# Lakewatch

The Alberta Lake Management Society Volunteer Lake Monitoring Program

# Crane Lake Report

2019

Lakewatch is made possible with support from:







WATERSHED ASSOCIATIO

## ALBERTA LAKE MANAGEMENT SOCIETY'S LAKEWATCH PROGRAM

LakeWatch has several important objectives, one of which is to collect and interpret water quality data from Alberta's Lakes. Equally important is educating lake users about aquatic environments, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. LakeWatch reports are designed to summarize basic lake data in understandable terms for the widest audience, and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in LakeWatch, and readers requiring more information are encouraged to seek those sources.

ALMS would like to thank all who express interest in Alberta's aquatic environments, and particularly those who have participated in the LakeWatch program. These leaders in stewardship give us hope that our water resources will not be the limiting factor in the health of our environment.

If you require data from this report, please contact ALMS for the raw data files.

## ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Ron Young for his commitment to collecting data at Crane Lake. We would also like to thank Sarah Davis Cornet, Caleb Sinn, and Pat Heney, who were summer technicians in 2019. Executive Director Bradley Peter and Program Coordinator Caitlin Mader were instrumental in planning and organizing the field program. This report was prepared by Pat Heney, Bradley Peter, and Caleb Sinn.

## CRANE LAKE

Crane Lake was originally named Moore Lake, after Dr. Bromley Moore, a former president of the College of Physicians and Surgeons and a friend of the surveyor Marshall Hopkins<sup>1</sup>. Moore Lake is locally referred to as Crane Lake. Crane Lake is a medium sized (surface area = 9.28 km<sup>2</sup>) and deep (max depth = 26 m, mean depth = 8.3 m) water body located in the Beaver River Watershed. Located in Alberta's Lakeland Region, Crane Lake is valued for its clear water and natural shoreline.

The lake is situated about 280 km northeast of Edmonton in the municipal district of Bonnyville. The town of Bonnyville, south of the lake, and Cold Lake, east of the lake, are the principal urban centers of the area. Most of Crane Lake's shoreline is crown land. Two former Provincial Areas, Crane Lake East and West, have been disestablished and divested to the Municipal District of Bonnyville. There are two commercial resorts on the south shore. Crane Lake is a headwater lake with a small drainage basin that is only four times the size of the lake. The only inlets are two minor streams: one on the northeast shore and one on the west shore. The



Crane Lake- Photo by Ageleky Bouzetos 2015

outlet flows from the east shore into nearby Hilda and Ethel Lakes and eventually into the Beaver River.

The watershed area for Crane Lake is 43.90 km<sup>2</sup> and the lake area is 10.29 km<sup>2</sup>. The lake to watershed ratio of Crane Lake is 1:4. A map of the Crane Lake watershed area can be found at: http://alms.ca/wp-content/uploads/2016/12/Crane.pdf

<sup>&</sup>lt;sup>1</sup> Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/

## METHODS

**Profiles:** Profile data is measured at the deepest spot in the main basin of the lake. At the profile site, temperature, dissolved oxygen, pH, conductivity and redox potential are measured at 0.5 - 1.0 m intervals. Additionally, Secchi depth is measured at the profile site and used to calculate the euphotic zone. For select lakes, metals are collected at the profile site by hand grab from the surface on one visit over the season.

**Composite samples:** At 10-sites across the lake, water is collected from the euphotic zone and combined across sites into one composite sample. This water is collected for analysis of water chemistry, chlorophyll-a, nutrients and microcystin. Quality control (QC) data for total phosphorus was taken as a duplicate true split on one sampling date. ALMS uses the following accredited labs for analysis: Routine water chemistry and nutrients are analyzed by Maxxam Analytics, chlorophyll-*a* and metals are analyzed by Innotech Alberta, and microcystin is analyzed by the Alberta Centre for Toxicology (ACTF).

*Invasive Species:* : Invasive mussel monitoring involved sampling with a 63 µm plankton net at three sample sites twice through the summer season to determine the presence of juvenile dreissenid mussel veligers. Technicians also harvested potential Eurasian watermilfoil (*Myriophyllum spicatum*) samples and submitted them for further analysis at the Alberta Plant Health Lab to genetically differentiate whether the sample was the invasive Eurasian watermilfoil or a native watermilfoil. In addition, select lakes were subject to a bioblitz, where a concerted effort to sample the lake's aquatic plant diversity took place.

*Data Storage and Analysis:* Data is stored in the Water Data System (WDS), a module of the Environmental Management System (EMS) run by Alberta Environment and Parks (AEP). Data goes through a complete validation process by ALMS and AEP. Users should use caution when comparing historical data, as sampling and laboratory techniques have changed over time (e.g. detection limits). For more information on data storage, see AEP Surface Water Quality Data Reports at <u>www.alberta.ca/surface-water-quality-data.aspx.</u>

Data analysis is done using the program R.<sup>1</sup> Data is reconfigured using packages tidyr <sup>2</sup> and dplyr <sup>3</sup> and figures are produced using the package ggplot2 <sup>4</sup>. Trophic status for each lake is classified based on lake water characteristics using values from Nurnberg (1996)<sup>5</sup>. The Canadian Council for Ministers of the Environment (CCME) guidelines for the Protection of Aquatic Life are used to compare heavy metals and dissolved oxygen measurements. Pearson's Correlation tests are used to examine relationships between total phosphorus (TP), chlorophyll-*a*, total kjeldahl nitrogen (TKN) and Secchi depth, providing a correlation coefficient (r) to show the strength (0-1) and a p-value to assess significance of the relationship. For lakes with >10 years of long term data, trend analysis is done with non-parametric methods. The seasonal Kendall test estimates the presence of monotonic (unidirectional) trends across individual seasons (months) and is summed to give an overall trend over time. For lakes that had multiple samplings in a single month, the value closest to the middle of the month was used in analysis

<sup>&</sup>lt;sup>1</sup>R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <u>https://www.R-project.org/</u>.

<sup>&</sup>lt;sup>2</sup> Wickman, H. and Henry, L. (2017). tidyr: Easily Tidy Data with 'spread ()' and 'gather ()' Functions. R package version 0.7.2. https://CRAN.R-project.org/package=tidyr.

<sup>&</sup>lt;sup>3</sup> Wickman, H., Francois, R., Henry, L. and Muller, K. (2017). dplyr: A Grammar of Data Manipulation. R package version 0.7.4. http://CRAN.R-project.org/package=dplyr.

<sup>&</sup>lt;sup>4</sup> Wickham, H. (2009). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

<sup>&</sup>lt;sup>5</sup>Nurnberg, G.K. (1996). Trophic state of clear and colored, soft- and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake and Reservoir Management 12: 432-447.

BEFORE READING THIS REPORT, CHECK OUT <u>A BRIEF INTRODUCTION TO</u> <u>LIMNOLOGY</u> AT ALMS.CA/REPORTS

## WATER CHEMISTRY

ALMS measures a suite of water chemistry parameters. Phosphorus, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 2 for a complete list of parameters.

The average total phosphorus (TP) concentration for Crane Lake was 17  $\mu$ g/L (Table 2), falling into the mesotrophic, or moderately productive trophic classification. This value is lower than most historical averages for Crane Lake. Detected TP was lowest when sampled on August 14 at 13  $\mu$ g/L, and peaked at 21  $\mu$ g/L on September 24 (Figure 1).

Average chlorophyll-*a* concentration in 2019 was 5.3  $\mu$ g/L (Table 2), falling into the mesotrophic, or moderate productivity trophic classification. Like TP, Chlorophyll-*a* was lowest at the start of the season, with a minimum of 3.1  $\mu$ g/L on June 14 and a maximum of 7.9  $\mu$ g/L on September 24.

Finally, the average TKN concentration was 0.9 mg/L (Table 2) with concentrations highest on July 13 at 1.0 mg/L.

Average pH was measured as 8.92 in 2019, buffered by moderate alkalinity (453 mg/L CaCO<sub>3</sub>) and bicarbonate (445 mg/L HCO<sub>3</sub>). Aside from bicarbonate, sodium was the dominant ion contributing to a moderate conductivity of 908  $\mu$ S/cm (Table 2).



Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Crane Lake.

#### METALS

Samples were analyzed for metals once throughout the summer (Table 3). In total, 27 metals were sampled for. It should be noted that many metals are naturally present in aquatic environments due to the weathering of rocks and may only become toxic at higher levels.

Metals were measured on August 6, 2019 at Crane Lake at the surface and all measured values fell within their respective guidelines (Table 3).

## WATER CLARITY AND SECCHI DEPTH

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi depth. Two times the Secchi depth equals the euphotic depth – the depth to which there is enough light for photosynthesis.

The average Secchi depth of Crane Lake in 2019 was 4.01 m (Table 2). Secchi depth was relatively consistent throughout the season, with values indicating a very clear water column relative to most central and south Albertan lakes (Figure 2).



Figure 2. Secchi depth values measured four times over the course of the summer at Crane Lake in 2019.

## WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen (DO) profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

Temperatures of Crane Lake varied throughout the summer, with a minimum temperature of 7.2°C at 26.5 m on June 13, and a maximum temperature of 19.6°C measured at 1.5 m on August 14 (Figure 3a). The lake was strongly stratified during all of the sampling trips, with a steep drop in temperature and dissolved oxygen between 10 and 14 meters below the surface. This indicates that the top and bottom of the water column mix little throughout the open water season.

Crane Lake remained well oxygenated through the upper layer of the water column throughout the summer, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 3b). The oxygen level fell below this level in the bottom 10 to 12 meters throughout the sampling season, due to a lack of mixing with the warmer water on the surface. This is typical for a stratified lake such as Crane Lake.



Figure 3. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Crane Lake measured four times over the course of the summer of 2019.

## MICROCYSTIN

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, can cause severe liver damage when ingested and skin irritation with prolonged contact. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20  $\mu$ g/L. Blue-green algae advisories are managed by Alberta Health Services. Recreating in algal blooms, even if microcystin concentrations are not above guidelines, is not recommended.

Microcystin levels in Crane Lake fell below the recreational guideline of  $20 \ \mu g/L$  for at the locations and times sampled in Crane Lake in 2019. Microcystin concentrations were below the detection limit of 0.1 micrograms per litre on July 13. A value of 0.10 is used for the purpose of calculating average concentration in instances of no detection.

Microcystin Concentration (µg/L)
0.13
<0.10
0.11
0.12
0.10

Table 1. Microcystin concentrations measured four times at Crane Lake in 2019.

#### INVASIVE SPECIES MONITORING

Dreissenid mussels pose a significant concern for Alberta because they impair the function of water conveyance infrastructure and adversely impact the aquatic environment. These invasive mussels have been linked to creating toxic cyanobacteria blooms, decreasing the amount of nutrients needed for fish and other native species, and causing millions of dollars in annual costs for repair and maintenance of water-operated infrastructure and facilities.

Monitoring involved using a 63  $\mu$ m plankton net at three sample sites to look for juvenile mussel veligers in each lake sampled. No mussels were detected at Crane Lake in the summer of 2019.

Eurasian watermilfoil is non-native aquatic plant that poses a threat to aquatic habitats in Alberta because it grows in dense mats preventing light penetration through the water column, reduces oxygen levels when the dense mats decompose, and outcompetes native aquatic plants.

Suspect samples collected from Crane Lake on July 13 were confirmed to be the native Northern watermilfoil (*Myriophyllum sibiricum*).

#### WATER LEVELS

There are many factors influencing water quantity. Some of these factors include the size of the lake's drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake. Requests for water quantity monitoring should go through Alberta Environment and Parks Monitoring and Science division.

Water levels in Crane Lake have remained relatively stable since monitoring began in 1980 (Figure 4). Since 1980, Crane Lake water levels have fluctuated within about a 0.5m range.

Note: Environment Canada provided a revision for Crane Lake water level data from May, 1980 to October, 2009. A correction of -0.344m was applied to the stage record from 1980 to 2009.



Figure 4. Water levels measured in meters above sea level (masl) from 1980- 2019. Data retrieved from Environment Canada (1980 – 2018), and Alberta Environment and Parks (2019).

Parameter	1980	1981	1997	2005	2006	2007	2008	2009
TP (µg/L)	/	27	23	24	23	22	23	19
TDP (µg/L)	/	11	10	11	11	10	12	12
Chlorophyll- <i>a</i> (µg/L)	7.9	8.2	7.0	7.1	4.8	3.6	2.5	2.3
Secchi depth (m)	2.70	3.30	3.50	3.22	2.88	3.15	4.00	3.81
TKN (mg/L)	1.2	0.9	1.0	1.0	1.0	0.9	0.9	0.8
NO2-N and NO3-N (μg/L)	5	3	8	6	6	3	3	5
NH₃-N (µg/L)	29	22	7	10	14	13	10	15
DOC (mg/L)	15	14	/	14	14	14	13	14
Ca (mg/L)	17	17	16	14	15	15	15	15
Mg (mg/L)	41	40	48	42	48	49	50	47
Na (mg/L)	89	81	116	125	112	124	124	125
K (mg/L)	7	8	8	8	8	8	8	8
SO4 <sup>2-</sup> (mg/L)	18	21	28	24	28	26	30	35
Cl <sup>-</sup> (mg/L)	21	21	26	29	30	30	30	31
CO₃ (mg/L)	0.2	/	39	41	41	43	43	42
HCO₃ (mg/L)	/	/	415	457	459	461	469	467
рН	/	/	8.90	8.92	8.94	8.88	8.89	8.94
Conductivity (µS/cm)	9	9	822	842	873	862	870	867
Hardness (mg/L)	724	704	233	207	234	241	246	231
TDS (mg/L)	/	/	482	509	507	523	532	533
Microcystin (μg/L)	/	/	/	0.16	0.39	0.14	0.10	0.13
Total Alkalinity (mg/L CaCO₃)	354	356	400	443	444	450	456	454

Table 2a. Average Secchi depth and water chemistry values for Crane Lake. Historical values are given for reference.

Parameter	2010	2011	2013	2014	2015	2016	2017	2018	2019
TP (μg/L)	29	25	26	20	12	14	13	13	17
TDP (μg/L)	11	14	13	9	7	6	5	4	6
Chlorophyll- <i>a</i> (µg/L)	2.3	6.3	3.2	2.5	3.1	4.2	3.7	4.7	5.3
Secchi depth (m)	3.75	3.69	3.55	3.65	3.65	3.65	3.86	4.02	4.01
TKN (mg/L)	1.0	1.0	1.3	0.9	1.0	0.9	0.9	0.9	0.9
NO2-N and NO3-N (μg/L)	4	5	4	22	3	3	2	4	2
NH₃-N (μg/L)	15	11	13	23	25	25	15	15	12
DOC (mg/L)	13	13	21	14	13	12	13	13	15
Ca (mg/L)	13	14	14	16	12	12	14	15	16
Mg (mg/L)	51	50	54	40	55	57	53	54	52
Na (mg/L)	133	121	129	135	125	136	128	128	123
K (mg/L)	8	6	8	8	8	9	9	9	8
SO4 <sup>2-</sup> (mg/L)	27	21	22	26	30	29	30	29	27
Cl <sup>-</sup> (mg/L)	31	30	30	31	34	34	33	33	36
CO₃ (mg/L)	37	41	41	45	42	48	43	42	53
HCO₃ (mg/L)	480	471	413	549	480	466	458	468	445
рН	8.89	8.95	9.08	8.80	8.91	8.96	8.93	8.87	8.92
Conductivity (µS/cm)	893	890	819	914	916	924	906	900	908
Hardness (mg/L)	243	243	256	205	254	264	254	260	255
TDS (mg/L)	536	515	543	556	540	550	536	544	535
Microcystin (µg/L)	0.09	0.09	0.07	0.08	0.06	0.14	0.13	0.12	0.12
Total Alkalinity (mg/L CaCO₃)	456	454	407	450	460	464	446	454	453

Table 2b. Average historical Secchi depth and water chemistry values for Crane Lake.

Table 3. Concentrations of metals measured in Crane Lake on in each sampling year since 2005. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Values exceeding these guidelines are presented in red.

Metals (Total Recoverable)	2005	2006	2007	2008	2009	2010	2018	2019	Guidelines
Aluminum μg/L	2.10	9.07	5.36	8.86	7.95	4.37	1.70	3.7	100ª
Antimony μg/L	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.024	/
Arsenic µg/L	4.27	3.02	3.66	4.48	3.67	3.06	4.08	4.61	5
Barium μg/L	13.4	14.4	14.4	13.8	14.0	13.3	13.8	15.4	/
Beryllium µg/L	0.003	0.003	<0.003	<0.003	<0.003	0.005	0	0.0015	100 <sup>c,d</sup>
Bismuth µg/L	0.0005	0.001	0.002	0.004	0.0019	0.0005	0	0.0015	/
Boron µg/L	255	327	276	289	311	301	289	288	1500
Cadmium µg/L	0.010	0.005	0.010	0.013	0.012	0.013	0.010	0.005	0.26 <sup>b</sup>
Chromium µg/L	0.24	0.36	0.22	0.41	0.47	0.18	0.10	0.05	/
Cobalt µg/L	0.010	0.025	0.013	0.015	0.020	0.009	0.020	0.021	1000 <sup>d</sup>
Copper μg/L	0.25	0.38	0.24	1.31	0.29	0.24	0.08	0.14	<b>4</b> <sup>b</sup>
Iron μg/L	6.5	6.0	6.8	8.8	19.9	5.2	7.0	8	300
Lead µg/L	0.050	0.066	0.100	0.035	0.013	0.014	0.000	0.004	<b>7</b> <sup>b</sup>
Lithium µg/L	65.7	72.5	61.8	62.1	73.1	66.1	67.9	63.9	2500 <sup>e</sup>
Manganese µg/L	1.8	1.7	2.5	1.9	1.3	1.4	1.4	2.42	200 <sup>e</sup>
Molybdenum μg/L	3.19	3.59	3.15	3.23	3.00	2.90	2.29	2.16	73 <sup>c</sup>
Nickel µg/L	0.01	0.09	0.06	<0.005	0.13	0.06	0.05	0.07	150 <sup>b</sup>
Selenium μg/L	0.2	0.5	0.4	0.7	0.4	0.4	0.8	0.4	1
Silver μg/L	0.001	0.001	<0.0005	0.0014	0.0038	0.000875	<0.0005	<0.1	0.25
Strontium μg/L	68	75.2	73.8	69	69.9	69.2	70.9	80.4	/
Thallium μg/L	0	0.01	0.002	0.0018	0.0031	0.0013	<0.001	0.001	0.8
Thorium μg/L	0.004	0.006	0.018	0.020	0.001	0.005	<0.001	0.002	/
Tin μg/L	0.02	0.03	<0.03	<0.03	<0.03	0.015	0.06	0.03	/
Titanium μg/L	0.61	0.79	0.07	0.74	0.57	0.59	0.36	0.35	/
Uranium μg/L	0.19	0.21	0.21	0.21	0.18	0.18	0.17	0.151	15
Vanadium µg/L	0.15	0.25	0.21	0.235	0.268	0.181	0.11	0.097	100 <sup>d,e</sup>
Zinc μg/L	2.08	2.5	0.751	0.362	0.329	0.66	0.5	0.4	30

Values represent means of total recoverable metal concentrations.

<sup>a</sup> Based on pH  $\geq$  6.5

<sup>b</sup> Based on water hardness > 180mg/L (as CaCO3 )

<sup>c</sup> CCME interim value.

<sup>d</sup> Based on CCME Guidelines for Agricultural use (Livestock Watering).

<sup>e</sup> Based on CCME Guidelines for Agricultural Use (Irrigation).

A forward slash (/) indicates an absence of data or guidelines.

## LONG TERM TRENDS

Trend analysis was conducted on the parameters total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth to look for changes over time in Crane Lake. In sum, non-significant increases were observed in chlorophyll-*a*, significant increasing trends were observed in Secchi depth and TDS, and significant decreasing trends were observed in TP. Secchi depth can be subjective and is sensitive to variation in weather - trend analysis must be interpreted with caution. In addition, chlorophyll-*a* trends should be interpreted with caution as sampling of Crane Lake takes place early in the morning before most phytoplankton activity in the water column occurs. Data is presented below as both a line graph (all data points) or a box-and-whisker plot. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes*.

Parameter	Date Range	Trend	Probability		
Total Phosphorus2005-2019		Decreasing	Significant		
Chlorophyll-a	2005-2019	Increasing	Non-significant		
Total Dissolved Solids 2005-2019		Increasing	Significant		
<b>Secchi Depth</b> 2005-2019		Increasing	Significant		

Table 4. Summary table of trend analysis on Crane Lake data from 2005 to 2019.

#### Definitions:

Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

Box and Whisker Plot: a box-and-whisker plot, or boxplot, is a way of displaying all of our annual data. The median splits the data in half. The 75<sup>th</sup> percentile is the upper quartile of the data, and the 25<sup>th</sup> percentile is the lower quartile of the data. The top and bottom points are the largest and smallest observations.



#### Total Phosphorus (TP)

Total phosphorus (TP) has decreased significantly over the course of data collection at Crane Lake (Tau = -0.41, p < 0.001).



Figure 5. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2005 and 2019 (n = 52). The value closest to the 15<sup>th</sup> day of the monthly was chosen to represent the monthly value in cases with multiple monthly samples.

#### Chlorophyll-a

Chlorophyll-*a* has not changed significantly since sampling began at Crane Lake (p = 0.17, Table 2). When the past 14 years are examined, TP and Chlorophyll *a* did not significantly correlate (r=0.18, p=0.15).



Figure 6. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 2005 and 2019 (N=53). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

#### Total Dissolved Solids (TDS)

Total dissolved solids have increased significantly since sampling began in 2005 (Tau= 0.42, p < 0.001). This is likely not due to evaporative losses as Crane Lake's water levels have not declined in recent years.



Figure 7. Monthly TDS values measured between June and September over the long term sampling dates between 2005 and 2019 (n = 44). The value closest to the  $15^{th}$  day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

#### Secchi Depth

Trend analysis found that water quality measured as Secchi depth has increased (become more clear) over the sampling period (Tau = 0.23, p = 0.016).



Figure 8. Monthly Secchi depth values measured between June and September over the long term sampling dates between 2005 and 2019 (n=52). The value closest to the  $15^{th}$  day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 6. Results of Seasonal Kendall Trend test using monthly total phosphorus (TP), chlorophyll-*a* and Secchi depth data from June to September on Crane Lake data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll-a	Total Dissolved Solids (TDS)	Secchi Depth
Statistical Method	-	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall
The strength and direction (+ or -) of the trend between -1 and 1	Tau	-0.41	0.13	4.22 x 10 <sup>-1</sup>	0.23
The extent (slope) of the trend	Slope	-0.0022	0.0002	5.49 x 10 <sup>-3</sup>	0.0001
The statistic used to find significance of the trend	Z	-4.39	1.37	4.05	2.41
Number of samples included	n	52	53	44	52
The significance of the trend	р	1.12 x 10 <sup>-5</sup> *	0.172	5.18 x 10 <sup>-5</sup> *	0.016*

\*p < 0.05 is significant within 95%