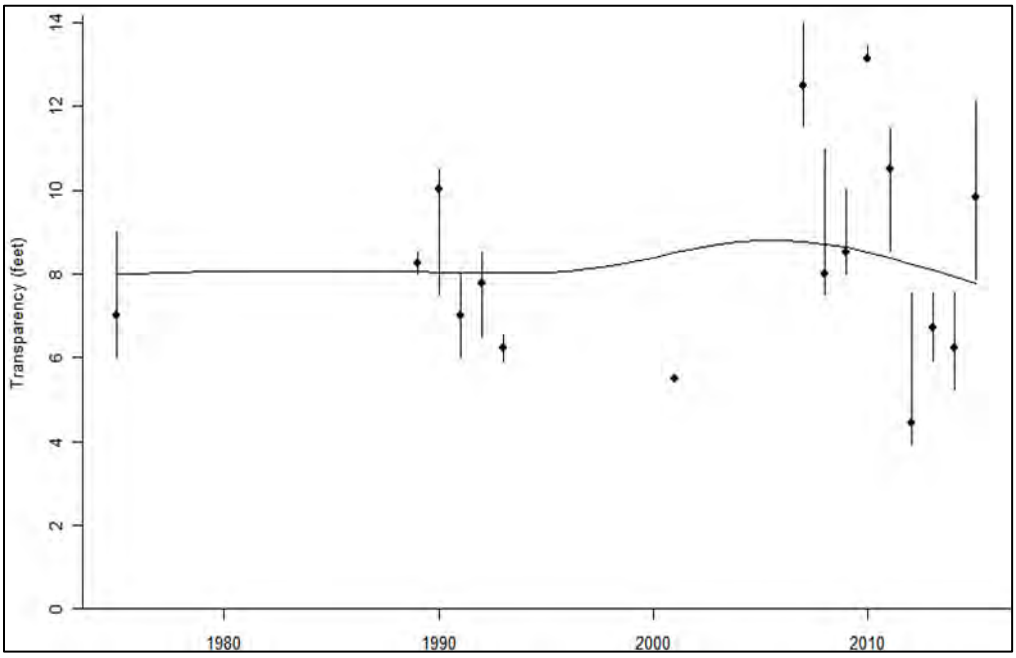

Figure 10. Secchi trend analysis

Summary

All of the water quality data from the MPCA's monitoring activities, those of its citizen volunteers and of other state and local partners, are gathered together and used to assess the condition of Minnesota lakes by determining if thresholds set to protect a lake's recreational uses (swimming, wading, boating, etc.) are being met. Annual assessments of lake and stream data are conducted on a rotating watershed basis. Aerie Lake is located within the St. Louis River major watershed. In 2009 and 2010, a selection of streams and lakes within this watershed were monitored as part of the MPCA's intensive monitoring schedule. More information on the monitoring results and next steps for the watershed can be found here: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/st.-louis-river.html#overview.

Based on water quality data collected as part of CLMP+ in 2014-2015, Aerie Lake has very good water quality and is considered to be fully meeting the thresholds set to protect lakes in the NLF ecoregion for aquatic recreation (Table 3).

Table 3. A comparison of water quality data from Aerie Lake to the lake eutrophication standards for the NLF ecoregion.

	TP (µg/L)	Chl-*a* (µg/L)	Secchi (m)
Thresholds set to protect lakes in the NLF ecoregion for aquatic recreation use	<30	<9	>2.0
Aerie Lake 2-year summer averages	10	7	2.5

Engagement at the local level will be required to maintain Aerie Lake's high level of water quality.

Recommendations

- Continue to participate in the CLMP and regularly collect transparency data to provide the continuous water quality records needed for trend assessment.
- Continue to minimize as much as possible the potential for phosphorus to be routed, or loaded, to the lake. This entails limiting lakeshore development (or utilizing good shoreland management during development) and retaining as much undeveloped land in the lake catchment as possible.
- Engage with county and township officials to ensure protection of wetlands in the surrounding watershed. Wetlands trap and filter sediments and nutrients, limiting their eventual run-off into Aerie Lake.
- Best management practices should be used when applying road deicers. Specifically, minimize the salting of roads near the lakes, and stockpile snow in upland areas away from the lakeshore.
- Maintain native aquatic plant beds to support fishery habitat and the quality and balance of the fish community. Native aquatic plants also provide natural wave breaks and results in decreased shoreline erosion. Increased wave action stirs lake sediments, clouding the water, making it difficult for new plants to grow.
- Maintain remaining shoreline emergent aquatic vegetation – potentially important habitat for invertebrates and juvenile fish in addition to being a natural trap for washed in sediments and nutrients. Educate shoreland homeowners on the benefits of this habitat. The Minnesota Shoreland Management Guide (http://shorelandmanagement.org) provides useful information on this and other issues relevant to conserving the lake's beneficial uses.