

Water Resources Report

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT
2020 ANNUAL REPORT



Executive Summary

The Riley Purgatory Bluff Creek Watershed District (RPBCWD) had a successful water quality sampling season in 2020, completing a full year of sample collection and data analysis. This effort was made possible through multiple partnerships with municipalities and organizations based within the watershed. The results from the 2020 sampling effort are presented in this report.

2020 LAKE SUMMARY

During the 2020 monitoring season, 13 lakes and two high value wetlands were monitored throughout the District. Regular water quality lake sampling was conducted on each lake approximately every two weeks throughout the growing season (June-September). In addition to regular lake sampling, the District monitored water levels on each lake, assessed carp populations on eight waterbodies, and collected zooplankton and phytoplankton populations in five lakes. Staff were able to remove 201 common carp from the Purgatory Creek Recreation Area during the spring spawning run in attempt to reduce overall carp numbers in the system. The District also monitored public access points and analyzed water samples for the presence of zebra mussels in these 14 waterbodies. Although Lotus Lake was listed for zebra mussels in 2018, only eDNA tested positive and no adults or veligers were found. A second application of alum was applied to Lake Riley in 2020. Herbicide treatments for curly leaf pondweed were carried out on Lotus Lake, Mitchell Lake, Riley Lake, Hyland Lake, and Red Rock for curly leaf pondweed.

Surface water samples were collected, analyzed, and compared to standards set by the Minnesota Pollution Control Agency (MPCA) to assess overall lake health. Figure i displays lakes sampled in 2020 that met or exceeded the MPCA lake water quality standards for Chlorophyll-a (Chl-a), Total Phosphorus (TP), and Secchi Disk depth during the growing season (June-September). The MPCA has specific standards for both 'deep' lakes (Lake Ann, Lotus Lake, Lake Riley, and Round Lake) and 'shallow' lakes (Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake) (MPCA 2016).

In 2020, Lake Ann, Lake Lucy, Lake Riley, Rice Marsh Lake, Hyland Lake, Round Lake, and Duck Lake met all three MPCA standards. The Riley Chain of Lakes showed improvement since 2019 with Lake Lucy meeting all standards in 2020. Lake Riley had the highest recorded summertime secchi disk average (4.64 m) since data collection began in the 1970s. Rice Marsh Lake continued to meet all standards following the alum treatment which occurred in 2018. Lake Susan did not meet the TP and Chl-a standard. Silver Lake of the Purgatory Chain of Lakes met all standards in 2018, but similarly to 2019, did not meet and increased in both Chl-a and TP levels in 2020. Lotus, Mitchell, and Red Rock Lakes had

reduced water quality in 2020, failing to meet all three water quality standards. Hyland Lake had excellent water quality in 2020 which can be attributed to the alum treatment in 2019. Idlewild and McCoy high value wetlands did not meet the TP standard and Staring Lake improved slightly by meeting the TP standard in 2020. All lakes met the nitrate/nitrite water quality standard and only Lake Idlewild did not meet the chloride standard for lakes.

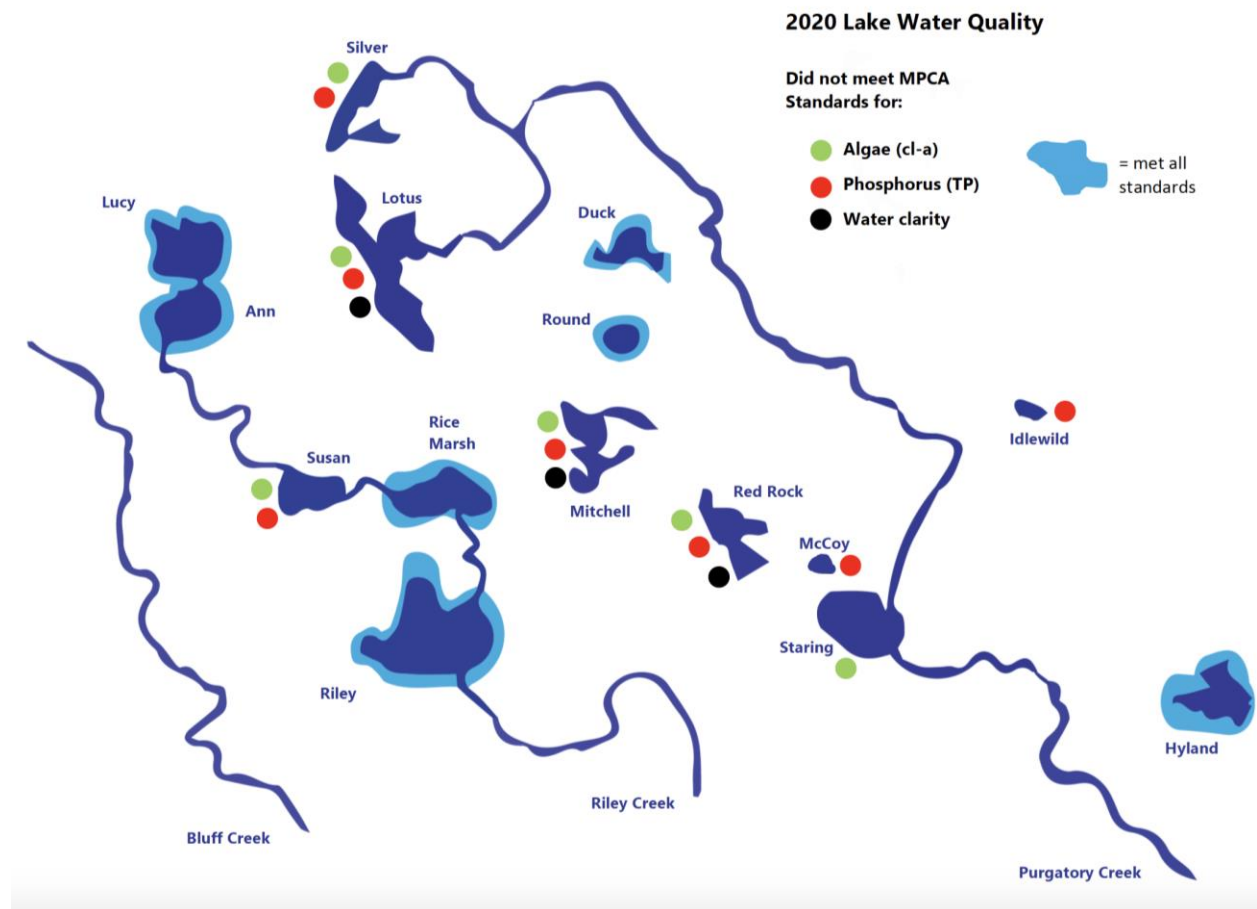


Figure i 2020 Lake Water Quality

Summary of the lake water quality data collected in 2020 by the Riley Purgatory Bluff Creek Watershed District as compared to the Minnesota Pollution Control Agency Water Quality Standards. Chlorophyll-a (green), Total Phosphorus (orange), and Secchi Disk depth (black) during the growing season (June-September) for both ‘deep’ lakes or lakes >15 ft deep and < 80% littoral area (Lake Ann, Lotus Lake, Lake Riley, and Round Lake), and ‘shallow’ lakes or lakes <15 ft deep and >80% littoral area (Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Lake McCoy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake). The corresponding dots next to each lake indicate which water quality standard was not met and lakes surrounded by blue met all water quality standards.

2020 STREAM SUMMARY

In 2020, the District and its partners collected water quality samples and performed data analysis on 23 different sampling sites along Riley Creek (six sites), Bluff Creek (six sites), and Purgatory Creek (twelve sites). During the 2020 creek monitoring season (April-September) water chemistry and turbidity were regularly measured at the 18-regular water quality creek monitoring sites every two weeks. Water samples were collected to assess nutrient (TP, OP, CL, and Chl-a) and total suspended sediment (TSS) concentrations. Creek flow was calculated from velocity measurements taken at consistent creek cross sections at each water quality monitoring location. Staff deployed automated sampling units on upper Bluff to assess pollutant loads and the potential for restoration projects. The District collected macroinvertebrates at all five Bluff Creek regular water quality monitoring sites in 2020. The lower sections of Purgatory Creek and uppermost reach of Bluff Creek were assessed and updated using the Creek Restoration Action Strategy (CRAS) evaluation. Overall, most stream sections scored by the CRAS were similar to years past with the exception of Reach 2 of Purgatory Creek which reduced water quality trends negatively impacted scores.

The summary for all three creeks is based on water quality parameters developed by the MPCA in 2014 for Eutrophication and TSS as well as impairment status for fish and macroinvertebrates. The parameters measured during the summer growing season (April-September) and the associated MPCA water quality limits for streams located in the Central River Region include: Dissolved Oxygen (DO) daily minimum > 4mg/L, summer season average TP < 0.1mg/L, TSS < 10% exceedance of 30mg/L limit during the summer season, summer season average Chl-a <18ug/L, and summer season average pH < 9su and >6su (MPCA, 2016).

Regular creek sampling sites R5 and R3 met all MPCA water quality standards assessed in 2020 (Figure ii), down from 4 sites in 2019 (P3, P4, P5 and R3). The overall number of water quality standard impairments increased from 2019 to 2020; Bluff had ten (previously nine), Riley had six (previously seven), and Purgatory had eleven (previously seven). Once again, TP was the water quality standard causing the most impairments in 2020 with nine of the 18 sites not meeting the standard (summer average <0.1 mg/L). TSS impairments decreased from seven impairments in 2019 to six 2020. Bluff Creek remained the stream with the most impaired water quality for its size, as previously seen between 2015-2019. The impairments included TP across all sites, as well as TSS across three sites, DO at B5, and a fish impairment at B1. All sites met the pH water quality limits in 2020 (< 9su and >6su). Unlike in 2015-2018, P2 met the Chl-a standard (summer average <18ug/L) and no other site exceeded the standard. Macroinvertebrate impairments by the MPCA included lower Purgatory and Riley Creek.

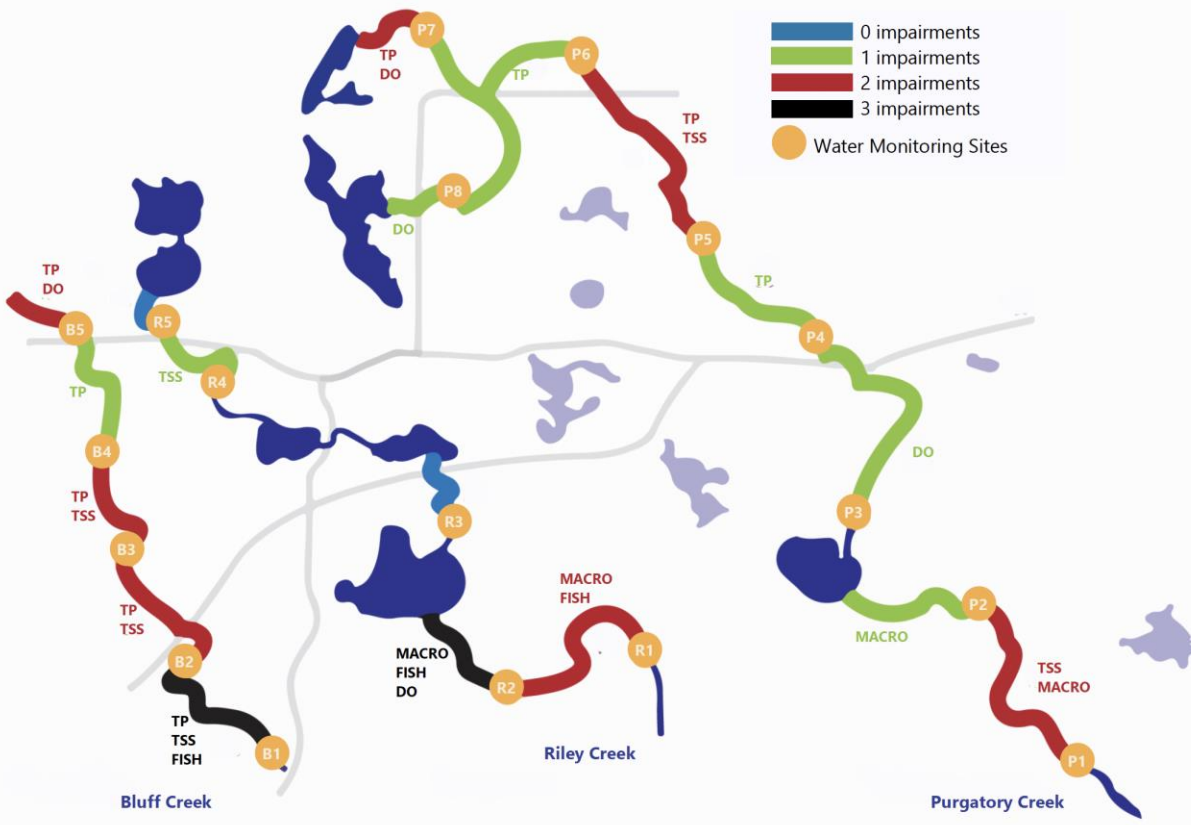


Figure ii 2020 Stream Water Quality

Summary of stream water quality data collected on Bluff Creek, Riley Creek, and Purgatory Creek in 2020 by the Riley Purgatory Bluff Creek Watershed District as compared to the Minnesota Pollution Control Agency (MPCA) Water Quality Standards. A total of 18 water monitoring locations (orange circles) were sampled and information gathered from the individual sites were applied upstream to the next monitoring location. The summer season (April-September) eutrophication and total suspended solids water quality standards used in this assessment included: Dissolved Oxygen (DO) daily minimum > 4 mg/L, average Total Phosphorus (TP) < 0.1 mg/L, Total Suspended Solids (TSS) < 10% exceedance of 30 mg/L limit, average Chlorophyll-a (CHLA) < 18 ug/L, average pH < 9 su and > 6 su. The corresponding labels next to each stream section indicate which water quality standard were not met.

Table of Contents

Executive Summary.....	i
List of Tables.....	3
List of Exhibits.....	3
Acronyms & Abbreviations.....	4
1 Introduction and Overview	6
2 Methods.....	9
2.1 Water Quality Sampling	10
2.2 Analytical Laboratory Methods.....	11
3 Water Quality Standards.....	12
3.1 Lakes.....	13
3.2 Streams.....	13
4 Water Quality Data Collection	15
4.1 2020 Lakes Eutrophication Water Quality Summary.....	15
4.2 Alum Treatments.....	19
4.3 Chloride Monitoring	26
4.4 Nitrogen Monitoring	28
4.5 Lake Water Levels	30
4.6 Galpin Blvd Bluff Creek Crossing	32
4.7 Creek Restoration Action Strategy	35
4.8 Zooplankton and Phytoplankton.....	40
4.9 Lake Susan Spent-Lime Treatment System	49
4.10 Stormwater Ponds.....	51
5 Aquatic Invasive Species	56
5.1 AIS Management	56
5.2 Aquatic Plant Management	58
5.3 Common Carp Management.....	62
5.4 Zebra Mussels.....	66
6 Lake and Creek Fact Sheets.....	69
7 References.....	70
8 Exhibits	i

List of Figures

Figure i 2019 Lake Water Quality.....	ii
Figure ii 2019 Stream Water Quality	iv
Figure 1 Riley Purgatory Bluff Creek Watershed District Boundary	6
Figure 2 2020 Lake Growing Season Mean Chlorophyll-a	16
Figure 3 2020 Lakes Growing Season Mean Total Phosphorus	17
Figure 4 2020 Lakes Growing Season Mean Secchi Disk Depth.....	18
Figure 5 Hyland Lake Total Phosphorus Levels pre- and post- Alum Treatment	21
Figure 6 Lake Riley Total Phosphorus Levels pre- and post- Alum Treatment	22
Figure 7 Rice Marsh Lake Total Phosphorus Levels pre- and post- Alum Treatment	23
Figure 8 Lotus Lake Total Phosphorus Levels pre- and post- Alum Treatment	24
Figure 9 Round Lake Total Phosphorus Levels pre- and post- Alum Treatment	25
Figure 10 Heavy Salt Application.....	26
Figure 11 2013-2020 Chloride Levels within the Purgatory Chain of Lakes	27
Figure 12 2013-2020 Chloride Levels within the Riley Chain of Lakes	27
Figure 13 2013-2020 Chloride Levels within EP Stormwater Ponds	27
Figure 14 2020 Lakes Summer Average of Nitrogen.....	28
Figure 15 2019 and 2020 Upper Bluff Creek Total Suspended Solids	33
Figure 16 2020 Upper Bluff Creek Water Levels.....	34
Figure 17 2019 Lake Riley Zooplankton Counts (#/m ²)	41
Figure 18 2019 Lake Riley Phytoplankton Abundance (#/L) by Class.	42
Figure 19 2019 Lotus Lake Zooplankton Counts (#/m ²)	42
Figure 20 2019 Lotus Lake Epilimnetic Grazing Rates.....	43
Figure 21 2019 Lotus Lake Phytoplankton Abundance (#/L) by Class.	43
Figure 22 2019 Lake Susan Zooplankton Counts (#/m ²)	44
Figure 23 2019 Lake Susan Epilimnetic Grazing Rates	44
Figure 24 2019 Lake Susan Phytoplankton Abundance (#/L) by Class.....	45
Figure 25 2019 Rice Marsh Lake Zooplankton Counts (#/m ²)	45
Figure 26 2019 Rice Marsh Lake Epilimnetic Grazing Rates.....	46
Figure 27 2019 Rice Marsh Lake Phytoplankton Abundance (#/L) by Class.	46
Figure 28 2019 Staring Lake Zooplankton Counts (#/m ²).....	47
Figure 29 2019 Staring Lake Grazing Rates.....	47
Figure 30 2019 Staring Lake Phytoplankton Abundance (#/L) by Class.	48
Figure 31 Spent Lime Treatment System	49
Figure 32 Spent Lime/Sand Mixture Column Testing.....	49
Figure 33 Pool Sand/Spent Lime Mixture Column Testing Phosphorus Removals	50
Figure 34 2020 Total Phosphorous Percent Reduction - Lake Susan Spent Lime Treatment System	50
Figure 35 EnviroDIY Pond Continuous Monitoring Station	51
Figure 36 Minnetonka Iron Filings Application	52
Figure 37 2018 & 2020 Lake Ann Brittle Naiad Maps.	59
Figure 38 2019 Staring Lake Brittle Naiad Map.....	61
Figure 39 2020 Lake Susan Brittle Naiad Map	61
Figure 40 2019 Lake Susan Brittle Naiad Map	61
Figure 41 Captured Common Carp	62
Figure 42 2016-2020 Bluegill Trap Net Catches.....	62
Figure 43 2019-2020 Length Frequency of PCRA Spring Removals	64
Figure 44 Common Carp Removal at the PCRA Berm	64
Figure 45 2019 Lotus Lake Zebra Mussel Map.....	66

List of Tables

Table 2 District Water Resource Sampling Partnerships	7
Table 3 Monthly Field Data Collection Locations	8
Table 4 Sampling Parameters	9
Table 5 Basic Water Quality Monitoring Activities	11
Table 6 RMB Environmental Laboratories Parameters and Methods Used for Analyses	12
Table 7 MPCA Water Quality Standards for Shallow and Deep Lakes	13
Table 8 MPCA Stream Water Quality Standards	14
Table 12 Aluminum Sulfate Treatments in RPBCWD	19
Table 13 Aluminum Sulfate Effectiveness on Lake Surface and Bottom Total Phosphorous	20
Table 24 Lake Water Levels Summary	31
Table 25 2019 and 2020 Galpin Road Bluff Creek Crossing Nutrient Loading Summary	33
Table 26 2019 and 2020 Upper Bluff Creek Phosphorus	33
Table 29 Severe Reaches Identified by the Creek Restoration Action Strategy	35
Table 30 2020 Creek Restoration Action Strategy Updates	36
Table 31 2018-2020 Bank Pin Data	39
Table 49 2020 Lake Susan Spent Lime Treatment System Nutrient Removals	50
Table 53 2019-2020 Stormwater Pond Summary	55
Table 54 2020 Aquatic Invasive Species Summary	56
Table 55 Aquatic Invasive Species Infested Lakes	57
Table 57 2018 & 2019 Lotus Lake Brittle Naiad Maps	60
Table 63 2020 Common Carp Biomass Estimates	63
Table 64 2019 Common Carp Biomass Estimates	64
Table 67 Purgatory Creek Recreational Area Common Carp Removal vs Environmental Variables	65
Table 69 Suitability for Zebra Mussels in Lake Riley and Lotus Lake	68

List of Exhibits

Exhibit A	Lake Water Levels
Exhibit B	Fyke Net Data
Exhibit C	Zooplankton Summary Data
Exhibit D	Phytoplankton Summary Data
Exhibit E	Lake and Creek Fact Sheets

Acronyms & Abbreviations

Ac	Acre
BMP	Best Management Practice
cBOD	5-day Carbonaceous Biochemical Oxygen Demand
Cf	Cubic feet
Cfs	Cubic feet per second
Chl-a	Chlorophyll-a
Cl	Chloride
CPUE	Catch Per Unit Effort
CRAS	Creek Restoration Action Strategy
CS	Chronic Standard
DO	Dissolved Oxygen
<i>E. coli</i>	<i>Escherichia coli</i>
EP	Eden Prairie
EPA	Environmental Protection Agency
EWM	Eurasian Watermilfoil
Ft	Foot/Feet
FWSS	Freshwater Scientific Services
GPS	Global Positioning System
Ha	Hectare
HAB	Harmful Algal Bloom
IBI	Index of Biological Integrity
In	Inch
Kg	Kilogram
L	Liter
Lb	Pound
M	Meter
MCWD	Minnehaha Creek Watershed District
METC	Metropolitan Council
Mg	Milligram
mL	Milliliter
MNDNR	Minnesota Department of Natural Resources
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MS	Maximum Standard
MS4	Municipal Separate Storm Sewer System
NA	Not Available
NCHF	North Central Hardwood Forest
NH ₃	Ammonia
NO ₂	Nitrite
NO ₃	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NURP	National Urban Runoff Program
NWS	National Weather Service
OHWL	Ordinary High-Water Level
ORP	Oxidation Reduction Potential
Ortho-P	Orthophosphate
PAR	Photosynthetic Active Radiation
PCL	Purgatory Chain of Lakes
RCL	Riley Chain of Lakes
RPBCWD/District	Riley Purgatory Bluff Creek Watershed District
Sec	Second
Sp.	Species
SRP	Soluble Reactive Phosphorus
TDP	Total Dissolved Phosphorus

TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TPA	Total Phytoplankton Abundance
TP	Total Phosphorus
TRPD	Three Rivers Park District
TSS	Total Suspended Solids
UAA	Use and Attainability Assessment
UMN	University of Minnesota-St. Paul Campus
WD	Watershed District
WIDNR	Wisconsin DNR
WMO	Watershed Management Organization
YOY	Young of Year

1 Introduction and Overview

The Riley Purgatory Bluff Creek Watershed District was established on July 31st, 1969, by the Minnesota Water Resources Board acting under the authority of the watershed law. The District is located in the southwestern portion of the Twin Cities Metropolitan Area. It consists of a largely developed urban landscape and encompasses portions of Bloomington, Chanhassen, Chaska, Deephaven, Eden Prairie, Minnetonka, and Shorewood (Figure 1). This total area for the watershed is close to 50 square miles located in both Hennepin and Carver Counties and includes three smaller subwatersheds: Riley Creek Watershed, Purgatory Creek Watershed, and Bluff Creek Watershed.

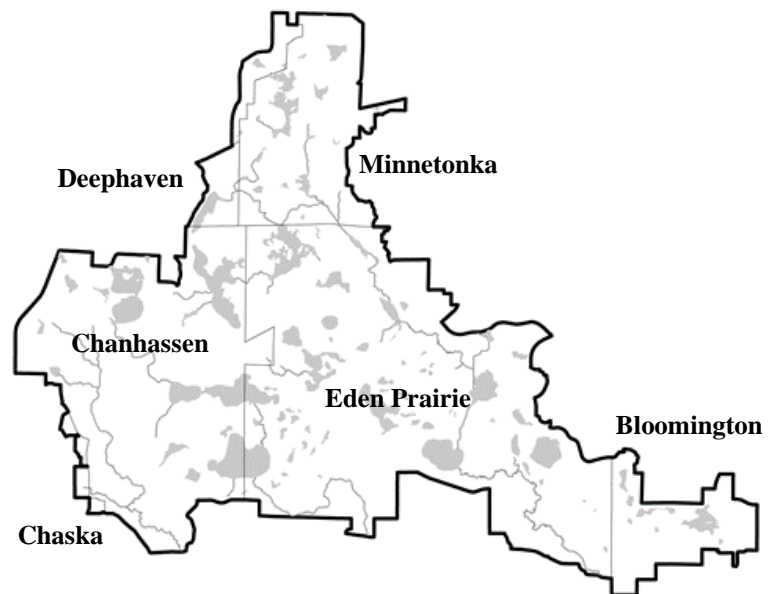


Figure 1 Riley Purgatory Bluff Creek Watershed District Boundary

Data collection and reporting are the foundation for the RPBCWD's work. Regular, detailed water quality monitoring provides the District with scientifically reliable information that is needed to decide if water improvement projects are needed

and how effective they are in the watershed. Data collection remains a key component of the District's work as we strive to de-list, protect, and improve the water bodies within the watershed. The purpose of this report is to summarize the water quality and quantity results collected over the past year, which can be used to direct the District in managing our water resources.

Through partnerships with various cities, Three Rivers Park District (TRPD), the University of Minnesota (UMN), Metropolitan Council (METC), and Carver County, water quality data was collected on 13 lakes, two high value wetlands (Lake Idlewild and Lake McCoy), and 22 creek sites in the District. The 23 creek sites include six on Bluff Creek, six on Riley Creek, and ten on Purgatory Creek. Lake McCoy and Neil Lake, which are within the watershed boundaries, have not been part of the District's sampling regime. Each partner was responsible for monitoring certain parameters of their respective lakes/streams and reporting their findings, allowing for more time and attention to be given to each individual water resource (Table 1).

Water quality and water quantity was monitored at each stream site during the field season (April-September) approximately twice a month. The METC also has continuous monitoring stations near the outlet of each creek as part of its Watershed Outlet Monitoring Program (WOMP) or long-term monitoring program which identifies pollutant loads entering the Minnesota River. District EnviroDIY stations were also installed at some stream locations to gather more information. In addition to water quality monitoring, creek walks were also conducted to gather more information about the current stream conditions in the District. This information was included in the Creek Restoration Action Strategy (CRAS), which was developed by the District to identify and prioritize future stream restoration sites. Bank pin data was collected near each of the water quality monitoring sites to measure generalized sedimentation and erosion rates across all three streams. Macroinvertebrates were collected at all Bluff Creek water quality sites in September.

Lakes were also monitored bi-weekly during the summer growing season (June-September) for water quality. Lake levels were continuously recorded from ice out to ice in. Lake water samples were also collected in early summer and analyzed for the presence of zebra mussel veligers. Additionally, during every sampling event, boat launch areas and zebra mussel monitoring plates were scanned for adult zebra mussels. Zooplankton and phytoplankton samples were also collected on five lakes to assess the overall health of the population as it applies to fishery health and water quality. Plant surveys and herbicide treatments were also conducted to assess overall health of the plant community and to search/treat for invasive plants. Common Carp have been identified as being detrimental to lake health and are continually monitored by the District. In the summer of 2020, eight stormwater ponds were also monitored and

sampled bi-weekly as a part of a cooperative study with the University of Minnesota and the city of Eden Prairie. Winter monitoring occurred on the Purgatory Chain of Lakes as well as four separate stormwater ponds in 2019. Extending the monitoring activities into the winter months can provide key insights into ways to improve water quality during the summer months. Winter monitoring also allows us to evaluate the influence of chloride levels in our lakes. The data collection and reporting events were tracked throughout the year and can be seen in **Table 2**. In addition to lakes and streams, multiple specialty projects were monitored to evaluate their effectiveness at preventing or contributing pollutant loads to the watershed.

Table 1 District Water Resource Sampling Partnerships

Water Resource	RPBCWD	Three Rivers Park District	Eden Prairie	University of MN	Metropolitan Council	Carver County
Duck Lake	■		■			
Hyland Lake	■	■				
Lake Ann	■					■
Lake Idlewild	■					
Lake Lucy	■					
Lake Riley	■			■		
Lake Susan	■			■		■
Lotus Lake	■					■
McCoy	■		■			
Mitchell Lake	■		■	■		
Red Rock Lake	■		■			
Rice Marsh Lake	■					
Round Lake	■		■			
Silver Lake	■					
Staring Lake	■			■		
Bluff Creek	■				■	
Purgatory Creek	■				■	
Riley Creek	■		■		■	

Table 2 Monthly Field Data Collection Locations

Water Resource	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Ann					■	■	■	■	■	■		
Duck Lake	■	■	■		■	■	■	■	■	■		
Hyland Lake	■	■	■		■	■	■	■	■	■	■	
Lake Idlewild	■	■	■		■	■	■	■	■	■		
Lotus Lake	■	■	■		■	■	■	■	■	■		
Lake Lucy					■	■	■	■	■	■		
McCoy					■	■	■	■	■	■	■	
Mitchell Lake	■	■	■		■	■	■	■	■	■	■	
Red Rock Lake	■	■	■		■	■	■	■	■	■		
Rice Marsh Lake	■	■	■		■	■	■	■	■	■		
Round Lake	■	■	■		■	■	■	■	■	■	■	
Lake Riley					■	■	■	■	■	■		
Staring Lake	■	■	■		■	■	■	■	■	■		
Lake Susan					■	■	■	■	■	■		
Silver Lake	■	■	■		■	■	■	■	■	■		
Bluff Creek	■	■	■	■	■	■	■	■	■	■		
Purgatory Creek	■	■	■	■	■	■	■	■	■	■		
Riley Creek	■	■	■	■	■	■	■	■	■	■		

*Water Level Sensors were placed on all lakes.

2 Methods

Water quality and quantity monitoring entails the collection of multi-probe sonde data readings, water samples, zooplankton samples, phytoplankton samples, macroinvertebrate samples, zebra mussel veliger samples, and physical readings, as well as recording the general site and climactic conditions at the time of sampling. Listed in the following sections are the methods and materials, for both lake and stream monitoring, used to gather the water quality and quantity data during the 2020 field-monitoring season. **Table 3** identifies many of the different chemical, physical, and biological variables analyzed to assess overall water quality.

Table 3 Sampling Parameters

Parameter	Analysis	Summer Lakes	Winter Lakes	Streams	Reason for Monitoring
Total Phosphorus	Wet	■	■	■	Nutrient, phosphorus (P) controls algae growth
Orthophosphate	Wet	■	■	■	Nutrient, form of P available to algae
Chlorophyll-a, pheophytin	Wet	Surface	Surface	■	Measure of algae concentration
Ammonia as N	Wet	■	■		Nutrient, form of nitrogen (N) available to algae
Nitrate + Nitrite as N	Wet	■	■		Nutrient, also oxygen substitute for bacteria
Total Kjeldahl Nitrogen	Wet	■			Nutrient, sum of nitrogen bound in organics
Calcium	Wet	■			Measure of water hardness
Total Alkalinity, adjusted	Wet	Surface	Surface		Measure of ability to resist drop in pH
Total Suspended Solids	Wet			■	Measure of the solids in water (block light)
Chloride	Wet	■	■	■	Measure of chloride ions, salts in water
Temperature	Sonde	■	■	■	Impacts biological and chemical activity in water
pH	Sonde	■	■	■	Impact chemical reactions (acidic or basic)
Conductivity	Sonde	■	■	■	Ability to carry an electrical current (TSS & Cl)
Dissolved Oxygen	Sonde	■	■	■	Oxygen for aquatic organisms to live
Macroinvertebrates	Wet			■	Organisms fluctuate due to environmental variables
Oxidation Reduction Potential	Sonde	■	■	■	Tracks chemistry in low or no oxygen conditions
Phycocyanin	Sonde	■	■		Pigment, measures cyanobacteria concentration
Phytoplankton	Wet	■			Organisms fluctuate due to environmental variables
Photosynthetic Active Radiation	Sonde	■	■		Measure of light available for photosynthesis
Turbidity	Sonde			■	Measure of light penetration in shallow water
Secchi disk depth	Observation	■	■		Measure of light penetration in deeper water
Transparency Tube	Observation			■	Measure of light penetration into shallow water
Zooplankton	Wet	■			Organisms fluctuate due to environmental variables
Zebra Mussel Veligers	Wet	■			Larval form of zebra mussels/plate checks (AIS)

2.1 Water Quality Sampling

The monitoring program supports the District's 10-year water management plan to delist waters from the MPCA's 303d Impaired Waters list. The parameters monitored during the field season help determine the sources of water quality impairments and provide supporting data that is necessary to best design and install water quality improvement projects.

Multi-probe sondes (Hach Lake DS-5/Stream MS-5; YSI EXO3) were used for collecting water quality measurements across both streams and lakes. Sonde readings measured include temperature, pH, dissolved oxygen, conductivity, photosynthetic active radiation (PAR), oxidation reduction potential (ORP), and phycocyanin. Secchi disk depth readings were recorded at the same time as sonde readings were collected at all lake sampling locations. When monitoring stream locations, transparency, turbidity (Hach 2100Q), and flow measurements (Flow Tracker) were collected. General site conditions related to weather and other observations were recorded as well. A list of the variety of parameters monitored during each sampling event can be seen in **Table 3**.

At each lake monitoring location, multiple water samples are collected using a Van Dorn, or depth integration sampler, for analytical laboratory analysis. For Duck, Idlewild, Rice Marsh, Silver, and Staring Lakes, water samples were collected at the surface and bottom due to the shallow depths (2-3m). For all other lakes within the District, water samples were collected at the surface, middle (when stratified), and bottom of the lake. Lakes are monitored at the same location on each sampling trip, typically at the deepest location of the lake. All samples are collected from whole meter depths except for the bottom sample, which is collected 0.5 meters from the lake bottom to prevent disrupting the sediment. The surface sample is a composite sample of the top two meters of the water column. The middle sample is collected from the approximate midpoint of the temperature/dissolved oxygen change (>1 degree Celsius change) or thermocline. Pictures and climatic data are collected at each monitoring site. Water quality information collected in the winter is collected utilizing the same procedures as in the summer. Zooplankton samples were collected using a 63 micrometer Wisconsin style zooplankton net and Phytoplankton samples were collected using a 2 m integrated water sampler on Lake Susan, Lotus Lake, Staring Lake, Lake Riley, and Rice Marsh Lake. Zooplankton are collected by lowering the net to a depth of 0.5 meters from the bottom at the deepest point in the lake and raised slowly. Zebra mussel veliger samples were collected on all lakes using the same zooplankton sampling procedures but collected at three sites and consolidated before being sent to a lab for analysis. A Zeiss Primo Star microscope with a Zeiss Axiocam 100 digital camera was used to monitor zooplankton populations, scan for invasive zooplankton, and to calculate Cladoceran-grazing rates on algae.

Water quality samples collected during stream monitoring events were collected from the approximate middle (width and depth) of the stream in ideal flow conditions or from along the bank when necessary. Both water quality samples and flow monitoring activities were performed in the same section of the creek during each sampling event. Stream velocity was calculated at 0.3 to 1.5-foot increments across the width of the stream using the FlowTracker Velocity Meter at each sampling location. If no water or flow was observed, only pictures and climatic data were collected. Macroinvertebrate samples were collected on one stream per year on a rotating basis. A D-net was used to sample macroinvertebrates and each habitat type was sampled proportional to the amount of habitat in each reach. The activities associated with the monitoring program are described in **Table 4**.

Table 4 Basic Water Quality Monitoring Activities

Pre-Field Work Activities	<ul style="list-style-type: none"> Calibrate Water Quality Sensors (sonde) Obtain Water Sample Bottles and Labels from Analytical Lab Prepare Other Equipment and Perform Safety Checks Coordinate Events with Other Projects and Other Entities
Summer Lake – Physical and Chemical	<ul style="list-style-type: none"> Navigate to Monitoring Location Read Secchi Disk Depth and Record Climatic Data Record Water Quality Sonde Readings at Meter Intervals Collect Water Samples from Top, Thermocline, and Bottom
Summer Lake – Biological	<ul style="list-style-type: none"> Collect Zooplankton Tow (pulling a net) from Lake Bottom to Top Collect Phytoplankton Tow (2 m surface composite sample) Collect Zebra Mussel Veliger Tow (pulling a net) from Lake Bottom to Top at Multiple Sites
Winter Lakes	<ul style="list-style-type: none"> Navigate to Monitoring Location Record Ice Thickness Read Secchi Disk Depth and Record Climatic Data Record Water Quality Sonde Readings at Meter Intervals Collect Water Samples from Top and Bottom
Streams – Physical, Chemical, and Biological	<ul style="list-style-type: none"> Navigate to Monitoring Location Measure Total Flow by Measuring Velocity at 0.3 to 1 Foot Increments across Stream Record Water Quality Sonde Measurements from Middle of Stream Read Transparency Tube and Perform Turbidity Test Collect Water Samples from Middle of Stream Collect macroinvertebrate samples (D-net collection across representative habitat types) Collect Climatic Data and Take Photos
Post-Field Work Activities	<ul style="list-style-type: none"> Ship Water Samples to Analytical Lab Enter Data, Perform Quality Control Checks, and Format Data for Database Clean and Repair Equipment Reporting and Summarizing Data for Managers, Citizens, Cities, and Others

2.2 Analytical Laboratory Methods

RMB Environmental Labs, located in Bloomington, MN, is the third-party company that is responsible for conducting the analytical tests on the water samples that were collected by the District staff. The methods used by the laboratory to analyze the water samples for the specified parameters are noted in **Table 5**. Zebra mussel veliger samples were also sent to RMB Labs for analysis.

Additional samples were sent to the Metropolitan Council (METC), St. Paul, MN. These samples included quality samples for the Watershed Outlet Monitoring Program (WOMP) program. METC allows staff to bring samples in on a Friday which is not possible with RMB because samples must be shipped. Additionally, macroinvertebrate samples were sent to Dean Hansen of the University of Minnesota for identification and 10% of zooplankton and all phytoplankton samples were sent to Margaret Rattei at Barr Engineering for quality control duplicate samples.

Table 5 RMB Environmental Laboratories Parameters and Methods Used for Analyses

Parameter	Standard Method
Alkalinity	EPA 310.2 , SM 2320 B-2011
Ammonia	EPA 350.1 Rev 2.0 or Timberline Ammonia-001
Nitrogen, Nitrate & Nitrite	EPA 353.2 Rev 2.0
Chlorophyll-a	SM 10200H
Total Phosphorus	EPA 365.3
Orthophosphate	EPA 365.3
Chloride	SM 4500-Cl E-2011
Total Kjeldahl Nitrogen	EPA 351.2 or Timberline Kjeldahl Nitrogen-001
Calcium	EPA 200.7

3 Water Quality Standards

In 1974, the Federal Clean Water Act set forth the requirements for states to develop water quality standards for surface waters. In 2014, specific standards were developed for eutrophication and TSS for rivers and streams. In Minnesota, the agency in charge of regulating water quality is the Minnesota Pollution Control Agency (MPCA). Water quality monitoring and reporting is a priority for the District to determine the overall health of the water bodies within the watershed boundaries. The District’s main objectives are to prevent a decline in the overall water quality within lakes and streams and to prevent water bodies from being added to the 303d Impaired Water Bodies list (MPCA). The District is also charged with the responsibility to take appropriate actions to improve the water quality in water bodies that are currently listed for impairments.

There are seven ecoregions within Minnesota; the RPBCWD is within the Northern Central Hardwood Forest (NCHF) ecoregion. Rural areas in the NCHF are dominated by agricultural land and fertile soils characterize the ecoregion. For most water resources in the region, phosphorus is the limiting (least available) nutrient within lakes and streams, meaning that the available concentration of phosphorus often controls the extent of algal growth. The accumulation of excess nutrients (i.e. TP and Chl-a) in a waterbody is called eutrophication. This relationship has a direct impact on the clarity and recreational potential of our lakes and streams. Water bodies with high phosphorus concentrations and increased levels of algal production have reduced water clarity and limited recreational potential.

All lakes sampled in the district are considered Class 2B surface waters. The MPCA states that this class of surface waters should support the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. They should also be suitable for aquatic recreation of all kinds, including bathing. This class of surface water is not protected as a source of drinking water. For more detailed information regarding water quality standards in Minnesota, please see the MPCA’s Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment, 305(b) Report, and 303 (d) List of Impaired Waters. These

resources provide information to better understand the water quality assessment process and the reasoning behind their implementation.

3.1 Lakes

The MPCA has specific standards for both ‘deep’ lakes (lakes >15 ft deep and < 80% of the total lake surface area able to support aquatic plants – littoral area), and ‘shallow’ lakes (lakes <15 ft deep and >80% littoral area). Except for chlorides, summer growing season (June-September) averages of the parameters listed in **Table 6** for each lake and are compared to the MPCA standards to determine the overall state of the lake. The standards are set in place to address issues of eutrophication or excess nutrients in local water bodies. Water samples are collected and sent to an analytical lab to assess concentrations of TP, Chl-a, and chlorides. If result values are greater than the standards listed in **Table 6**, the lake is considered impaired. Secchi disk readings are collected to measure the transparency, or visibility, in each lake. A higher individual reading corresponds to increased clarity within the lake (this indicates the Secchi Disk was visible at a deeper depth in the water column).

Chlorides (Cl) are of increasing concern in MN, especially during the winter when road salt is heavily used. Targeted sampling occurs during the winter, early spring melting periods when salts are being flushed through our waterbodies, and monthly during the summer to set a base line. The Cl standard is the same for both deep lakes and shallow lakes. **Table 6** includes both the Cl chronic standard (CS) and a maximum standard (MS). The CS is the highest water concentration of Cl to which aquatic life, humans, or wildlife can be exposed to indefinitely without causing chronic toxicity. The MS is the highest concentration of Cl in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality.

Table 6 MPCA Water Quality Standards for Shallow and Deep Lakes

Parameter	Shallow Lakes Criteria	Deep Lakes Criteria
Total Phosphorus (mg/L)	≤ 0.060	≤ 0.040
Chlorophyll-a (ug/L)	≤ 20	≤ 14
Secchi Disk (m)	≥ 1	≥ 1.4
Chloride Chronic Standard (mg/L)	230	230
Chloride Maximum Standard (mg/L)	860	860

3.2 Streams

Table 7 displays water quality parameters developed by the MPCA in 2014 for eutrophication and TSS. The standards include some parameters the District has not yet incorporated into their monitoring procedures that may eventually be added in the future. All streams sampled in the District are considered Class 2B surface waters. The MPCA states that this class of surface waters should support the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. They should also be suitable for aquatic recreation of all kinds, including bathing. This class of surface water is not protected as a source of drinking water. For more detailed information regarding water quality standards in Minnesota, please see the MPCA’s Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment, 305(b) Report, and 303 (d) List of Impaired Waters. These resources provide information to better understand the water quality assessment process and the reasoning behind their implementation.

Eutrophication pollution is measured based upon the exceedance of the summer growing season average (May-September) of TP levels and Chl-a (seston), five-day biochemical oxygen demand (cBOD, amount of DO needed by organisms to breakdown organic material present in a given water sample at a certain temperature over a five-day period), diel DO flux (difference between the maximum DO concentration and the minimum daily DO concentration), or summer average pH levels. Streams that exceed phosphorus standard but do not exceed the Chl-a (seston), cBOD, diel DO flux, or pH standard meet the eutrophication standard. The District added Chl-a to its monthly sampling regime in 2015 to account for the polluted condition when Chl-a (periphyton) concentration exceeds 18 ug/L. The daily minimum DO concentration for all Class 2B waters cannot dip below 4 mg/L to achieve the MPCA standard, which was used in the analysis for this report.

Table 7 MPCA Stream Water Quality Standards

MPCA Standard	Parameter	Criteria
Eutrophication	Phosphorus	≤ 100ug/L
	Chlorophyll-a (seston)	≤ 18ug/L
	Diel Dissolved Oxygen	≤ 3.5mg/L
	Biochemical Oxygen Demand	≥ 2mg/L
	pH Max	≤ 9su
	pH Min	≥ 6.5su
Total Suspended Solids	TSS	≤ 30mg/L

TSS is a measure of the amount of particulate (soil particles, algae, etc.) in the water. Increased levels of TSS can be associated with many negative effects including nutrient transport, reduced aesthetic value, reduced aquatic biota, and decreased water clarity. For the MPCA standard, TSS concentrations are assessed from April through September and cannot exceed 30 mg/L more than 10 percent of the time during that period.

4 Water Quality Data Collection

To improve water quality within the watershed, the District conducts studies to root out key sources of pollution or other negative variables that impact our lakes and streams. Once identified, the District will often monitor these locations and eventually act to improve the water resource if the data confirms the suspicion. Below is a summary of each special project/monitoring and an overall summary of the water quality data the District has collected in 2020.

4.1 2020 Lakes Eutrophication Water Quality Summary

Chlorophyll-a

The 2020 growing season Chl-a mean concentrations for all lakes sampled within the District are shown in **Figure 2**. Of the three main lake water quality standards (Chl-a, TP, Secchi), Chl-a and TP were the nutrient with the most site impairments in 2020. Overall, nine of the 15 lakes sampled in 2020 met the MPCA Chl-a standards for their lake classification (six lakes met standard in 2018 and 2019): Lake Ann, Lake Riley, Round Lake, Duck Lake, Lake Idlewild, Lake Lucy, Rice Marsh Lake, and Lake McCoy (new in 2020).

Four lakes sampled within the District are categorized as ‘deep’ by the MPCA (>15 ft deep, < 80% littoral area): Lake Ann, Lotus Lake, Lake Riley, and Round Lake. The MPCA standard for Chl-a in deep lakes (< 14 ug/L) was met by Lake Ann, Lake Riley and Round Lake. Lake Riley had the lowest summer Chl-a average of all lakes sampled (2.8 ug/l). Similar to 2019, Lotus Lake did not meet the standard with Chl-a average concentrations were more than twice the MPCA standard at 34 ug/l (an increase of 1 ug/L from 2019). The remainder of the lakes sampled in 2020 are categorized as ‘shallow’ by the MPCA (<15 ft deep, >80% littoral area): Duck Lake, Hyland Lake, Lake Lucy, Lake McCoy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake. Water quality metrics on Lake Idlewild and Lake McCoy, classified as a high-value wetlands, were compared to MPCA shallow lake standards. The water quality standard for shallow lakes (< 20 ug/L) was met by Duck Lake, Hyland Lake, Lake Idlewild, Lake Lucy, Lake McCoy, and Rice Marsh Lake in 2020. Lake Lucy improved to meeting the standard in 2020 with a reduction in Chl-a concentrations of 17 ug/L. Mitchell Lake, Red Rock Lake, Silver Lake, and Staring Lake had Chl-a values 1.5-2 times the MPCA standard.

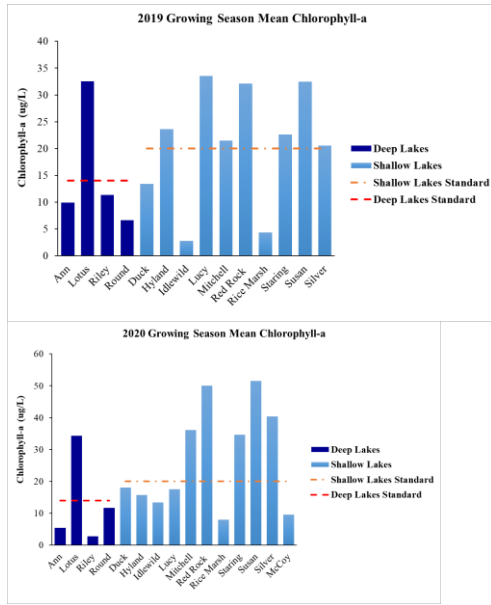


Figure 2 2020 Lake Growing Season Mean Chlorophyll-a

Lakes growing season (June-September) mean chlorophyll-a concentrations (ug/L) for shallow (lakes <15 ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15 ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2020. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for Chlorophyll-a for shallow (<20 ug/L-orange dashed line) and deep lakes (<14 ug/L-red dashed line).

Total Phosphorous

The TP growing season averages for all lakes sampled within the District in 2020 are shown in **Figure 3**. Overall, eight of the 15 lakes sampled met the MPCA total phosphorus standard for their lake classification in 2020: Lake Ann, Lake Riley, Round Lake, Duck Lake, Lake Hyland, Lake Lucy, Rice Marsh Lake, and Staring Lake. This represents a decrease from 11 of 14 sampled lakes that met the standard in 2019.

The MPCA standard for TP in deep lakes (<0.040 mg/L) was met by Lake Ann, Lake Riley, and Round Lake. TP concentrations in Lotus Lake, which met the standard in 2019, increased by 18% and did not meet the standard in 2020 (0.0416 mg/L). Lake Riley had the lowest summertime average TP concentration across all lake sampled in 2020 (0.0178 mg/L). For shallow lakes, the MPCA TP standard (<0.060 mg/L) was met by Duck Lake, Hyland Lake, Lake Lucy, Rice Marsh Lake, and Staring Lake in 2020. Despite having met the standard in 2019, Lake Susan, Mitchell Lake, and Lake Idlewild increased to just above the standard (0.067 mg/L, 0.061 mg/L, 0.062 mg/L respectively). Red Rock (0.858 mg/L) and Silver Lake (0.116 mg/L) were well above the MPCA standard. Silver Lake had the largest increase in 2020 and had the highest average summertime TP concentrations.

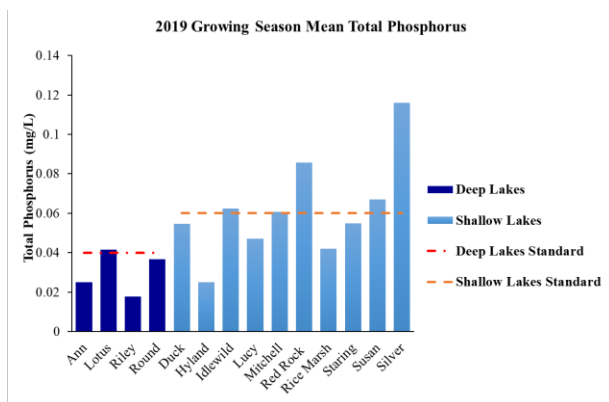
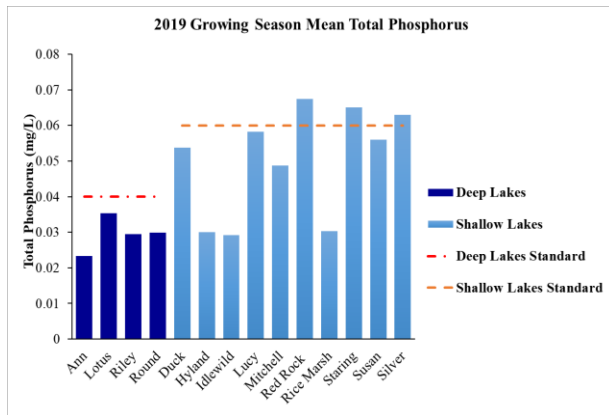


Figure 3 2020 Lakes Growing Season Mean Total Phosphorus

Lakes growing season (June-September) mean total phosphorus concentrations (mg/L) for shallow (lakes <15 ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15 ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2020. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for Total Phosphorus for shallow (<0.060 mg/L-orange dashed line) and deep lakes (<0.040 mg/L-red dashed line).

Secchi Disk

The 2020 secchi disk growing season means for all District lakes sampled are shown in **Figure 4**. Overall, eleven of the 15 lakes sampled met the MPCA secchi disk standard for their lake classification in 2020: Lake Ann, Lake Riley, Round Lake, Duck Lake, Lake Hyland, Lake Idlewild, Lake Lucy, Rice Marsh Lake, Staring Lake, Lake Susan, and Silver Lake. This represents a decrease from all lakes sampled lakes achieving the standard in 2019.

The MPCA standard for secchi disk depth/water clarity for deep lakes (> 1.4 m) was met by all Ann, Riley, and Round. Lotus met the standard in 2019 (1.54 m) but had reduced water clarity in 2020 (1.24 m). Ann and Round remained relatively stable from 2019 with secchi disk averages remaining between 2 and 2.5 m. Lake Riley had the highest summer average for all lakes sampled in 2020 and the average was the highest recorded since 1971 on the lake (4.64 m). For shallow lakes, all ten lakes monitored achieved the MPCA secchi disk depth water quality standard (>1m), an increase from eight of ten lakes monitored in 2018. For shallow lakes, the MPCA standard was not met by Mitchell and Red Rock in 2020. Red Rock had the lowest (worst) secchi reading at 0.66 m which was down from 1.11 m. Duck, Hyland, Idlewild, Silver, and Lucy had secchi readings near 2 and Rice Marsh was reduced from 2.6 m in 2019 to 2.2 m in 2020. Lake McCoy had depths less than 1 m and water clarity was to the lake bottom. Lake Staring and Lake Susan were just above the standard in 2020 (1.03 m).

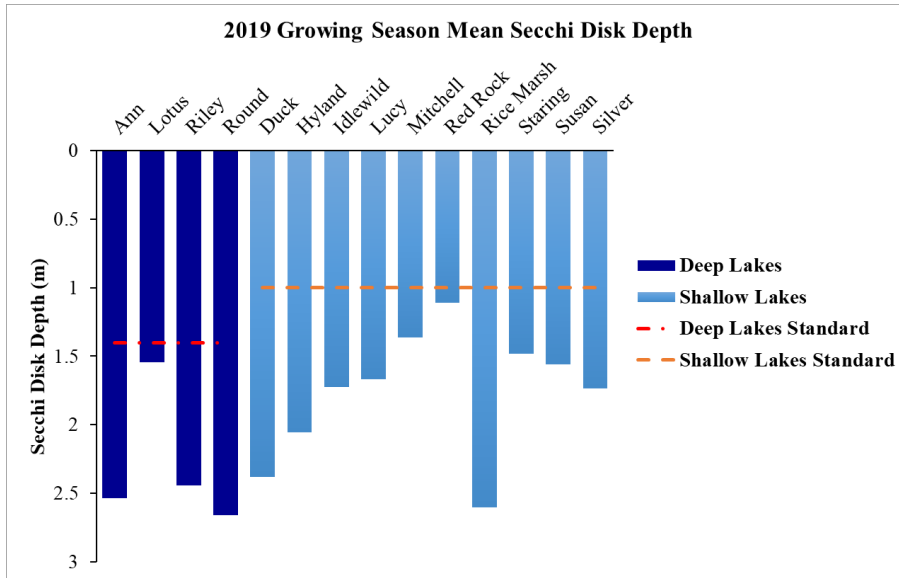
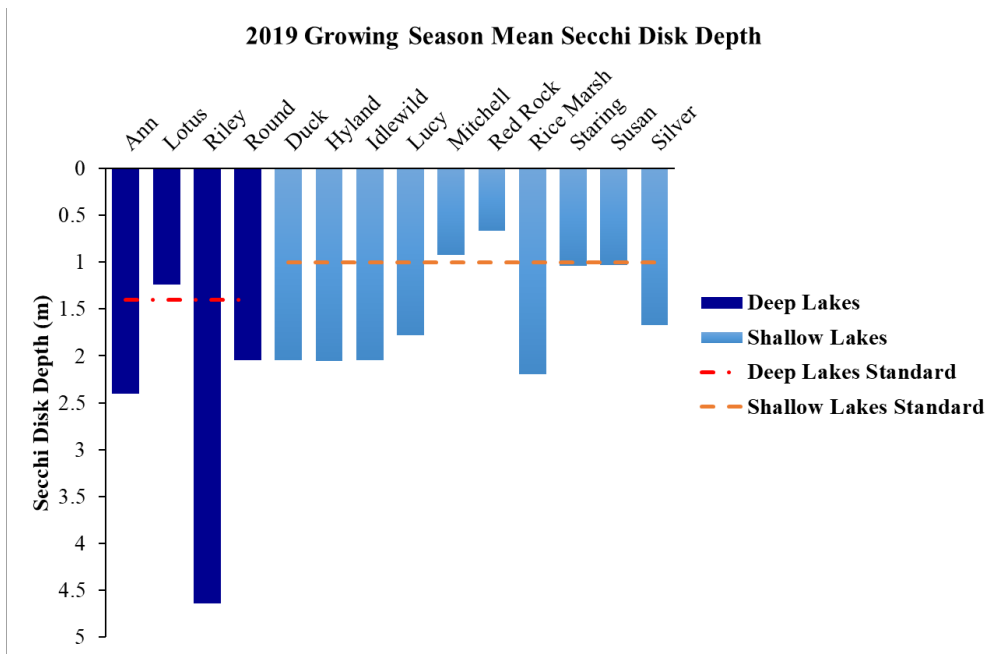


Figure 4 2020 Lakes Growing Season Mean Secchi Disk Depth

Lakes growing season (June-September) mean secchi disk depths (m) for shallow (lakes <15 ft. deep, >80% littoral area-light blue bars) and deep lakes (lakes >15 ft. deep, <80% littoral area-dark blue bars) in the Riley Purgatory Bluff Creek Watershed District during 2019. The dashed lines represent the Minnesota Pollution Control Agency water quality standards for secchi disk depths for shallow (>1 m-orange dashed line) and deep lakes (>1.4 m-red dashed line).



4.2 Alum Treatments

Alum (aluminum sulfate) is a compound derived from aluminum, the earth’s most abundant metal. Alum has been used in water purification and wastewater treatment for centuries and in lake restoration for decades. Many watershed management plans recommend that some lakes be treated with the alum to improve their water quality. An alum treatment provides a safe, effective and long-term control of the quantity of algae in our lakes, by trapping the nutrient phosphorus in sediments. Algal growth is directly dependent on the amount of phosphorus available in the water. Phosphorus enters the water in two ways:

- Externally: from surface runoff entering the water or from groundwater.
- Internally: from the sediments on the bottom of the lake.

Phosphorus already in the lake settles to the bottom and is periodically re-released from the sediments back into the water. Even when external sources of phosphorus have been significantly reduced through best management practices, the internal recycling of phosphorus within a lake can still support explosive algal growth. Alum is used primarily to control this internal loading of phosphorus from the sediments of the lake bottom. The treatment is most effective when it occurs after external sources of phosphorus have been actively controlled. Internal phosphorus loading is a large problem in Twin Cities Metropolitan Area lakes because of historic inputs of phosphorus from the urban storm water runoff. Phosphorus in runoff has concentrated in the sediments of urban lakes as successive years of algal blooms have died and settled to the lake bottoms. This phosphorus is recycled from the lake sediments into the overlying waters, primarily during summer periods, when it contributes to the growth of nuisance algal blooms.

Alum is applied by injecting it directly into the water several feet below the surface. On contact with water, alum becomes floc, or aluminum hydroxide (the principal ingredient in common antacids such as Maalox). This fluffy substance settles to the bottom of the lake. On the way down, it interacts with phosphorus to form an aluminum phosphate compound that is insoluble in water. Phosphorus in the water is trapped as aluminum phosphate and can no longer be used as food by algae. As the floc settles downward through the water, it also collects other suspended particles in the water, carrying them down to the bottom and leaving the lake noticeably clearer. On the bottom of the lake, the floc forms a layer that acts as a kind of phosphorus barrier by combining with (and trapping) the phosphorus as it is released from the sediments. This reduces the amount of internal recycling of phosphorus in the lake. An alum treatment can last 10–15 years or even longer, depending on the level of external phosphorus loading to the lake. The less phosphorus that enters the lake from external sources after it is applied, the more effective the treatment will be for a longer period.

A list of the alum treatments completed and proposed second doses in the District can be found in **Table 8**. Treatments are split into two doses to ensure the entirety of the lake is being treated effectively. District staff and its partners have continued to monitor phosphorous levels within treatment lakes to evaluate the success of the treatment and to assess when a second dose might be needed. More information about Lake Riley, Lotus Lake, Rice Marsh Lake, Round Lake, and Hyland Lake nutrient and water clarity data can be seen in the Fact Sheets located in 8 Exhibits E.

Table 8 Aluminum Sulfate Treatments in RPBCWD

Lake	First Dose	Second Dose
Riley	5/5/2016	6/11/2020
Lotus	9/18/2018	TBD
Rice Marsh	9/21/2018	TBD
Round	11/15/2012	10/24/2018
Hyland	6/3/2019	TBD

Figure 5 through **Figure 9** illustrates total phosphorus (TP) levels prior to treatment, through the end of the 2020 growing season for all lakes that received an alum treatment. As seen across all lakes, after alum was applied, TP levels within each lake declined considerably for both the surface and lake bottom. In all cases, in the years following the alum treatment, lakes met the MPCA water quality standard for TP

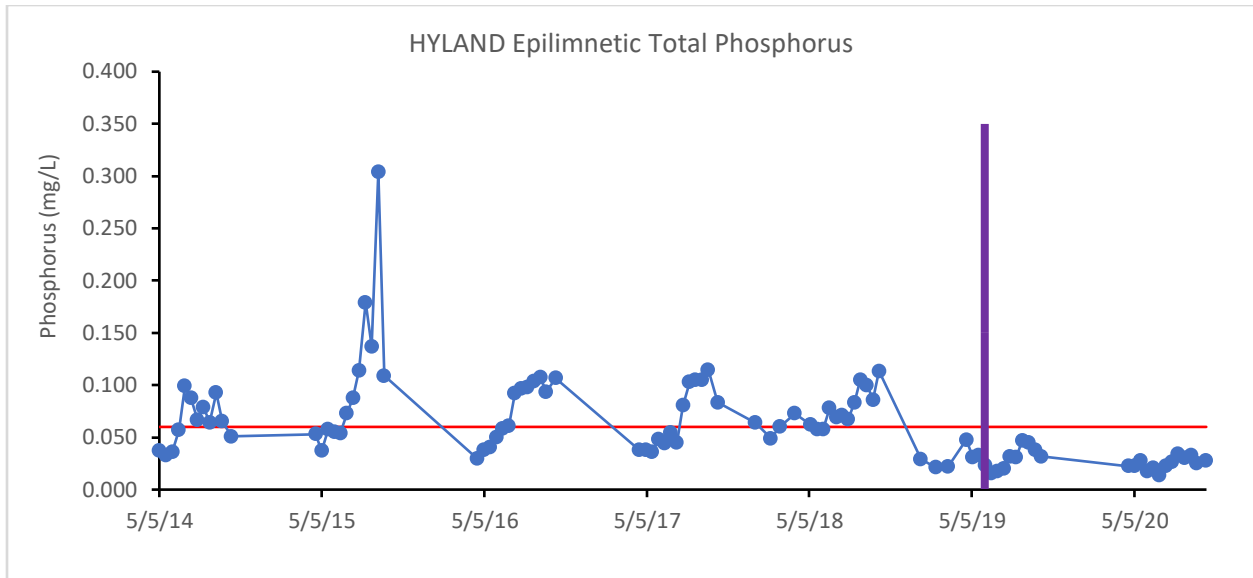
(exception – 2013 Round Lake and 2020 Lotus Lake). In addition, often both Secchi and Chlorophyll-a levels were improved which led to some lakes meeting all three water quality standards after treatment (Hyland, Rice Marsh, Riley, and Round). In **Table 9** the percent reduction of surface and bottom growing season values of total phosphorous pre- and post-alum treatment can be seen across all lakes. Utilizing two years of post-treatment data, it appears Rice Marsh and Hyland Lake were very effective alum treatments with phosphorus reductions of 52% and 66% respectively. Despite having smaller reductions in total phosphorus at the surface, Round Lake had reductions in lake bottom total phosphorus comparable with the other treated lakes (84% (dose 1) and 94% (dose 2) for Round Lake). In 2020, Lake Riley received the second dose of alum which led to an overall reduction of 61% surface and 92% bottom phosphorous reductions compared to pre alum years. Lake Riley had a historically good water quality year in 2020 with record secchi disk depths of 4.6 m. After the first dose, water quality in Lotus Lake did not resound as well as the other lakes (only 19% surface and 46% bottom). This may be due to the very high phosphorous release rates observed from the sediment cores taken. A second dose would further reduce the release rates. The shallower areas of the lake may also have higher release rates and may be contributing to the high phosphorus levels. The District will monitor TP and OP in both deep water basins that received alum (south and east) in Lotus Lake to gauge phosphorus release rates in the east basin. Additional sediment coring will also most likely occur before the second alum application. Overall, the results indicate that alum applications are effective and can drastically reduce phosphorous levels within a lake. Staff will continue to monitor each lake to determine second dose application and gauge temporal success of each treatment.

Table 9 Aluminum Sulfate Effectiveness on Lake Surface and Bottom Total Phosphorous

Surface TP		Dose 1			Dose 2	
Lake	Years	Average TP Pre	Average TP Post	% Reduction	Average TP Post	% Reduction
Riley	2009-2020	0.0458	0.0270	41	0.0178	61
Lotus	2017-2020	0.0475	0.0386	19	Not Complete	
Rice Marsh	2017-2020	0.0767	0.0365	52		
Round	2008-2020	0.0420	0.0379	10	0.0333	21
Hyland	2017-2020	0.0810	0.0274	66	Not Complete	

Bottom TP		Dose 1			Dose 2	
Lake	Years	Average TP Pre	Average TP Post	% Reduction	Average TP Post	% Reduction
Riley	2014-2020	0.6357	0.1707	73	0.0496	92
Lotus	2017-2020	0.3245	0.1739	46	Not Complete	
Rice Marsh	2017-2020	0.1483	0.0330	78		
Round	2010-2020	0.9504	0.1540	84	0.0548	94
Hyland	No Data					

*D1=dose 1; D2= dose 2



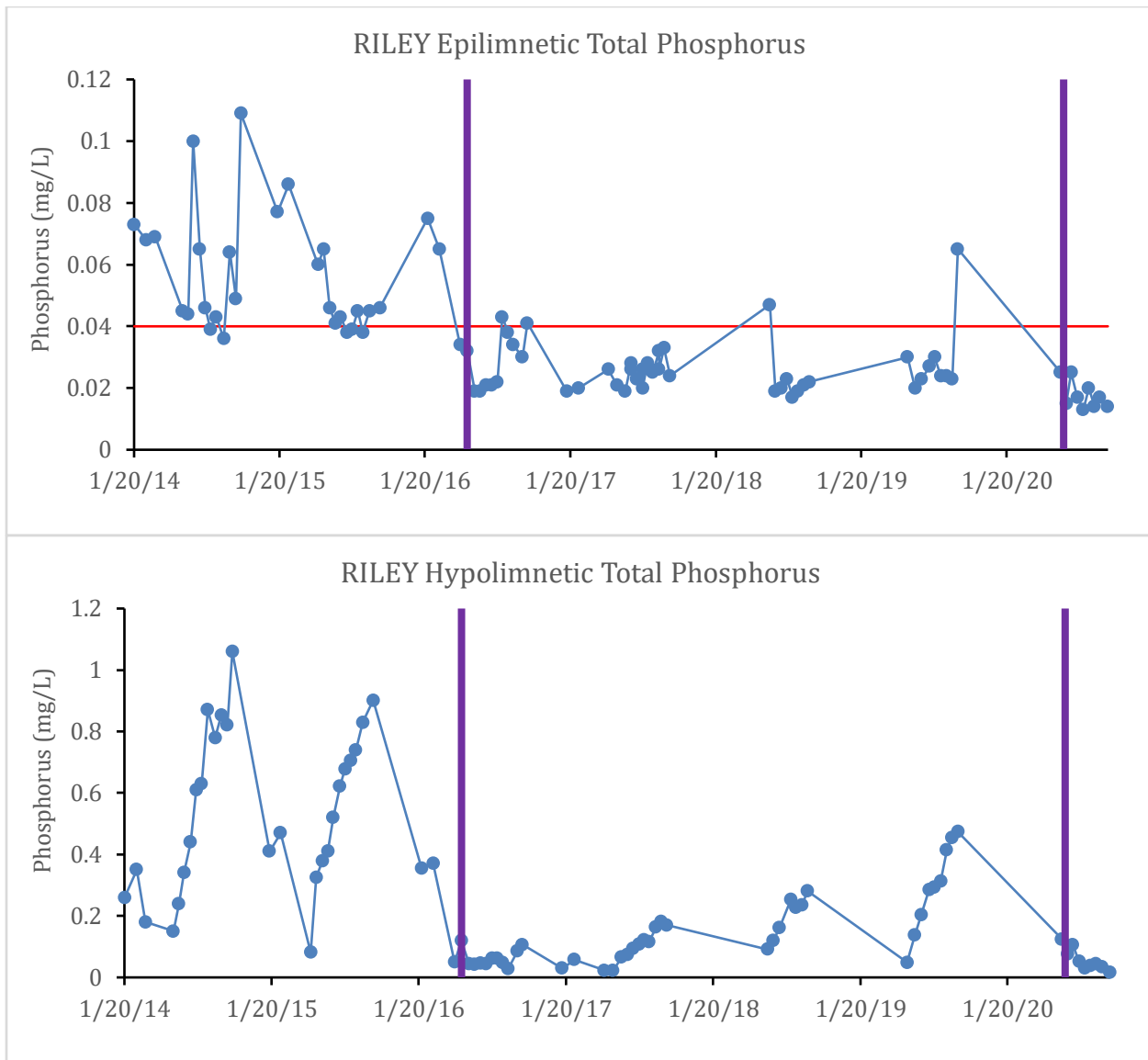


Figure 6 Lake Riley Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Lake Riley between January 20, 2014 and September 30, 2020. The aluminum sulfate (Alum) treatments occurred on May 5, 2016 and June 11, 2020 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 2 m composite samples taken at the lake surface and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1 m above the sediment near the deepest point in the lake. The MPCA water quality standard for TP is represented in the upper graph by the horizontal red line (0.04 mg/L).

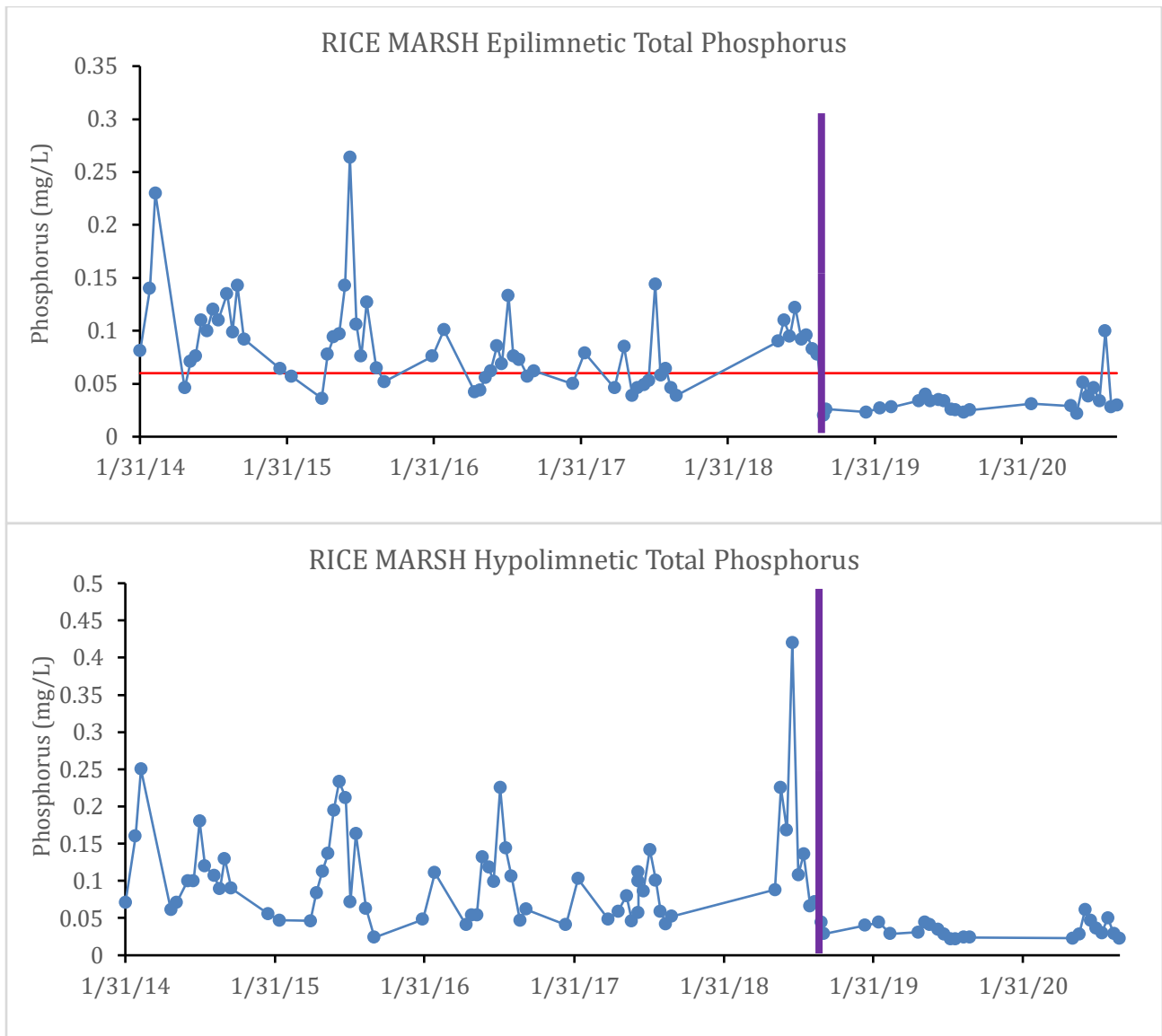


Figure 7 Rice Marsh Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Rice Marsh Lake between January 31, 2014 and September 23, 2020. The aluminum sulfate (Alum) treatment occurred on September 21, 2018 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 2 m composite samples taken at the lake surface and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1 m above the sediment near the deepest point in the lake. The MPCA water quality standard for TP is represented in the upper graph by the horizontal red line (0.06 mg/L).

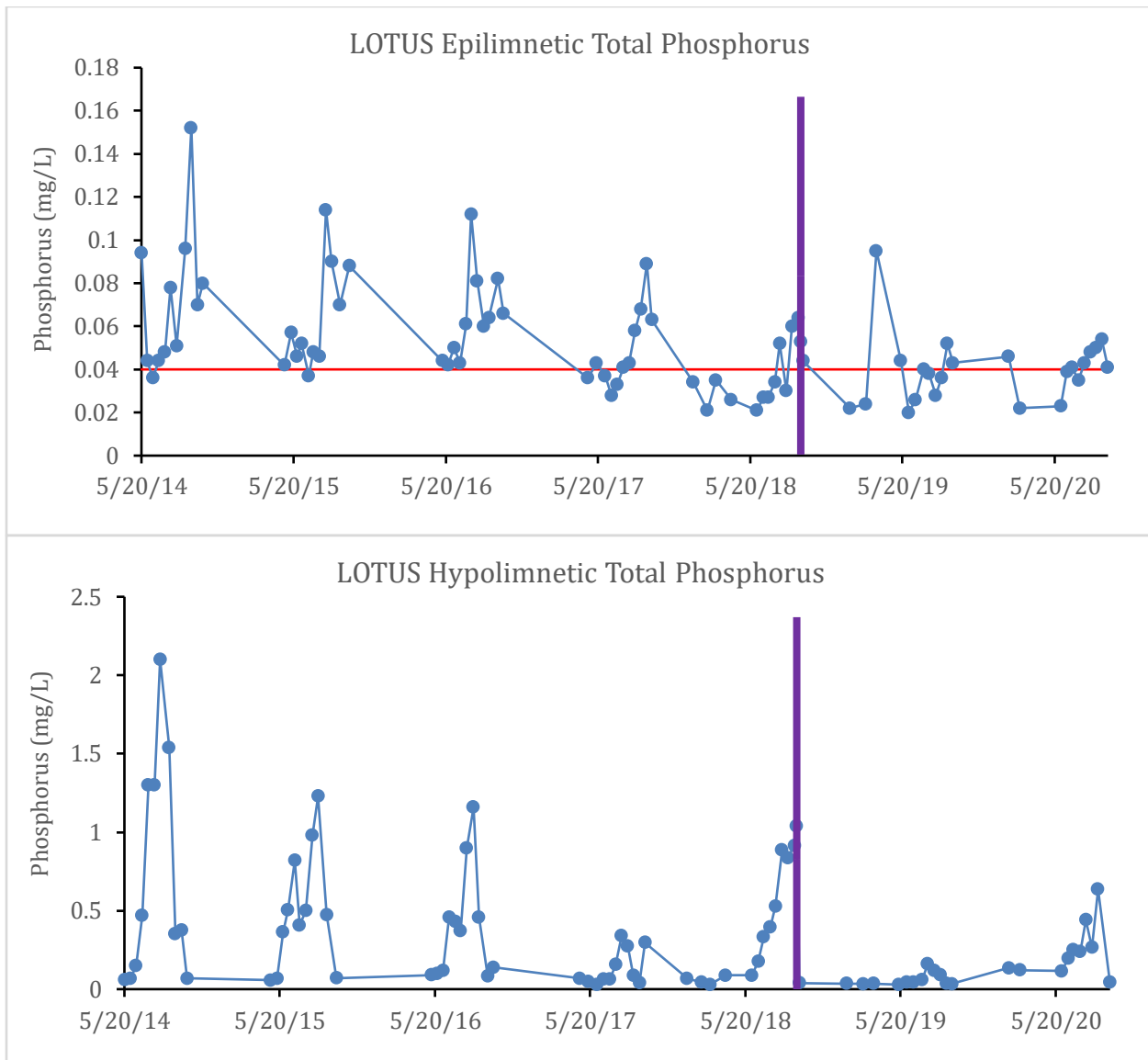


Figure 8 Lotus Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Lotus Lake between May 6, 2014 and September 24, 2020. The aluminum sulfate (Alum) treatment occurred on September 18, 2018 (indicated by vertical bar). The upper graph displays TP levels (mg/L) measured from 2 m composite samples taken at the lake surface and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1 m above the sediment near the deepest point in the lake. The MPCA water quality standard for TP is represented in the upper graph by the horizontal red line (0.04 mg/L).

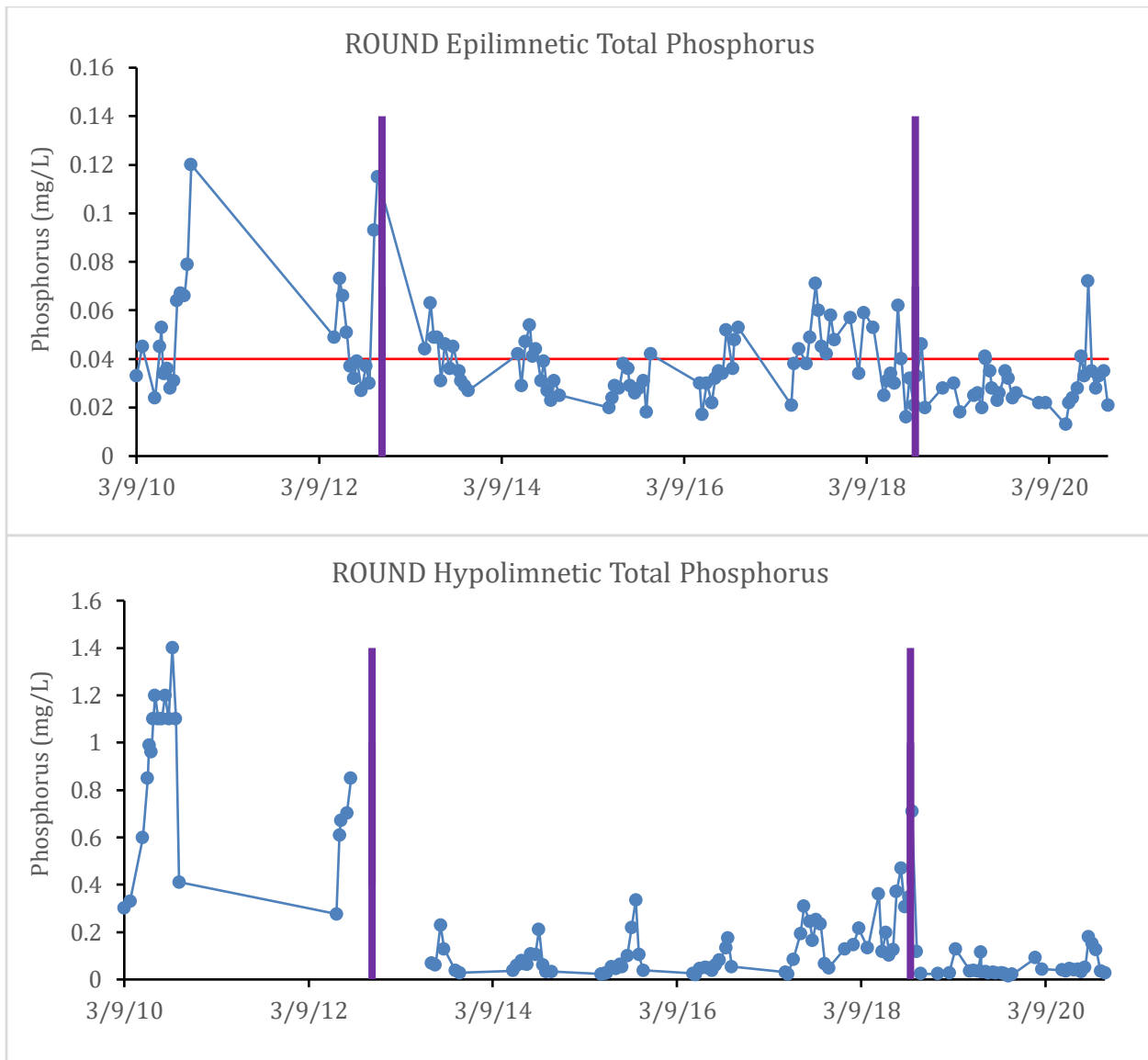


Figure 9 Round Lake Total Phosphorus Levels pre- and post- Alum Treatment

Total phosphorus levels (TP) in Round Lake between March 9, 2010 and October 30, 2020. The aluminum sulfate (Alum) treatments occurred on November 15, 2012 and October 24, 2018 (indicated by vertical bars). The upper graph displays TP levels (mg/L) measured from 2 m composite samples taken at the lake surface and the lower graph displays the TP levels (mg/L) measured from samples taken 0.5-1 m above the sediment near the deepest point in the lake. The MPCA water quality standard for TP is represented in the upper graph by the horizontal red line (0.04 mg/L).

4.3 Chloride Monitoring

Increasing chloride (Cl) levels in water bodies are becoming of greater concern within the state of Minnesota. It takes only one teaspoon of road salt to permanently pollute five gallons of water, as chlorides do not break down over time. At high concentrations, Cl can also be harmful to fish, aquatic plants, and other aquatic organisms. The MPCA Cl Chronic Standard (CS, highest water concentration of Cl to which aquatic life, humans, or wildlife can be indefinitely exposed without causing chronic toxicity) is 230mg/L for class 2B surface waters (all waters sampled within the district, excluding storm water holding ponds). The MPCA Cl Maximum Standard (MS, highest concentration of Cl in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality) is 860mg/L for class 2B surface waters.



Figure 10 Heavy Salt Application

The District has been monitoring salt concentrations in our lakes and ponds since 2013 and will continue monitoring efforts to identify high salt concentration areas and to assess temporal changes in salt concentrations. In 2019, staff carried out Cl sampling in lakes and streams every other week during the spring, switching to monthly sampling in summer/fall/winter. In 2020, winter monitoring included the Purgatory Chain of Lakes (Lotus, Silver, Duck, Round, Mitchell, Red Rock, Staring, and Hyland), the Upper and Lower Purgatory Creek Recreation Area (UPCRA and LPCRA), Rice Marsh Lake, and a chain of ponds that drain the City of Eden Prairie Center to Purgatory Creek. During sampling, staff collected a surface 2 m composite sample (when possible) and a bottom water sample to be analyzed for Cl. Since 2013, except for multiple samples taken from Idlewild, every sample taken from the RCL and PCL, has fallen below the MPCA CS of 230mg/L (**Figure 11, Figure 12**). In 2020, Idlewild did not meet the chloride standard, but it often exceeded the standard in the past. The maximum concentration measured in Idlewild was from a bottom sample taken in March of 2019 which measured 390 mg/L. The only other lake that had chloride concentrations above the standard was Staring Lake in 2018. Multiple bottom concentrations exceeded the standard, however the average (top/bottom) did not. Overall, Cl levels have stayed relatively consistent within lakes year-to-year.

Figure 13 shows Cl levels within the four stormwater ponds, which includes all sampling events since 2013. Except for two sampling events, all samples taken from Pond K (top of the chain) exceed the class 2B MS. This includes 2013 samples which exceeded the maximum chloride concentrations the lab equipment can measure. Most samples taken from Eden Pond greatly exceed the class 2B CS, some exceeding the class 2B MS. In the spring of 2015, staff were no longer able to take accurate water samples on Pond B due to low water levels, so, sampling began on Pond A, directly upstream. In 2018, due to inconsistencies with getting samples without disturbing sediment, staff reverted again to sampling Pond A in place of Pond B for multiple monitoring events. It is important to note that these stormwater ponds are not classified as class 2B surface waters by the MPCA and so the standards do not apply. Moving from upstream to downstream (Pond K to Pond B) it appears that the ponds are retaining much of the chloride they are receiving from the surrounding watershed during the winter even during melting events. This is preventing high chloride levels from reaching Purgatory Creek. During significant rain events in the spring, chloride most likely is flushed downstream at a larger scale than in the winter or during normal water level periods.

Staff will rotate the winter monitoring of Cl to the Riley Chain of Lakes in 2021 which will include: Lucy, Ann, Susan, Rice Marsh, and lake Riley, along with the stormwater ponds draining Eden Prairie Center. Once-a-month Cl sampling will continue as part of the monthly sampling SOP's during the regular growing season on both lakes and streams.

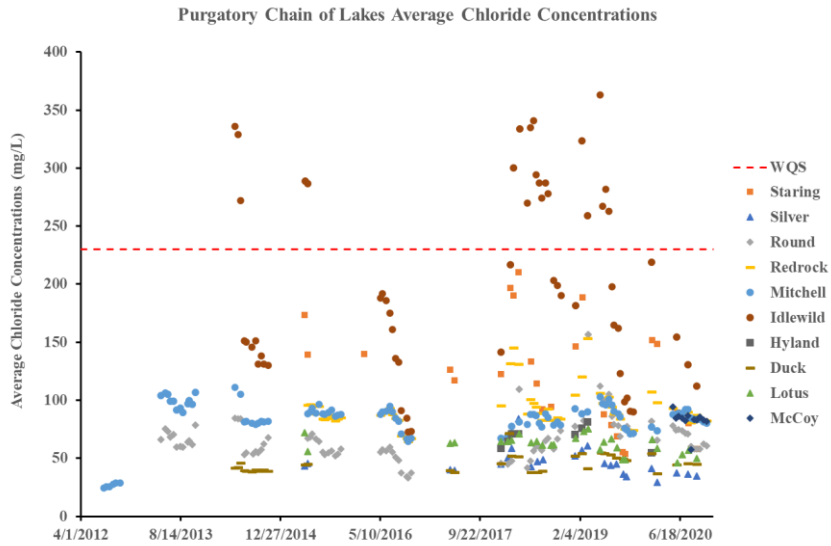


Figure 11 2013-2020 Chloride Levels within the Purgatory Chain of Lakes

All average chloride sampling results (mg/L) on the Purgatory Chain of Lakes from 2013-2020. The MPCA chloride chronic standard for class 2B waters (230mg/L) is indicated by the red line.

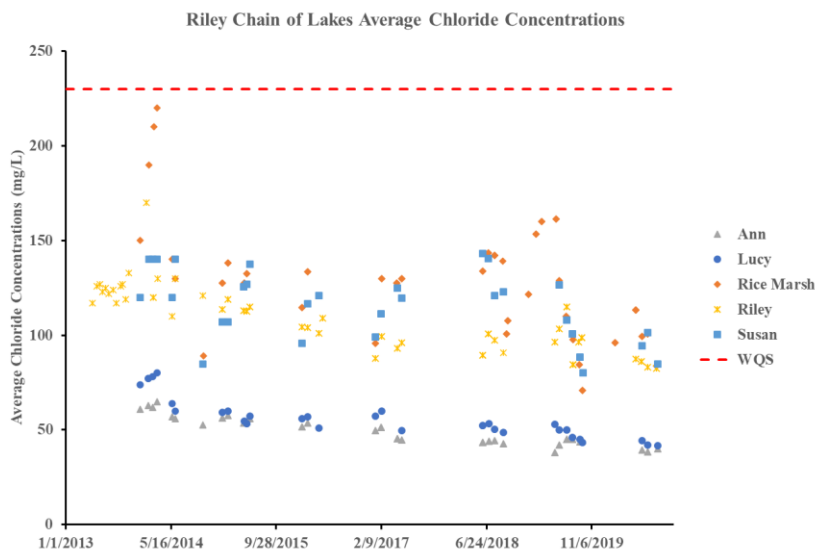


Figure 12 2013-2020 Chloride Levels within the Riley Chain of Lakes

All average chloride sampling results (mg/L) on the Riley Chain of Lakes from 2013-2020. The MPCA chloride chronic standard for class 2B waters (230mg/L) is indicated by the red line.

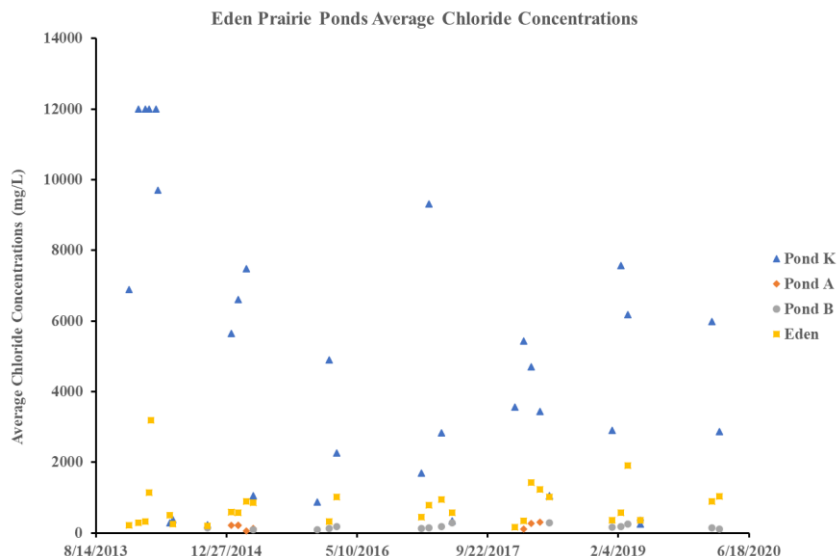


Figure 13 2013-2020 Chloride Levels within EP Stormwater Ponds

All average chloride results (mg/L) on stormwater ponds draining the City of Eden Prairie Center to Purgatory Creek from 2013-2020.

4.4 Nitrogen Monitoring

The toxicity of nitrates to aquatic organisms has been a growing concern in MN over the last decade. Nitrate (NO_3), the most available form of nitrogen for use by plants, can accumulate in lakes and streams since aquatic plant growth is not limited by its abundance. While nitrate has not been found to directly contribute to eutrophication of surface waters (phosphorus is the main cause of eutrophication) and is not a MPCA water quality standard, studies have found that nitrate can cause toxicity in aquatic organisms. In 2010, the MPCA released the Aquatic Life Water Quality Standards Technical Support Document for Nitrate: Technical Water Quality Standard Amendments to Minn. R. chs. 7050 and 7052 (still in the draft stage for external review) to address concerns of the toxicity of nitrate in freshwater systems and develop nitrate standards for class 2B and 2A systems. Sources of excess nitrate in freshwater systems are linked to human activities that release nitrogen into water. The draft chronic standard (CS) of 4.9mg/L nitrate-N.

Once a month during regular sampling, staff collects a surface 2m composite and a bottom water sample to be analyzed for nitrate+nitrite and ammonia+ammonium. In 2019, staff added Total Kjeldahl Nitrogen (TKN) to its monthly sampling regime. Organic-N levels are determined in a laboratory method called Total Kjeldahl Nitrogen (TKN). This measures the combination of organic N and ammonia+ammonium. Organic-N can be biologically transformed to ammonium and then to nitrate and nitrite forms. Because of this, monitoring for TKN could provide important supplemental data if staff observe increases in harmful forms of N in the future. Three Rivers Park District conducts water sampling on Hyland Lake and shares data with the District. Their lab tests do not specifically test for nitrogen as nitrate+nitrite or ammonia, therefore, nitrogen data on Hyland only includes TKN. The District monitors for nitrates in lakes as a part of its regular sampling regime. The District tests for nitrates in the form of nitrate+nitrite (the combined total of nitrate and nitrite, **Table 10**). This lab also tests for ammonia in the form of ammonia+ammonium. As seen in **Error! Reference source not found.**, all the lakes in the District met the draft nitrate CS. It is also important to note that the lab equipment used to test for nitrate has a lower limit of 0.03 mg/L. Therefore, it is possible that some of the samples contained less than 0.03 mg/L nitrate; because of this, actual average nitrate levels in District lakes may be lower than what measured (**Table 10**).

Ammonia (NH_3), a more toxic nitrogen-based compound, is also of concern when discussing toxicity to aquatic organisms. It is commonly found in human and animal waste discharges, as well as agricultural fertilizers in the form of ammonium nitrate. When ammonia builds up in an aquatic system, it can accumulate in the tissues of aquatic organisms and eventually lead to death. The MPCA does have standards for assessing toxicity of ammonia; the CS of ammonia in class 2B is 0.04 mg/L. RMB Environmental Lab water sample testing methods measures for ammonia in the form of ammonia+ammonium. The lab lower limit for these samples is 0.04 mg/L. The lower limit for sample data provided by the City of Eden Prairie for Red Rock, Round, McCoy, and Mitchell Lakes is 0.16 mg/L. Due to these limits, some of the average levels of Ammonia+Ammonium provided in **Table 10** may actually be lower than what is given. In lakes and streams, ammonium (NH_4^+) is usually much more predominant than ammonia (NH_3) under normalized pH ranges. Ammonium is less toxic than ammonia, and not until pH exceeds 9 will ammonia and ammonium be present in about equal quantities in a natural water system (as pH continues to rise beyond 9, ammonia becomes more predominant than ammonium). **Table 10** shows ammonia+ammonium average levels in each lake during the growing season. These numbers are not of concern at this point seeing that pH levels were normal throughout the 2020 growing season and because lab testing measures the combination of ammonia and ammonium. This suggesting that most of nitrogen found in these tests was from the less toxic compound ammonium.

Table 10 2020 Lakes Summer Average of Nitrogen

2020 growing season (June-September) averages of nitrate+nitrite, ammonia, and total kjeldahl nitrogen levels for District lakes. The MPCA proposed chronic standard (CS) is included in the table (orange). The NH4 (CS) standard should not be directly compared to lake values (see text). Lower limit of lab analysis of nitrate+nitrite is 0.03 mg/L and ammonia+ammonium is 0.04 mg/L.

Lake	Average Nitrate-N	Average Ammonia+Ammonium	Total Kjeldahl Nitrogen
MPCA	4.90mg/L	*0.04mg/L NH4	-
Ann	0.030	0.794	1.513
Duck	0.030	0.063	0.821
Hyland			0.663
Idlewild	0.030	0.060	0.591
Lotus	0.030	1.377	3.200
Lucy	0.030	1.578	1.745
McCoy	0.050	0.160	1.475
Mitchell	0.050	0.194	1.688
Red Rock	0.050	0.169	1.863
Rice Marsh	0.030	0.069	0.840
Riley	0.032	0.541	0.970
Round	0.050	0.160	1.100
Silver	0.030	0.095	1.127
Staring	0.030	0.304	1.463
Susan	0.033	0.566	1.588

4.5 Lake Water Levels

In-Situ Level Troll 500, 15-psig water level sensors, as well as METER Environment Hydros 21 water level sensors, have been placed on most lakes throughout the watershed district to monitor water quantity and assess yearly and historical water level fluctuations. These sensors are mounted inside a protective PVC pipe that are attached to a vertical post and placed in the water. A staff gauge, or measuring device, is also mounted to the vertical post, and surveyed by District staff to determine the elevation for each level sensor. Once the water elevation is established, the sensors record continuous water level monitoring data every 15 minutes from ice out until late fall. New in 2018, staff built and deployed two EnviroDIY stations run by EnviroDIY Mayfly circuit boards on Rice Marsh Lake and Lake Riley. These units were housed in a Pelican brand waterproof case which were mounted to one of the District's standard level sensor posts/staff gauges. These stations were outfitted with the Hydros 21 water level sensors, a solar panel, as well as a radio which allowed for remote communication with the station for real-time viewing of elevation/data.

Lake level data is used for developing and updating the District's models, which are used for stormwater and floodplain analysis. Monitoring the lake water levels can also help to determine the impact that climate change may have on lakes and land interactions in the watershed. Lake level data is also used to determine epilimnetic zooplankton grazing rates (located in section 4.9). Lake level data is submitted to the Minnesota Department of Natural Resources (MNDNR) at the end of each monitoring season and historical data specific to each lake can be found on MNDNR website using the Lakefinder database. See 8 Exhibits A for 2019 level sensor results. Lake Levels for 2018 are also provided for a year-to-year comparison. In both the Lakefinder database and in 8 Exhibits A, the Ordinary High-Water Level (OHWL) is displayed so water levels can be compared to what is considered the "normal" water level for each lake. The OHWL is used by governing bodies like the RPBCWD for regulating activities that occur above and below this zone. National Oceanic and Atmospheric Administration (NOAA) precipitation data collected from the area was also included in 8 Exhibits A to evaluate how rain events influenced lake levels. Rain data recorded at the Flying Cloud Drive Airport, Eden Prairie, MN is included alongside lake level data from lakes in Hennepin County (including Lake Riley). A combination of rain data from Meteorological Station Chanhassen WSFO and Chanhassen 1.0 ESE is included alongside lake level data from lakes in Carver County.

In 2019, lake level measurements were collected on 13 lakes in the District and one high value wetland, Lake Idlewild (**Table 11**). Silver Lake experienced the greatest seasonal water level change over the 2019 season, increasing 0.567ft from sensor placement to the last day of recording (Oct. 29). Staring Lake had the largest range of fluctuation through 2019, having a low elevation of 814.499ft, and a high of 816.344ft (1.845ft difference). On average, lake levels decreased by 0.165ft over the 2019 season. The average fluctuation range across all lakes was 1.121ft.

Table 11 Lake Water Levels Summary

The 2019 (March-November) and historical recorded lake water levels (ft) for all monitored lakes within the Riley Purgatory Bluff Creek Watershed District. 2019 data includes the overall change in water level, the range of elevation fluctuation, and the highest and lowest recorded elevations. Historical data includes the highest and lowest historical recorded levels and the date they were taken.

Lake	2019 Lake Water Level Data				Historical Lake Water Levels			
	Seasonal Flux	Flux Range	High level	Low level	Highest Level	Date	Lowest Level	Date
Ann	-0.419	0.782	956.743	955.961	957.93	2/18/1998	952.80	9/28/1970
Duck	-0.155	0.892	915.303	914.411	916.12	6/20/2014	911.26	11/10/1988
Hyland	-0.295	1.068	817.299	816.231	818.68	8/11/1987	811.66	12/2/1977
Idlewild	-0.224	1.031	854.497	853.466	860.78	3/29/1976	853.10	1/7/1985
Lotus	-0.193	0.958	896.353	895.395	897.08	7/2/1992	893.18	12/29/1976
Lucy	-0.453	0.744	956.807	956.063	957.67	6/20/2014	953.29	11/10/1988
Mitchell	-0.351	1.063	872.636	871.573	874.21	6/25/2014	865.87	7/25/1977
Red Rock	0.191	1.041	841.317	840.276	842.69	7/13/2014	835.69	9/28/1970
Rice Marsh	0.531	1.135	876.582	875.447	877.25	5/28/2012	872.04	8/27/1976
Riley	-1.145	1.447	865.559	864.112	866.74	7/6/1993	862.00	2/1/1990
Round	0.145	1.252	881.067	879.815	884.26	8/17/1987	875.29	7/25/1977
Silver	0.567	1.021	900.089	899.068	901.03	6/20/2012	894.78	6/6/1972
Staring	-0.136	1.845	816.344	814.499	820.00	7/24/1987	812.84	2/12/1977
Susan	-0.378	1.419	882.288	880.0869	883.77	6/21/2014	879.42	12/29/1976
Average	-0.165	1.121						

4.6 Galpin Blvd Bluff Creek Crossing

Bluff Creek is listed on the 2002 and 2004 Minnesota Section 303(d) List of Impaired Waters due to impairment of turbidity and low fish Index of Biological Integrity (IBI) scores. Turbidity in water is caused by suspended sediment, organic material, dissolved salts and stains that scatter light in the water column making the water appear cloudy. Excess turbidity can degrade aesthetic qualities of water bodies, can harm aquatic life, and have greater thermal impacts from increased sediment deposition in the stream. Primary sources contributing TSS within the Bluff Creek Watershed are streambank and bluff erosion, as well as poorly vegetated ravines and gullies (Barr 2013). These sources of sediment are contributing excess TSS loadings, mobilized by stormwater runoff from the watershed under high flow conditions. In addition, total phosphorous levels across all five Bluff Creek water quality sites are consistently above then MPCA water quality standard from year to year ($\leq 0.1\text{mg/L}$). The Creek Restoration Action Strategy identified subreaches B5B and B5C near Galpin Road as sites that could benefit from restoration/stabilization and therefore reduce downstream nutrient and sediment loading.

When a project is identified RPBCWD staff will often monitor a site before and after the project is implemented. This is to confirm a project is warranted and to monitor the effectiveness of a project. In 2019 and 2020, staff placed an automated sampling unit at the culvert under Galpin Road. This was done to better quantify rain event nutrient loading from upstream sources from Bluff Creek. Analyzing the “first flush” of a storm event is important because these events are when water pollution entering storm drains in areas with high proportions of impervious surfaces is typically more concentrated compared to the remainder of the storm. Water samples were collected and analyzed for total dissolved phosphorus (TDP), ortho-phosphorous (OP), total phosphorus (TP), total suspended solids (TSS), and Chlorophyll-a (Chl-a) in 2019. The automated water-sampling unit also estimated flow of the creek at that point.

In 2019 and 2020, total phosphorus levels at the upper Bluff Creek site during storm events were high compared to the MPCA standards, as seen in **Error! Reference source not found..** As seen in **Table 12**, the average TP across 17 samples was 0.525 mg/L in 2019 and 0.425 mg/L in 2020. This level is over four times the MPCA eutrophication water quality standard for class 2B streams ($\leq 0.1\text{ mg/L TP}$). Across both years, all TP samples collected measured above the MPCA standard with the highest TP concentration having occurred in early August in 2019 at 1.77 mg/L and 1.12 mg/L in mid-October of 2020. 2019 TDP average in 2019 was 0.135 mg/L with the highest measurement of 0.237 mg/L (**Table 12**). OP average in 2020 was 0.094 mg/L with the highest measurement of 0.168 mg/L. The average amount of TSS across the 17 samples taken was 84.6 mg/L in 2019. The average amount of TSS across the 15 samples taken was 26.4 mg/L in 2019. To achieve the MPCA TSS stream water quality standard, a stream may not exceed 30 mg/L TSS more than 10% of the time. Across all the sampling events, nine of the 17 samples taken in 2019 were above 30 mg/L TSS and only five of the fifteen samples taken in 2020 were above the standard (**Error! Reference source not found.**). Four of the six in 2019 and five of six in 2020 Chl-a samples collected were less than the MPCA eutrophication water quality standard of $\leq 18\text{ ug/L Chl-a}$ (**Table 12**). It is important to remember that these samples are targeted samples, representative of the initial flush of water and pollutants that occurs during a rain event, and do not represent season-long pollutant levels in Bluff Creek. Therefore, a direct comparison to the MPCA water quality standards is cautioned.

Table 12 2019 and 2020 Galpin Road Bluff Creek Crossing Nutrient Loading Summary

Galpin Road Bluff Creek Crossing Total Dissolved Phosphorus (mg/L), Ortho-phosphorous (mg/L), Total Phosphorus (mg/L), Chlorophyll-a (ug/L), and Total Suspended Solids (mg/L) max, min, and average concentrations from random grab samples and an automated, level triggered and flow-paced samples in 2019 and 2020. The Minnesota Pollution Control Agency water quality standards are also included.

Parameter	Minimum	Maximum	2019 Average	2020 Average	MPCA Water Quality Standards
TP (mg/L)	0.11	1.77	0.525	0.425	≤ 0.1
TDP (mg/L)	0.025	0.237	0.135		
OP (mg/L)	0.031	0.168		0.094	
Chl-a (ug/L)	1.6	32	11.562	32	≤ 18
TSS (mg/L)	4.1	800	84.6	26.4	≤ 30

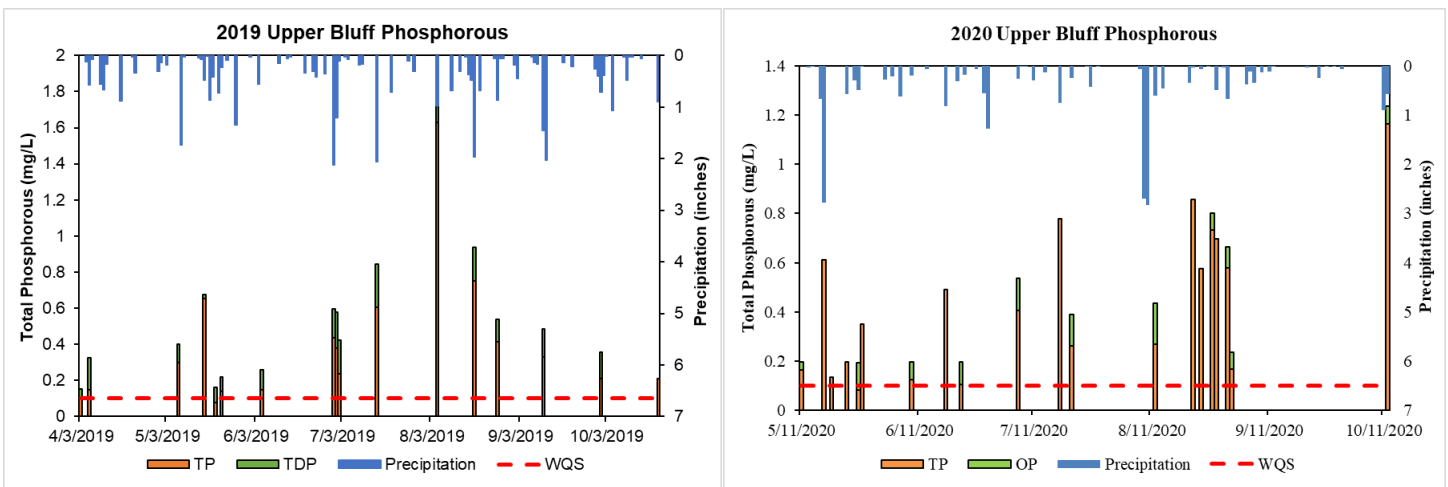


Table 13 2019 and 2020 Upper Bluff Creek Phosphorus

The Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) concentrations (mg/L) from Bluff Creek under Galpin Blvd from 2019 automated, level triggered, flow-paced samples. Dashed line represents the Minnesota Pollution Control Agency standard for TP in class 2B creeks (≤ 0.1mg/L).

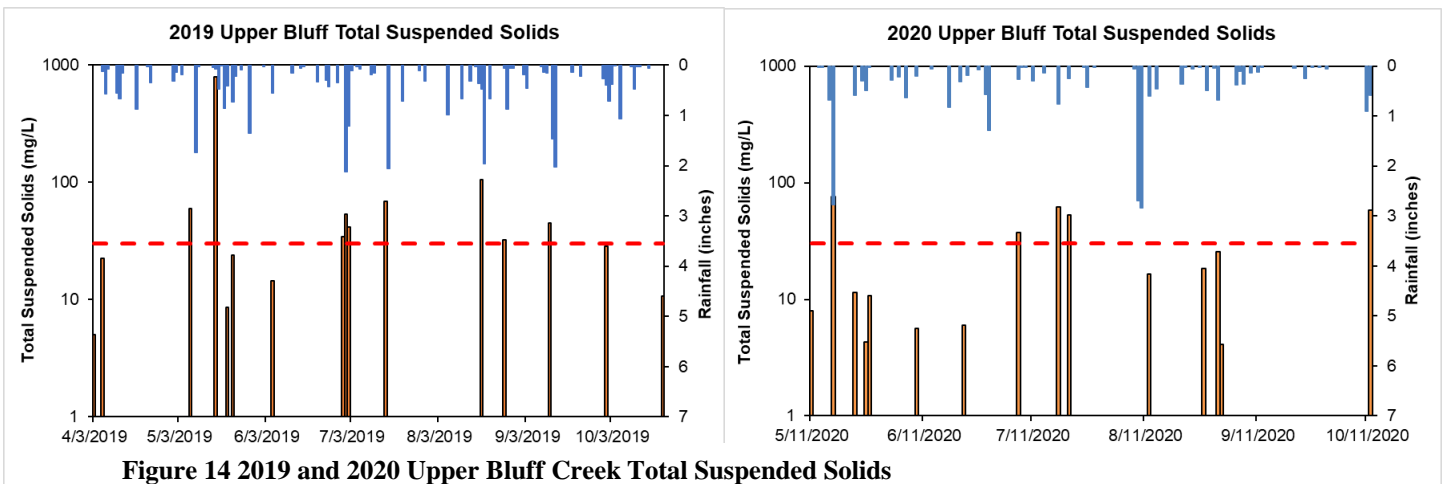


Figure 14 2019 and 2020 Upper Bluff Creek Total Suspended Solids

Total Suspended Solids (TSS) concentrations (mg/L) from Bluff Creek under Galpin Blvd from 2019 and 2020 automated, level triggered, flow-paced sampler. Dashed line represents the Minnesota Pollution Control Agency standard for TSS in class 2B creeks (≤ 30 mg/L TSS no more than 10% of the time).

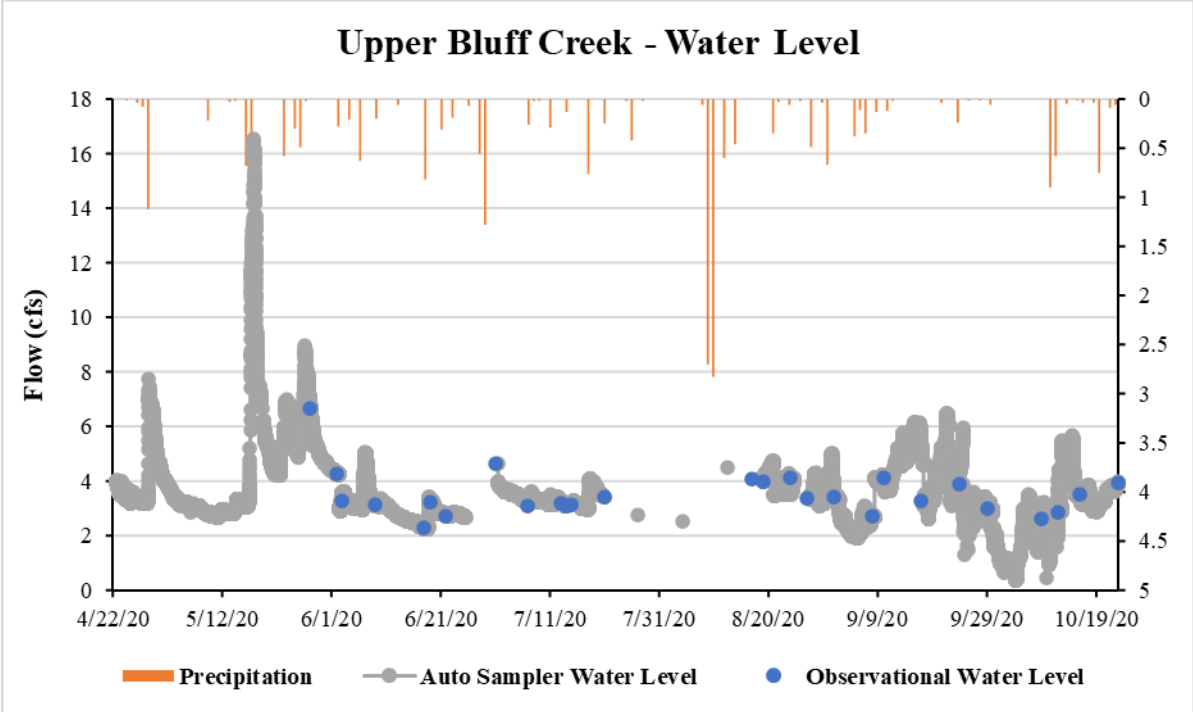


Figure 15 2020 Upper Bluff Creek Water Levels

Autosampler and Visual Water Levels from Bluff Creek under Galpin Blvd from 2020.

4.7 Creek Restoration Action Strategy

The RPBCWD developed the Creek Restoration Action Strategy (CRAS) to prioritize creek reaches, sub-reaches, or sites, in need of stabilization and/or restoration. The District has identified eight categories of importance for project prioritization including: infrastructure risk, erosion and channel stability, public education, ecological benefits, water quality, project cost, partnerships, and watershed benefits. These categories were scored using methods developed for each category based on a combination of published studies and reports, erosion inventories, field visits, and scoring sheets from specific methodologies. Final tallies of scores for each category, using a two-tiered ranking system, were used to prioritize sites for restoration/remediation. More information on the CRAS can be found on the District’s website: www.rpbcwd.org. The CRAS was finalized/adopted in 2015, updated in April of 2017, and published in the Center for Watershed Protection Science Bulletin in 2018. A severe site list was developed which includes subreaches from all three creeks (**Table 14**).

Table 14 Severe Reaches Identified by the Creek Restoration Action Strategy

Stream	Tier II Rank	Tier I Rank	Reach	Subreach	Location
Purgatory	1	9	P7	P7E	Covington Road to Pond in Covington Park
Riley	2	2	R2	R2E	Middle 1/3 between Dell Road and Eden Prairie Road
Bluff	3	5	BT3	BT3A	Audubon Road to Pioneer Trail
Purgatory	4	4	P1	P1E	1,350 feet DS of Pioneer Trail to Burr Ridge Lane
Bluff	5	1	B1	B1D	475 feet US of Great Plains Blvd to Great Plains Blvd
Bluff	6	7	B3	B3A	750 feet DS of Railroad to 860 feet DS of Railroad
Bluff	7	10	B3	B3C	1,675 feet US of Audubon Road to Lyman Blvd
Bluff	8	6	R2	R2D	Upper 1/3 between Dell Road and Eden Prairie Road
Bluff	9	3	B5	B5C	Galpin Blvd to West 78th Street
Bluff	10	8	B5	B5B	985 feet US of Galpin Blvd to Galpin Blvd

Note: US = Upstream; DS = Downstream

As part of CRAS, stream reaches are walked on a rotational basis after the initial assessment was completed. This will allow staff to evaluate changes in the streams and update the CRAS accordingly. In 2019 staff walked Reach 7 of Purgatory Creek and parts of Reach 3, 4, and 5. In 2020 staff walked Reach 1 and 2 of Purgatory Creek and Reach 5 of Bluff Creek. Staff conducted Modified Pfankuch Stream Stability Assessments, MPCA Stream Habitat Assessments (MSHA), took photos, and recorded notes of each subreach to assess overall stream conditions. In addition to creek walks, staff also checked bank pins which were installed in 2015 and 2018 near all the regular water quality sites. The bank pins were installed at “representative” erosion sites to evaluate general erosion rates for each reach. Changes to the CRAS based upon 2020 creek walks can be seen in **Table 15** and in our Fact Sheets. A summary of the 2020 creek walks can be seen in the section below.

In addition to CRAS scoring and measuring bank pins, staff also collected macroinvertebrates at all five Bluff Creek sites in 2020 (Purgatory Creek in 2019). Biological monitoring can often detect water quality problems that water chemistry analysis misses or underestimates. Chemical pollutants, agricultural runoff, hydrologic alterations, and other human activities have cumulative effects on biological communities over time. The condition of these communities represents the condition of their aquatic environment. The 2020 data was not available for this report.

Table 15 2020 Creek Restoration Action Strategy Updates

Tier I and Tier II scores for the Creek Restoration Action Strategy for 2017 and the corresponding updates from 2020 for subreaches within P1, P2, and B5.

Reach	Subreach	Location	2017 Tier I Scores	2020 Tier I Scores	Tier II Scores
B5	B5A	Ridgeview Road Recreational Trail to 985 feet US of Galpin Boulevard	16	14	28
B5	B5B	985 feet US of Galpin Boulevard to Galpin Boulevard	22	20	34
B5	B5C	Galpin Boulevard to West 78th Street	24	24	40
P2	P2A	Purgatory Creek Conservation Area to Staring Lake	14	18	30
P2	P2B	Staring Lake to Flying Cloud Drive	16	18	34
P2	P2C	Flying Cloud Drive to Creek Knoll Road	16	18	30
P2	P2D	Creek Knoll Road to 1,725 feet DS of Creek Knoll Road	14	18	28
P2	P2E	1,725 feet DS of Creek Knoll Road to Homeward Hills Road	14	18	28
P1	P1A	Homeward Hills Road to 1,250 feet DS of Homeward Hills Road	16	18	26
P1	P1B	1,250 feet DS of Homeward Hills Road to Pioneer Trail	20	20	36
P1	P1C	Pioneer Trail to 2,950 feet DS of Pioneer Trail	18	20	30
P1	P1D	2,950 feet DS of Pioneer Trail to 1,350 feet DS of Wild Heron Point	18	18	32
P1	P1E	1,350 feet DS of Wild Heron Point to Burr Ridge Lane	24	22	44
P1	P1F	Burr Ridge Lane to 1,250 feet US of Riverview Road	22	20	34
P1	P1G	1,250 feet US of Riverview Road to Riverview Road	16	18	22

BLUE=GOOD
 YELLOW=MODERATE
 ORANGE=POOR
 RED=SEVERE

In 2021, staff will finish the second complete walk of Bluff Creek and update accordingly. CRAS updates and potential additional monitoring for 2021 include:

- Placement of additional bank pins at sites that align with upcoming projects.
- Walk additional 1st order tributaries that have not been assessed.
- LRAS

- Assessing additional ravine erosion areas.
- Using the stream power index (SPI) to identify and assess potential areas of erosions upstream of wetland, creeks, and lakes.
- Installing EnviroDIY stations near areas of concern or where information is lacking.
- Utilize CRAS2 to advance creek stability assessments.
- Potentially add macroinvertebrates Index of Biotic Integrity to CRAS scoring methodology.

Purgatory Creek – P2

Reach 2 of Purgatory Creek begins at Mitchell road and ends at Highway 212. The reach stretches across subreaches P2A and P3B and encompasses approximately 1.02 stream miles. The culvert under Mitchell road was replaced and stabilized in 2014 and was in good shape. Substrate at the beginning of the reach consisted of predominantly gravel/cobble but began shifting to sand silt as staff moved downstream. For the last quarter of the reach the substrate again shifted to primarily sand/gravel/detritus with cobble and boulders sparsely distributed. Similarly, woody debris was relatively common early, but quickly faded out with a slight increase in the last quarter of the reach. Overall, stream sinuosity in this reach was very good. Channel development, on the other hand, was relatively poor (riffle/run/pool/sequences). The bank vegetation near Mitchell Road consisted of deciduous trees and sparse patches of terrestrial grasses which stretched about 10m in width from both stream banks. Beyond the 10m riparian zone the landscape was mainly an industrial/urban environment. Both banks had slope gradients between 20%-30% which flattened out about 100m downstream but increased to 40-50% for the last quarter of the reach. Downstream of Mitchell Road stream was approximately 3m wide and had depths ranging from 0.4-1m. Near Mitchell Road, staff observed an eroding stormwater culvert which was suspended about 1m above the outflow channel water surface and has been undercut about 1m. About 100m downstream of Mitchell Road the upland vegetation shifted to grasses/sedges and the riparian zone also increased in width to about 50m. In this stream section, undercutting was almost continuous along both banks, however, the banks were considered stable as it was a wetland stream. There was some bank sloughing occurring throughout this section. The channel displayed a high level of connectivity to the floodplain. As the stream shifted east along Highway 212 the surrounding vegetation changed to mostly buckthorn and deciduous trees. In the last quarter, the average stream depth was approximately 0.5m with an average channel width of 5m. The stream erosion increased in this section as the stream was incised about 0.5m with a few larger erosion areas present. Both Pfankuch and MSHA habitat scores were similar to 2017 scores.

Purgatory Creek – P4

Reach 4 of Purgatory Creek begins at Valley View Road and ends at Mitchell Road. The reach stretches across P4A and P4B which encompasses approximately 0.73 stream miles. Bank shaping/channel re-directing has occurred across the entirety of the reach. Starting downstream of the culvert under Valley View Road, the stream was approximately 6m wide and had a shallow depth, ranging from 0.2-0.6m. Slope gradients were less than 45%. The riparian zone on the right stream bank was wide while the left bank bordering Valley View Road was very narrow. The immediate vegetation consisted of wetland marsh grasses but shifted to deciduous trees shortly downstream. Substrates consisted of sand/silt/muck in the wetland reach. Moving downstream into the wooded area, substrate shifted to gravel/sand. Erosion (incision) increased as staff moved towards the bridge, measuring 0.75m in height. The Minnesota River Bluffs LRT Regional Trail culvert is 5m wide and has signs of wear including cracks and missing chunks.

At the beginning of subreach B, the stream enters the Bent Creek Golf Course. Buffer zones along the stream banks in P4B were absent. Mowed turf grass extended to the edge of the stream in most areas. These practices have increased/caused considerable bank erosion/sloughing, measuring 0.5m-0.75 in height on both banks. Areas where the bank erosion was most severe, small rock had been placed. This rock has the potential to erode and be moved downstream in high/swift water conditions. In slow areas

around stream bends, cattails were growing in patchy stands. Staff also observed considerable deposition of silt and muck at these points. The main substrate was comprised of muck/silt and mucky backwaters were present along the channel. Below the first golf course bridge a 3in diameter irrigation pipe crossed the channel. Moving downstream a stormwater culvert was present on the right bank and extended 3m into the stream channel. Near the end of the golf course on a right bank steep slope, a landscape tarp with cobble size riprap was added in attempt to stabilize the bank.

Purgatory Creek – P5 B/C/D/E

The assessment began immediately downstream from Hwy 62 extending to Valley View Road (approximately 2.4 stream miles). The reach includes five subreaches, of which the lower four were walked in 2019. Reach 5 of Purgatory Creek runs through grassy wetlands and a few areas of mixed deciduous forests. The stream was surrounded by residential housing and had a low slope gradient (<30%). The stream crosses under Eden Prairie Road, Rainbow Drive, a railroad bridge, and a walking trail bridge in subreach P5D upstream of Valley View Road. The creek was fairly straight and had limited channel development (riffle, run, pool). Erosion in this section was relatively low overall with sparse woody debris present within the channel. Overall, Reach 5 was a relatively stable section with some erosion occurring mainly below the choke points at culverts/bridges. After the railroad bridge choke point in P5C, it appears the channel erosion increased since the 2017 analysis. Subreach D had the most continuous erosion with banks incision ranging between 0.25-0.5m. No immediate infrastructure risk was apparent across all the subreaches. MSHA scores indicated limited to moderate habitat availability for aquatic organisms across all subreaches.

Purgatory Creek – P7

Reach P7 of Purgatory Creek originates from Silver Lake and ends at Highway 101 (approximately 1 stream mile). The reach includes five subreaches, of which P7B and P7E are ponding/wetland areas that were not scored by the CRAS. The stream upland vegetative communities in this section consisted of grass prairies, deciduous forests, and cattail marshes. Most banks along the stream were gradually sloped and had moderate-to-no erosion. The creek generally has low flows in this reach. Substrates were made up mostly of sand/silt. P7D did have a considerable amount of gravel/cobble with mixed boulders present. This stream reach was overall in good condition except for P7D. P7D was extremely incised with raw eroding banks up to 2m in height. A few mass wasting sites were also present and contributing sediment nearly all year long. P7D improved in Tier 1 scoring due to an increased MSHA habitat score and because the culvert under Covington Road was replaced and surrounding area stabilized in 2018. This stream enhancement eliminated a major mass wasting site and reduced the infrastructure risk to a score of three. The scoring was only dropped to a three because of a suspended and eroded stormwater culvert downstream of Covington Road was still present.

Bank Pins

In addition to creek walks, staff have also checked bank pins yearly since they were installed in 2015 near all the regular water quality sites. The bank pins were installed at “representative” erosion sites to evaluate erosion rates for each reach. Staff measured the amount of exposed bank pin or sediment accumulation if buried in 2016 through 2019 (2018 and 2019 measurements shown in **Table 16**). From this, staff can quantify estimates of lateral bank recession rates. Engineering firm Wenck Associates, Inc. also installed bank pins at 11 sites on lower Riley Creek (south of Lake Riley) and Purgatory Creek (south of Riverview Road) in 2008 and 2010, to monitor bank loss and quantify lateral recession rates (Wenck, 2017). From their monitoring results, Wenck was able to track the potential effectiveness of upstream bank repairs on bank-loss-reduction at the Purgatory Creek sites. Results from monitoring the Riley Creek bank pins informed Wenck’s recommendation to the City of Eden Prairie to prioritize several reaches for stabilization. In 2018, staff added pins at representative erosion sites near the following regular creek monitoring sites (if pins were installed on the left bank, it is denoted here as LB; RB denotes

pins installed on the right bank): 2 pins on LB at R4, 3 pins on RB and 3 pins on LB at R2, 3 pins on RB at B4, 3 pins on RB and 3 pins on LB at B3, 2 pins on RB at B2, and 1 pin on LB at P6. District staff will continue to monitor the bank pins/bank loss at our 18 regular monitoring sites. In 2019, reach R3 had the highest estimated lateral loss (in/year) while reach R2 had the highest bank loss per one yard stretch of creek (ft3).

Table 16 2018-2020 Bank Pin Data

Average lateral stream bank loss per year and the estimated bank volume loss for a one-yard section of streambank at each of the 18 regular creek monitoring sites from 2018-2020. Negative values denote areas of bank where there was sediment deposition. Empty cells denote sites where pins were not found. Orange-highlighted cells denote sites where bank pins were added on one or both banks in 2018. * Values in these cells are averages from the left bank; right bank pins were not found at these sites. ** The right bank heights used to calculate these values were taken from 2018 measurements.

Site	Average Lateral Loss (in/year)		Estimated bank loss per one yard stretch of creek (ft3)	
	2018	2019	2018	2019
R5	8.99	9.45	2.41	2.58
R4	0.42	4.44	0.25	1.97
R3	5.31	12.96	3.18	5.71
R2	--	6.45	--	6.93
R1	2.96	5.35	1.23	2.71
P8	0.55	2.99	0.12	0.93
P7	2.02	3.40	2.48	3.22
P6	0.73	5.39	0.35	1.95
P5	0.77	3.41	0.41	2.09
P4	0.83	2.09	0.27	**0.69
P3	0.94	1.96	0.51	1.38
P2	0.50	6.36	0.24	3.21
P1	0.38	*0.83	0.46	*0.82
B5	-0.79	1.78	-0.23	0.89
B4	5.58	11.45	3.66	6.59
B3	--	3.29	--	1.84
B2	3.00	*7.00	1.25	*4.08
B1	-0.67	5.54	-0.25	3.45

4.8 Zooplankton and Phytoplankton

In 2019, five lakes were sampled for both zooplankton and phytoplankton: Lake Riley, Rice Marsh Lake, Lake Susan, Lotus Lake, and Staring Lake. Zooplankton play an important role in a lake's ecosystem, specifically in fisheries and bio control of algae. Healthy zooplankton populations are characterized by having balanced densities (number per m²) of three main groups of zooplankton: Rotifers, Cladocerans, and Copepods. The Sedgwick-Rafter Chamber (SRC) was used for zooplankton counting and species identification. A two mL sub-sample was prepared in which all zooplankton were counted and identified to the genus and/or species level. The sample was scanned at 10x magnification to identify and count zooplankton using a Zeiss Primo Star microscope. Cladocera images were taken using a Zeiss Axiocam 100 digital camera and lengths were calculated in Zen lite 2012. The District analyzed zooplankton populations for the following reasons:

1. Epilimnetic Grazing Rates (Burns 1969): The epilimnion is the uppermost portion of the lake during stratification where zooplankton feed. Zooplankton can be a form of bio control for algae that may otherwise grow to an out-of-control state and therefore influence water clarity.
2. Population Monitoring (APHA, 1992): Zooplankton are a valuable food source for planktivorous fish and other organisms. The presence or absence of healthy zooplankton populations can determine the quality of fish in a lake. Major changes in a lake (significant reduction in common carp, winter kills, large scale water quality improvement projects, etc.) can change zooplankton populations drastically. By ensuring that the lower parts of the food chain are healthy, we can protect the higher ordered organisms.
3. Aquatic Invasive Species Monitoring: Early detection of water fleas is important to ensure these organisms are not spread throughout the District. These invasive species outcompete native zooplankton for food and grow large spines which make them difficult for fish to eat.

The Sedgwick-Rafter Chamber (SRC) was used for phytoplankton counting and species identification. A one mL aliquot of the sample was prepared using a Sedgwick Rafter cell. Phytoplankton were identified to genus level. The sample was scanned at 20x magnification to count and identify phytoplankton species using a Carl Zeiss Axio Observer Z1 inverted microscope equipped with phase contrast optics and digital camera. Higher magnification was used as necessary for identification and micrographs. The District analyzed phytoplankton populations for the following reasons:

1. Population Monitoring: Phytoplankton are the base of the food chain in freshwater systems and fluctuate throughout the year. By ensuring that the lower parts of the food chain are healthy, we can protect the higher ordered organisms such as macroinvertebrates and fish.
2. Toxin Producers and Algae Blooms: Some phytoplankton produce toxins that can harm animals and humans, or cause water to have a foul taste or odor (*Microcystis*, *Aphanizomenon*, *Dolichospermum*, *Planktothrix*, and *Cylindrospermopsis*). Monitoring these organisms can help us take the proper precautions necessary and identify possible sources of pollution. Just because toxic algae are found in a lake does mean it could cause harm. Specific conditions must be met for the algae to become toxic.

Lake Riley

In 2020, all three groups of zooplankton were captured in Lake Riley (8 Exhibits C) with 18% of the zooplankton captured Cladocera which is up from 6% in 2019. Unlike in 2019 rotifers were the least abundant zooplankton sampled (**Figure 16**). This may be due to zebra mussels increasing in number which can consume the smaller rotifers. The number of rotifers identified in 2020 slowly increased with the highest number observed during the last September sampling event. Copepod numbers decreased. Cladoceran numbers decreased over the course of the season. Total Cladoceran counts in 2019 were up slightly from 2018, but still less than what was seen in 2016 and 2017 (around 450 thousand). This reduction may be due to the continuing increase in water clarity caused by alum treatment, which leads to increased predation on zooplankton populations. Additionally, zebra mussels were discovered in 2018 which could also be contributing to the increase in water clarity and are removing phytoplankton (Cladoceran food source). The most numerous Cladocera found in Riley was *Chydorus sphaericus*, a species tolerant of widely ranging environmental conditions.

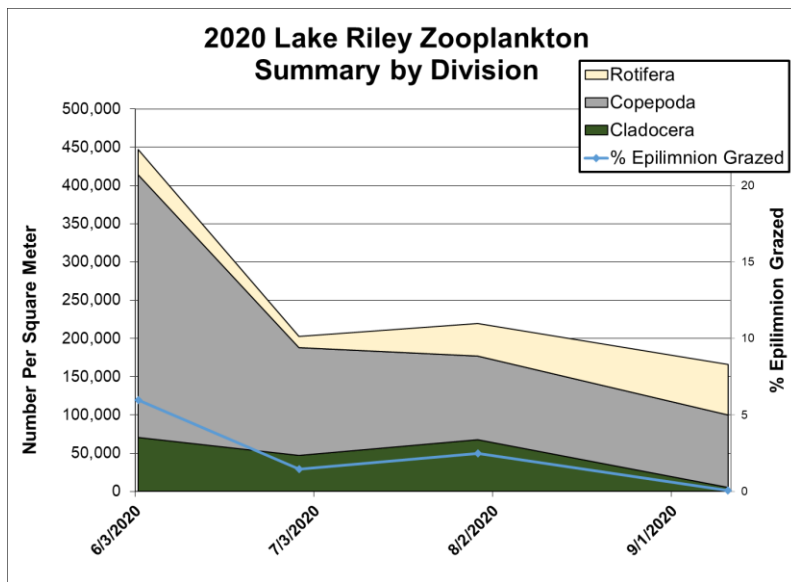


Figure 16 2020 Lake Riley Zooplankton Counts (#/m²) & Percent of Epilimnion Grazed

Cladocera consume algae and have the potential to improve water quality if they are abundant in large numbers. Due to the lower numbers of Cladocera as seen in 2019, grazing rates were near 0% across all sampling dates.

During the summer of 2019, staff collected five phytoplankton samples on Lake Riley (8 Exhibits D). The seasonal abundance of phytoplankton is presented in **Figure 17**. The dominant phytoplankton in May, July, and September were Cyanophyceae cells which made up 41%, 59%, and 63% of the total phytoplankton abundance (TPA), respectively. Cyanophytes, also known as cyanobacteria or blue-green algae, are a group of free-living bacteria that obtain energy through photosynthesis. Under favorable conditions large, toxic blooms of cyanobacteria can occur. *Aphanizomenon sp.* was the predominant cyanobacteria found and is known as a possible toxin producer that may potentially produce cylindrospermopsin, anatoxins, and saxitoxins. These toxic compounds have the potential to pose serious threats to human and environmental health via contamination of drinking water, recreational exposure to waterborne toxins and possible accumulation of toxins in the food-web. Chlorophyceae dominated the phytoplankton population in June and August (60% and 59% TPA, respectively).

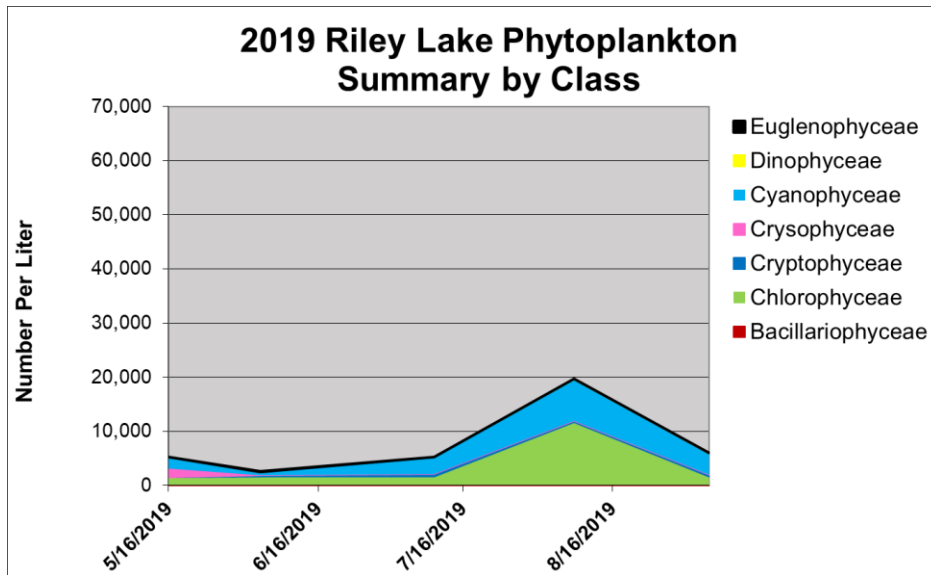


Figure 17 2019 Lake Riley Phytoplankton Abundance (#/L) by Class.

Lotus Lake

In 2019, all three groups of zooplankton were present in Lotus Lake (8 Exhibits C). In 2019 Rotifers were the least abundant zooplankton sampled (**Figure 18**) which is in contrast with 2018 when Rotifers were the most abundant overall. Copepod numbers varied significantly between sampling events throughout 2019. Cladoceran numbers began at 210 thousand in May before decreasing to less than 100 thousand for the June, July, and August. Cladocerans reached their highest numbers in September, at 362 thousand. The spring Cladocera numbers can be attributed to an abundance of *Daphnia galeata*, while *Daphnia retrocurva* was dominant in late fall. *Daphnia retrocurva* is known for its large curved helmet it develops in late spring-to-summer to reduce predation by planktivorous fish and invertebrates.

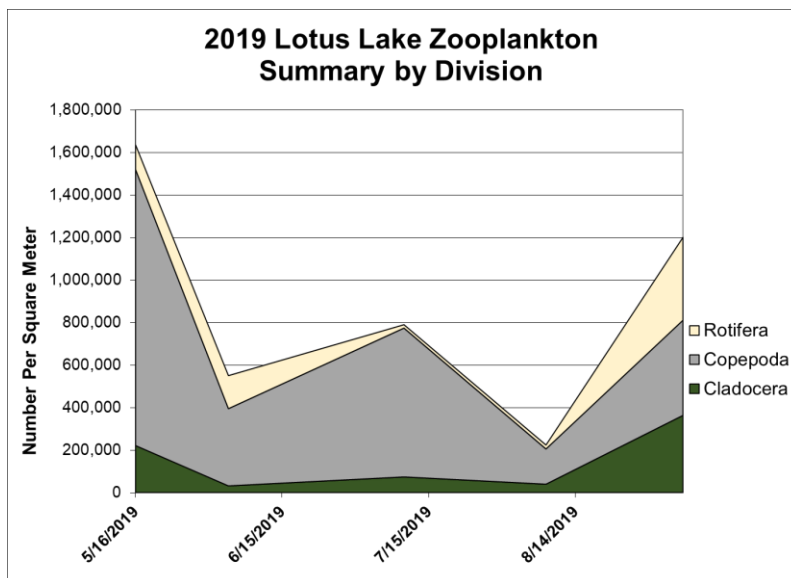
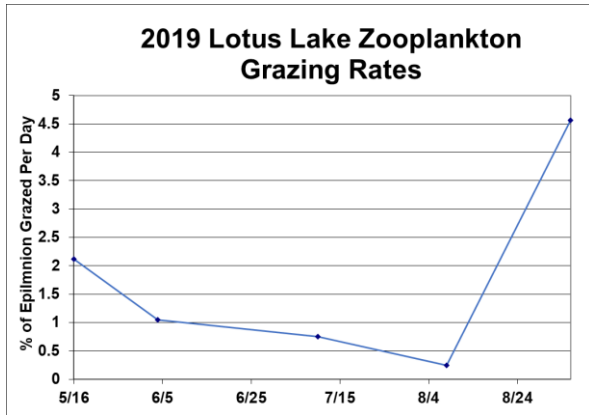


Figure 18 2019 Lotus Lake Zooplankton Counts (#/m²)



Large Cladocera consume algae and, if enough are present in a lake, they have the potential to improve water quality. The estimated epilimnetic grazing rates observed in 2018 ranged from 6% to 19%. In 2019 the rates were very low ranging from near 0% to under 5% (Figure 19). As expected, grazing rates followed a similar trend to what was seen in the population fluctuations; the largest grazing rate occurred on in September when the spike in *Daphnia retrocurva* numbers occurred.

Figure 19 2019 Lotus Lake Epilimnetic Grazing Rates

During the summer of 2019, staff collected five phytoplankton samples on Lotus Lake (8 Exhibits D). The abundance of phytoplankton across all sampling dates is presented in Figure 20. In July *Cryptomonas erosa* was briefly dominant, followed closely by Cyanobacteria (55% and 43% total phytoplankton abundance, respectively). *Cryptomonas* spp. are not known to produce toxins and are an important food source for zooplankton. Cyanobacteria was the dominant species on the May, June, August, and September sampling dates (58%, 59%, 87%, and 72% total phytoplankton abundance by sampling event). *Aphanizomenon* sp. was the dominant species of cyanobacteria in August and September, with a massive spike occurring in early August. *Aphanizomenon* are a potential producer of cylindrospermopsin, anatoxins, and saxitoxins.

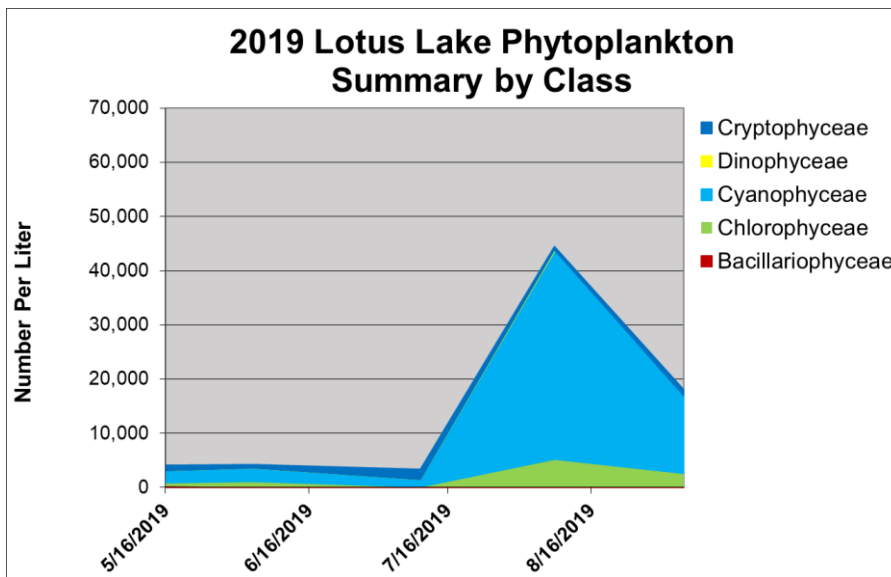


Figure 20 2019 Lotus Lake Phytoplankton Abundance (#/L) by Class.

Lake Susan

Similar to 2018, Rotifers were the most abundant zooplankton captured in Lake Susan in 2019 (8 Exhibits C). The rotifer population was variable over the sampling events with a notable decrease in rotifer numbers occurring in June and July. Copepod numbers declined from an early high of 872 thousand, dropping to an average of around 300 thousand for the rest of the season (Figure 21). Overall, Cladocera numbers were low relative to the other taxa, around 100 thousand individuals per sampling event, but were still around 5 times higher than Cladocera numbers in 2018 (<20 thousand per sampling event). The lowest Cladocera population recorded in 2019 was in early August when no individuals were captured.

The Cladocera population in Lake Susan was dominated by species in the genus *Daphnia*, of which *D. pulex* was most common.

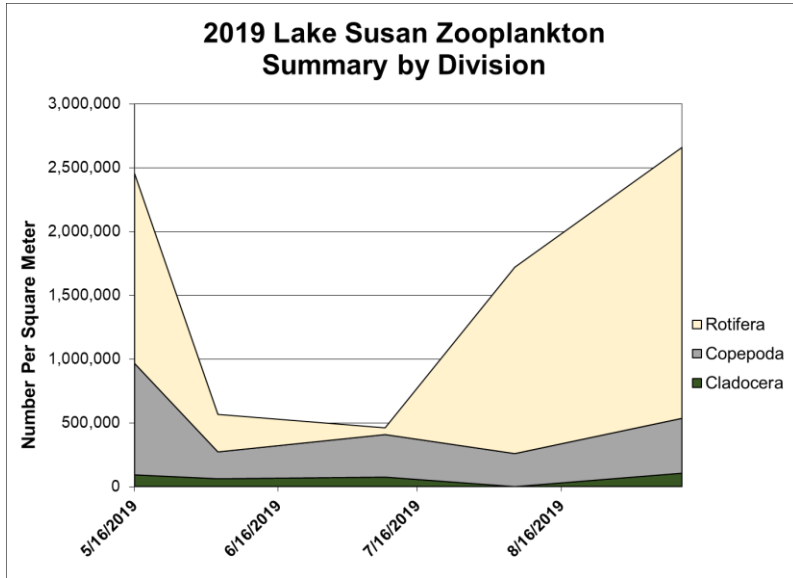


Figure 21 2019 Lake Susan Zooplankton Counts (#/m²)

The estimated epilimnetic grazing rates upon algae observed in 2018 were, ranging from 0.1% to 11%. However, in 2019, the epilimnetic grazing rate was only around 1% (Figure 22). This is mainly due to the very limited number of Cladocera present in all the samples collected. The highest grazing rate was observed in early June when *Daphnia pulex* were more numerous in the zooplankton community.

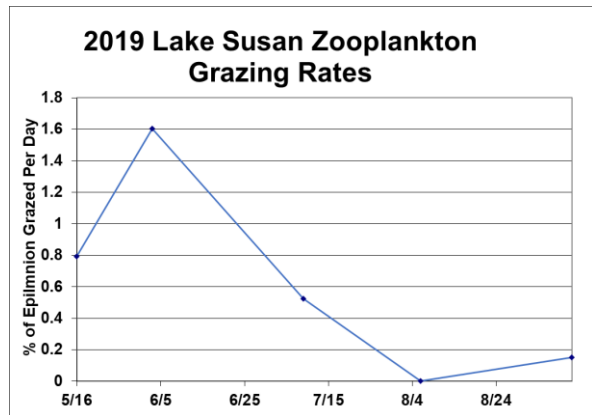


Figure 22 2019 Lake Susan Epilimnetic Grazing Rates

During the summer of 2019, staff collected five phytoplankton samples on Lake Susan (8 Exhibits D). The abundance of phytoplankton by Class is presented in Figure 23. From mid-May to mid-July, Cryptophytes and Chlorophytes were the co-dominant phytoplankton groups. Cryptophytes are motile unicellular algae that grow photosynthetically and are broadly distributed in lakes, usually preferring nutrient-rich environments. Chlorophytes, or green algae, are like Cryptophytes, but are non-motile. A large spike in the population of Cyanobacteria caused it to become the dominant phytoplankton species in August with a TPA values 64%. *Pseudanabaena limnetica* was the most common species of cyanobacteria during this event. *Pseudanabaena sp.* are filamentous, bloom forming organisms. They produce compounds that can impart muddy or moldy flavors to drinking water during large blooms. By mid-September the Cyanophytes had disappeared and been replaced as the dominant phytoplankton group by the Dinophyceae species *Ceratium hirundinella*. This unicellular species is known for its spiked shell formed of armored plates. Though generally harmless, blooms of *Ceratium* species can occur under the right conditions. The resulting oxygen depletion caused by these blooms can potentially result in fish kills.

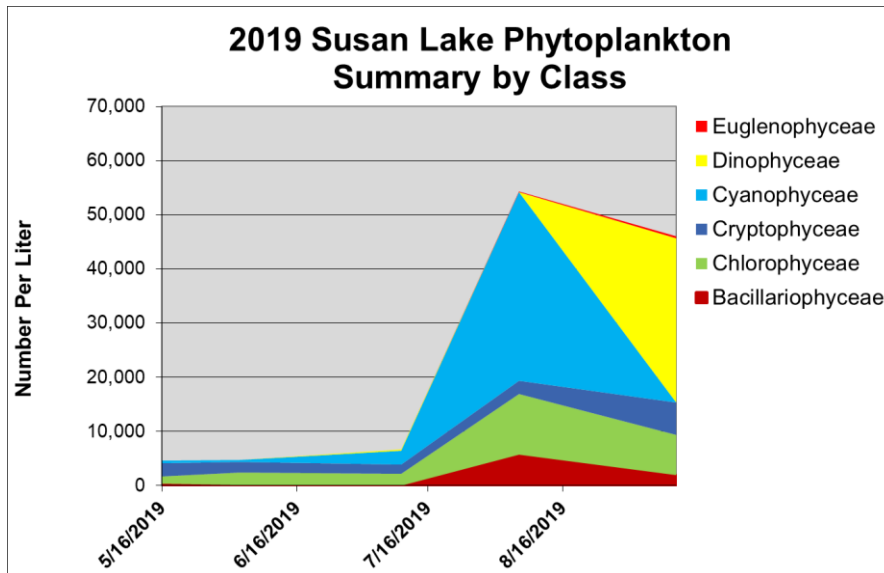


Figure 23 2019 Lake Susan Phytoplankton Abundance (#/L) by Class.

Rice Marsh Lake

In 2019, all three groups of zooplankton were captured in Rice Marsh Lake (8 Exhibits C), of which 8% of the population was comprised of Cladocerans, down from 13% in 2018 and 27% in 2017. As expected, rotifers were the most abundant zooplankton sampled in 2019 (**Figure 24**). However, 90% of Rotifers counted were sampled in May and June. Copepod densities were highest in May and remained relatively stable thereafter. Across all sampling dates the Cladoceran community was dominated by small-bodied zooplankton, consisting of mainly *Bosmina longirostris*, *Ceriodaphnia sp.*, and *Chydorus sphaericus*.

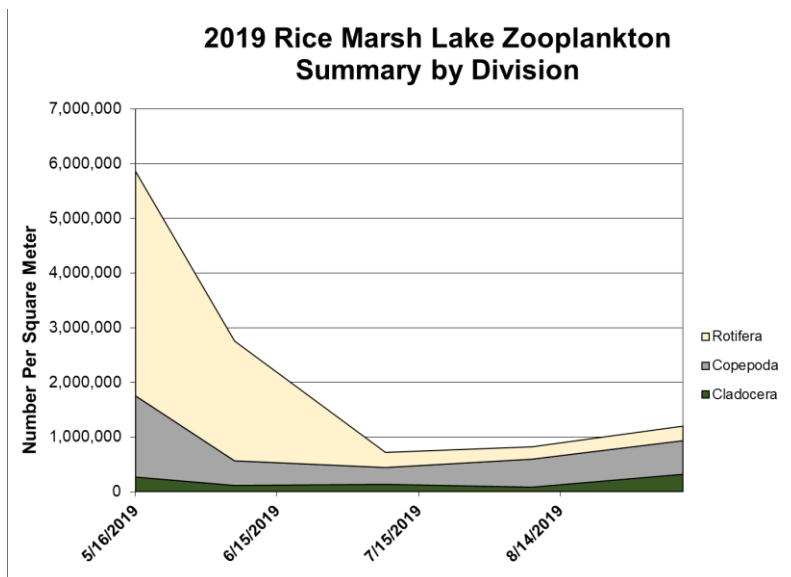


Figure 24 2019 Rice Marsh Lake Zooplankton Counts (#/m²)

The estimated epilimnetic grazing rates of Cladocera observed in 2018 ranged from near 0% to 23% on Rice Marsh Lake. In 2019, the epilimnetic grazing rate was highest during the May sample at 39% (**Figure 25**). After the first May sampling event, grazing rates averaged near 5% for the remainder of the

year. The highest May grazing rate was linked with the presence of the larger bodied Cladocera *Daphnia pulex*. The most common Cladocera present was *Bosmina longirostris* which are commonly found in bog lakes such as Rice Marsh Lake.

During the summer of 2019, staff collected five phytoplankton samples on Rice Marsh Lake (8 Exhibits D). Abundance of phytoplankton by Class for Rice Marsh Lake is presented in Figure 26. In 2019, there was a notable steep decline in Cyanobacteria as a percent of total phytoplankton abundance (TPA), from 82% in 2018 to just 9% in 2019. *Chlamydomonas globosa* (Chlorophyceae) was the dominant species of all five sampling events (83%, 60%, 37%, and 53% TPA).

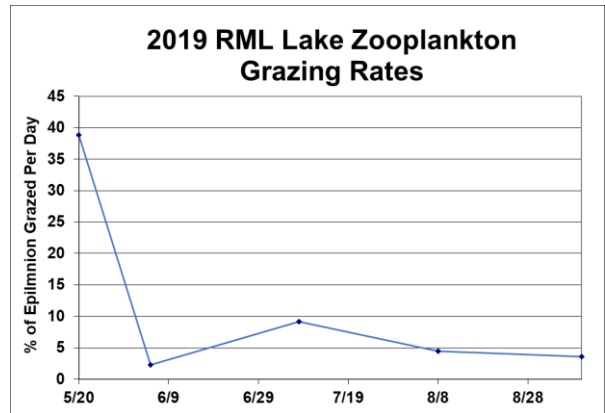


Figure 25 2019 Rice Marsh Lake Epilimnetic Grazing Rates

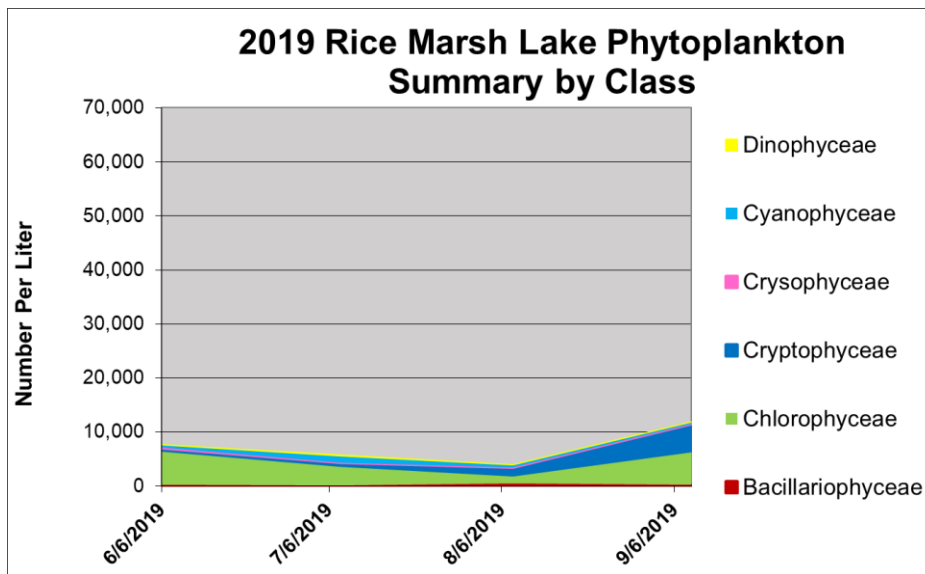


Figure 26 2019 Rice Marsh Lake Phytoplankton Abundance (#/L) by Class.

Staring

In 2019, all three groups of zooplankton were present in Staring Lake (8 Exhibits C). The June sampling event had the highest number organisms across all groups (Figure 27). Rotifer numbers experienced a significant spike to near 2.5 million in June, and an average of 500 thousand for the remainder of the year. The dominant Rotifer species was *Keratella cochlearis*, which occurs worldwide in virtually all bodies of water whether fresh, marine, or brackish. Copepod numbers were roughly steady at an average of 440 thousand per sampling event. Cladoceran numbers generally remained above 200 thousand except in July and August when they dipped below 100 thousand. The most abundant Cladocera were *Bosmina longirostris* which are common in lakes and ponds across the United States.

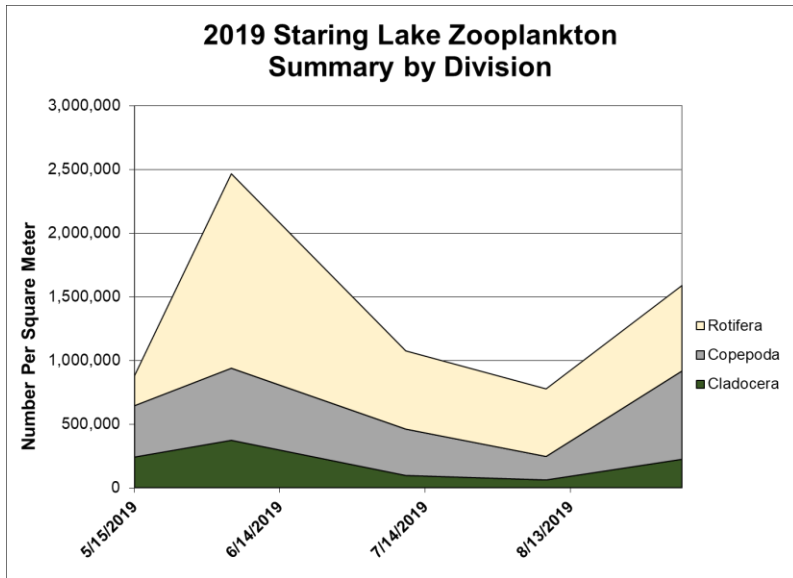


Figure 27 2019 Staring Lake Zooplankton Counts (#/m²)

Large Cladocera consume algae and may have the potential to improve water quality when present in large densities. The estimated epilimnetic grazing rates observed in 2018 ranged from 2% to 24%. The 2019 were much lower at 1-4% (Figure 28). The max grazing rate in May corresponded optimal feeding temperatures near 21 degrees Celsius.

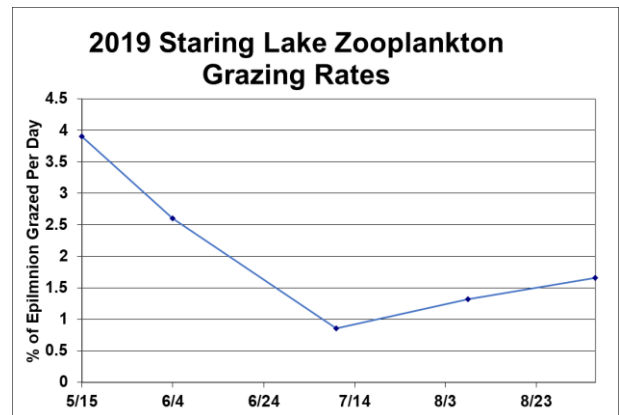


Figure 28 2019 Staring Lake Grazing Rates

During the summer of 2019, staff collected five phytoplankton samples on Staring Lake (8 Exhibits D). Abundance of phytoplankton by Class are presented in Figure 29. In May, the dominant class of phytoplankton, with 87% of the total phytoplankton abundance (TPA), was the Chlorophyceae (green algae). The June sampling event was dominated by Bacillariophyceae, the diatoms, with 56% of the TPA. Cyanophyceae, commonly known as cyanobacteria or blue-green algae, began to dominate in July (56%) and spiked in August with 75% of the TPA. Blue-green algae was absent in the September sample, being replaced by Cryptophyceae as the dominant class with 85% of the TPA.

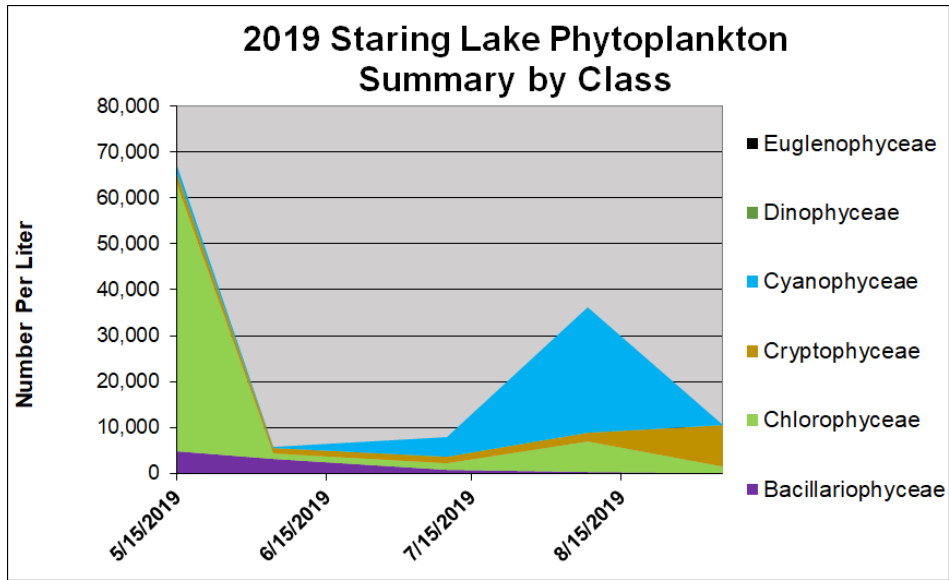


Figure 29 2019 Staring Lake Phytoplankton Abundance (#/L) by Class.

4.9 Lake Susan Spent-Lime Treatment System

Lake Susan is an 88-acre lake next to Lake Susan Park. It is an important resource in the city of Chanhassen and the Riley Purgatory Bluff Creek Watershed District. The lake is a popular recreational water body used for boating and fishing. Lake Susan is connected to four other lakes by Riley Creek. It receives stormwater runoff from 66 acres of land around it, as well as stormwater that enters two upstream lakes (Lake Ann and Lake Lucy). The stormwater entering the lake carries debris and pollutants, including the nutrient phosphorus. Phosphorus is a nutrient that comes from sources such as erosion, fertilizers, and decaying leaves and grass clippings. Excess phosphorus can cause cloudy water and algal blooms in lakes. Removing phosphorus from stormwater is a proven way to improve the water quality of lakes and streams.



Figure 30 Spent Lime Treatment System

In 2016, an innovative spent lime filtration system was constructed along a tributary stream draining a wetland on the south-west corner of Lake Susan (**Figure 30**). Based on system performance of the one other experimental spent lime filter site in the eastern Twin Cities area, modeling simulations based on available water quality measurements suggested the Lake Susan system had the potential to remove up to 45 pounds of phosphorus annually from water entering the lake. This would result in improved water quality and recreational opportunities. Spent lime is calcium carbonate that comes from drinking-water treatment plants as a byproduct of treating water. Instead of disposing of it, spent lime can be used to treat stormwater runoff. When nutrient-rich water flows through the spent lime system, the phosphorus binds to the calcium. The water flows out of the spent lime system, leaving the phosphorus behind.

Observation and monitoring data collected by District staff in 2016 - 2018, indicated inconsistent system performance and periods of extended inundation, which deviated from the original design parameters. District staff worked with Barr to review monitoring data and identify potential shortcomings the system (e.g., monitoring, materials, influent, changed conditions, etc.) During 2018, it was discovered that the spent lime media appeared to be significantly restricting flow of water through the filter. District and Barr staff conducted field testing of the filtration capacity of the spent lime and discovered that the spent lime structure had degraded into a clay-like consistency, thus essentially preventing water from filtering through the media. During the summer of 2019, District staff completed laboratory column testing for mixtures of spent lime and sand. Column testing indicated that mixing spent lime with sand improves the filtration capacity of the media, while still removing phosphorus. **Figure 31** is a photograph of the column testing completed by District staff during 2019. The testing revealed the following key points:



Figure 31 Spent Lime/Sand Mixture Column Testing

- Filtering water through sand washed to MNDOT standard specifications (washed sand) results in phosphorus export from the test columns.
- Water filtered through the various spent lime/pool sand mixtures elevated the pH in the effluent water, thus supporting the chemical reaction to precipitate phosphorus (i.e. remove phosphorus).

- Filtration rates through the various spent lime/pool sand mixtures appears relatively unchanged after 114 days of inundation and continuous flow for 10 days did not reduce drain times.
- Initial testing of plaster sand obtained from a local pit also results in phosphorus export from the material.
- Total phosphorus removals were generally higher the larger the content of spent lime in the mixture (Figure 32).

The laboratory testing completed by District staff was used to guide modifications to the spent lime system to improve filtration capacity and performance of the system. Modifications included the replacement of the deteriorated spent lime with a mixture of 70% plaster sand and 30% spent lime, replacement of the underdrain slotted piping, and the installation of an automated water control structure and solar panel.

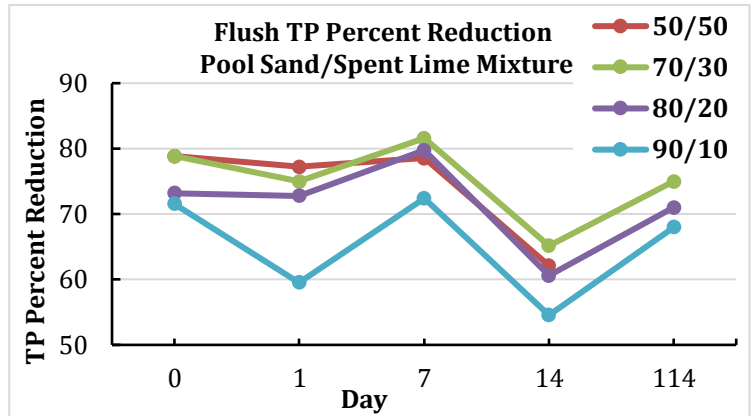


Figure 32 Pool Sand/Spent Lime Mixture Column Testing Phosphorus Removals

In 2020, water samples were collected and analyzed for total dissolved phosphorus (TDP), total phosphorus (TP), total suspended solids (TSS), ortho phosphorous (OP), and Chlorophyll-a (Chl-a) between 2020. TP was initially collected with other parameters added in August. The unit was brought online on 5/28/2020 and sampled Mondays and Fridays for 4 hours. On 6/23/2020, a month of testing and the addition of a stop log, the unit was changed to sample on Monday, Wednesday, and Friday for 5 hour periods. This was to increase the amount of water being treated. Overall, a total of 18 TP samples were collected over the summer yielding an average TP reduction of 62% (Figure 33, Table 17). The maximum reduction of 91% occurred in early July and removed 91% of the phosphorous. For TDP, TSS, OP, Chl-a, reductions were around 50% with some variability. It should be noted that although the system was functioning properly, outflows were still very high (0.193 mg/l). This indicated that the wetland system draining through the system may need additional treatment to further reduce TP loading to Lake Susan. Staff will continue to monitor the system in 2021 to ensure performance.

Table 17 2020 Lake Susan Spent Lime Treatment System Nutrient Removals

Analyte	N	Min	Mean	Max
TDP (mg/l)	6	36	53	65
TP (mg/l)	18	16	62	91
TSS (mg/l)	6	5	46	78
OP (mg/l)	3	46	49	55
CHLA (mg/l)	4	28	59	78

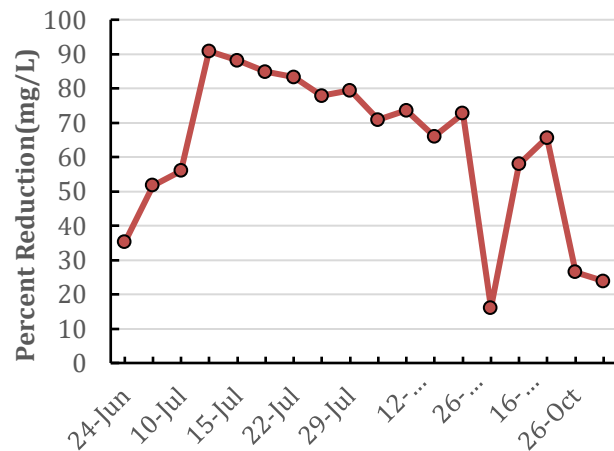


Figure 33 2020 Total Phosphorous Percent Reduction - Lake Susan Spent Lime Treatment System

4.10 Stormwater Ponds

Stormwater ponds are the most commonly used method for controlling pollutants, such as phosphorus, which are found in stormwater runoff. Phosphorus pollution is the primary component influencing eutrophication in freshwater resources. Excess phosphorus can lead to increased algal growth, turbid water, and loss of biodiversity and desirable aquatic habitat. Urban watersheds, like the Riley-Purgatory-Bluff Creek Watershed, typically export 5 to 20 times the amount of phosphorus than less developed watersheds due to an increase in the amount of impervious cover (streets, sidewalks, and driveways) and surface runoff for a watershed (Athayde et al. 1983, Dennis 1985). Potential sources of phosphorus pollution in the Riley Purgatory Bluff Creek Watershed District include stormwater runoff, sediment erosion, grass clippings, lawn fertilizer, and pet waste.

The Riley-Purgatory-Bluff Creek Watershed District stormwater pond project (RPBCWD 2014) began in 2010, with initial data collection conducted in the summers of 2010 and 2011 and the second phase beginning in 2012-2013. The purpose of the project was to ascertain if stormwater ponds were possible sources of pollution within the District and identify ponds with exceptionally high total phosphorus concentrations that could be targeted for remediation projects. With assistance of city partners, a total of 119 ponds were sampled across Bloomington, Chanhassen, Eden Prairie, Minnetonka, and Shorewood. In both 2012 and 2013, average total phosphorus levels were higher than the MPCA estimated typical total phosphorus range (0.1 mg/L to 0.25 mg/L) for effluent (outgoing) stormwater in all five of the cities sampled. This data served as a critical baseline for research carried out in 2019 and 2020.

The University of Minnesota, City of Eden Prairie (Wenck), and Limnotech used the previous stormwater pond study to launch additional research projects in 2018-2020 in attempt to understand the chemical/physical/biological complexity of stormwater ponds. On January 24th, 2020, RPBCWD held its first stormwater pond summit to get all interested/invested partners together to discuss current/ongoing/future research going on with stormwater ponds. On January 20th, 2021 the second stormwater was held and expanded upon what was learned from the original studies as well as helped guide future direction.

Staff and partners had similar approaches to monitoring; ponds were selected and monitored biweekly to collect nutrient and pond vertical profile data. The selected ponds varied in size, design, depth, and watershed load, and encompassed a good representation of what currently exists in the District. Sediment cores were collected on many ponds to evaluate phosphorus release and identify the chemical makeup of each sediment layer. Continuous monitoring also occurred on a number of ponds which included monitoring the surface and bottom of each pond for some or all the following parameters: wind, water level, conductivity, temperature, and DO. RPBCWD staff worked with staff from the environmental engineering/science consultant firm LimnoTech to implement EnviroDIY technology into everyday District water monitoring and data collection (**Figure 34**). Most of the data from each study is currently being evaluated but the following information is a summary of the research being carried out in the District:

[John Gulliver Lab – University of MN - Internal Phosphorus Loading in Stormwater Ponds - Remediation Utilizing Iron Filings – Sediment Phosphorous Release and Characterization](#)

- Ponds are stratified at a depth of 1-2 feet and the bottom sediment is pulling oxygen out of the water (zero oxygen at the bottom for 85% of the year in most ponds). Sediment releases



Figure 34 EnviroDIY Pond Continuous Monitoring Station

phosphorus because of lack of oxygen. Many of the ponds that are stratified are sheltered which suggests the trees are most likely reducing pond mixing. TP might not be the best way to measure phosphorus in the pond, because of duckweed soaking it up and concentrating phosphorous.

- The three study ponds all released phosphorus under anoxic conditions with two of the ponds also releasing phosphorus when oxygen was available. 30%-60% of phosphorus available from sediments in all the ponds was considered mobile (readily able to be used by algae or move out of system).
- Possible remediation options include treating ponds (iron filings), artificial mixing (aeration), selective withdrawal (water draining from different locations within the water column), reduce sheltering (tree removal), and/or dredging and source control (removing phosphorous from landscape before it reaches the pond).
- Results from 15 different ponds show there is a significant range of phosphorus release possible based upon seasonal changes in oxic and anoxic flux. In 2020, ponds released significantly more phosphorus than in 2019 which is hypothesized to be the result of drier conditions.
- Poornima Natarajan discussed possible predictors of the phosphorus flux from the sediment. They included measuring redox sensitive phosphorous, total releasable phosphorus, total sedimentary phosphorous, sediment oxygen exposure, and total organic content.
- The use of iron filings in stormwater ponds has been successfully tested by the University of Minnesota in improving water quality under lab conditions. The District, Cities, and the UMN worked together and applied iron filings to 2 ponds (**Figure 35**), which will be expanded to 3 in 2021, to test this innovative approach. Initial results from 2020 monitoring data shows variability in the results. Some ponds appeared to have some reductions, but others had little change. This variability can be partially explained by the seasonal variability in stormwater ponds which may be caused by different climatic conditions. UMN will continue monitoring activities in 2021.



Figure 35 Minnetonka Iron Filings Application

Jacque Finlay – University of Minnesota – Understanding Phosphorous Release in Urban Ponds - Stormwater Pond Research Overview

- Ponds are unexpectedly anoxic, promoting phosphorus release. Road salt accumulation may be part of why ponds stratify. Road salt sinks, accumulates, and persists. In ponds less than 3 ft and there is no spatial chloride variation across the pond. However, deeper ponds have considerable spatial variations with high chloride concentrations common from January to July. Some variability in chloride concentrations depend on precipitation patterns (i.e. lots of snow = lots of salt application). Ponds located in commercial areas had the highest salt concentrations.
- Water temperature stratification occurs early on in the spring in ponds – not a lot of wind caused mixing throughout the year. Ponds with 100% coverage by duckweed had very low oxygen levels. New ponds that are open and shallow had mixing occurring. Older and saltier ponds had low oxygen levels.
- Phosphorus concentrations are highly variable temporally (examples from MWMO-Kasota East Pond). Mass phosphorous balance testing was conducted on three ponds to determine how each pond was performing (inputs and outputs of phosphorous). Ponds varied in retention of phosphorus, were all anoxic almost all year, and had variable in phosphorus inputs and outputs. Overall, two ponds decreased and one increased in total phosphorous concentrations from inlet to outlet.

- Vinicius Taguchi discussed his literature review of fountain impacts on stormwater ponds to aerate and eliminate stratification. The literature review found that fountains do not serve as functional aeration units as only the area immediately around the fountain is affected.
- Duckweed and phosphorus - Finlay suggested that a feedback loop between duckweed and phosphorous does exist and that they are not independent.
- Last summer duckweed in several ponds was measured for phosphorus (mass of P per mass of dried duckweed). This was used to come up with a total mass of duckweed P for the whole pond based on the ratio of sampled area to pond surface area (sampled area = net sampler size [area] * number of samples). With the assumption that the duckweed could access P in the upper ~0.5 m of the water column (concentration of duckweed TP mg/L = total mass of duckweed P / volume of the pond from water surface to depth of 0.5 m), it was estimated that ~50% of the pond's upper water column TP was contained within the duckweed and the other half was in the water. This has implications in sampling by underestimating TP in ponds as currently the duckweed is "moved" or water is sampled under the duckweed layer. In the original pond study, water was grabbed at the surface, which included duckweed, and then was filtered through a screen. This may have captured a more complete TP picture in ponds. Ben Janke redesigned a pond outlet to essentially skim the duckweed to prevent it from moving downstream to reduce phosphorus loading.
- An undergrad removed duckweed on a very small/shallow pond to see the effect on pond stratification and phosphorous. The pond responded with an immediate increase in oxygen down to sediment surface and phosphorus concentration dropped.

Anthony Aufdenkampe – Limnotech - Mechanisms Driving Phosphorus Recycling in Constructed Stormwater Ponds: Implications for Management (stormwater.pca.state.mn.us)

- Anthony Aufdenkampe conducted a literature search on if ponds export phosphorous, if phosphorous removal efficiencies are less than design targets, and if influent/effluent studies were available (very limited). For over three decades, constructed stormwater ponds have been designed and maintained to maximize sedimentation and minimize scour during storm periods (EPA's Nationwide Urban Runoff Program (NURP)). However, we know that other mechanisms within a pond (fluxes) that are important to understand and include. These fluxes include inputs to the pond, sedimentation, mixing in the pond, sediment resuspension, internal loading, biological uptake and decay, groundwater exchange, and finally what is exported from the pond.
- Is it time to rethink pond design? Incorporate physical/geochemical/biological processes, consider temporal dynamics (storm events), and optimize mean annual load reductions in ponds rather than single inter-storm interval. Is it time to rethink pond monitoring? Focus on inlet outlet loads with continuous monitoring stations to capture all pond dynamics.
- Adapt the GLM (general lakes model)-AED2 to fit ponds with continuous pond data provided by EnvioDIY units and continuous nitrate and phosphorous analyzer at pond inlet and outlets. The goal is to develop a defensible designed model and provide maintenance recommendations for constructed stormwater ponds to maximize phosphorus retention. The model will have a sensitivity analysis of different drivers & factors to ensure performance and will eventually be used to simulate different design, retrofit and maintenance scenarios w/ input from stormwater practitioners. Develop a pond phosphorus management web tool for everyone to use.

Anne Wilkinson – Wenck – Harmful Algal Blooms in Stormwater Ponds

- Stormwater pond systems are preferred by Harmful Algal Blooms (HAB) because they are high in nutrients, warm, and have limited mixing. In this assessment, it was found that stormwater ponds experienced cyanobacteria blooms in late summer (the presence of cyanobacteria does not

necessarily indicate toxicity). District staff measured Chlorophyll-a and Phycocyanin during field monitoring which was used to gauge HAB presence.

- Mitigating the HAB risk could be done by discouraging public access, increasing public outreach, promoting short water residence time, reducing DP and internal loading, and increasing mixing potential. More research is needed in this field to better understand the extent of risks of HAB in stormwater ponds.
- Wilkinson stated that because duckweed takes up all of the sunlight on the pond's surface even the most buoyant algae are not able to compete with high duckweed cover.

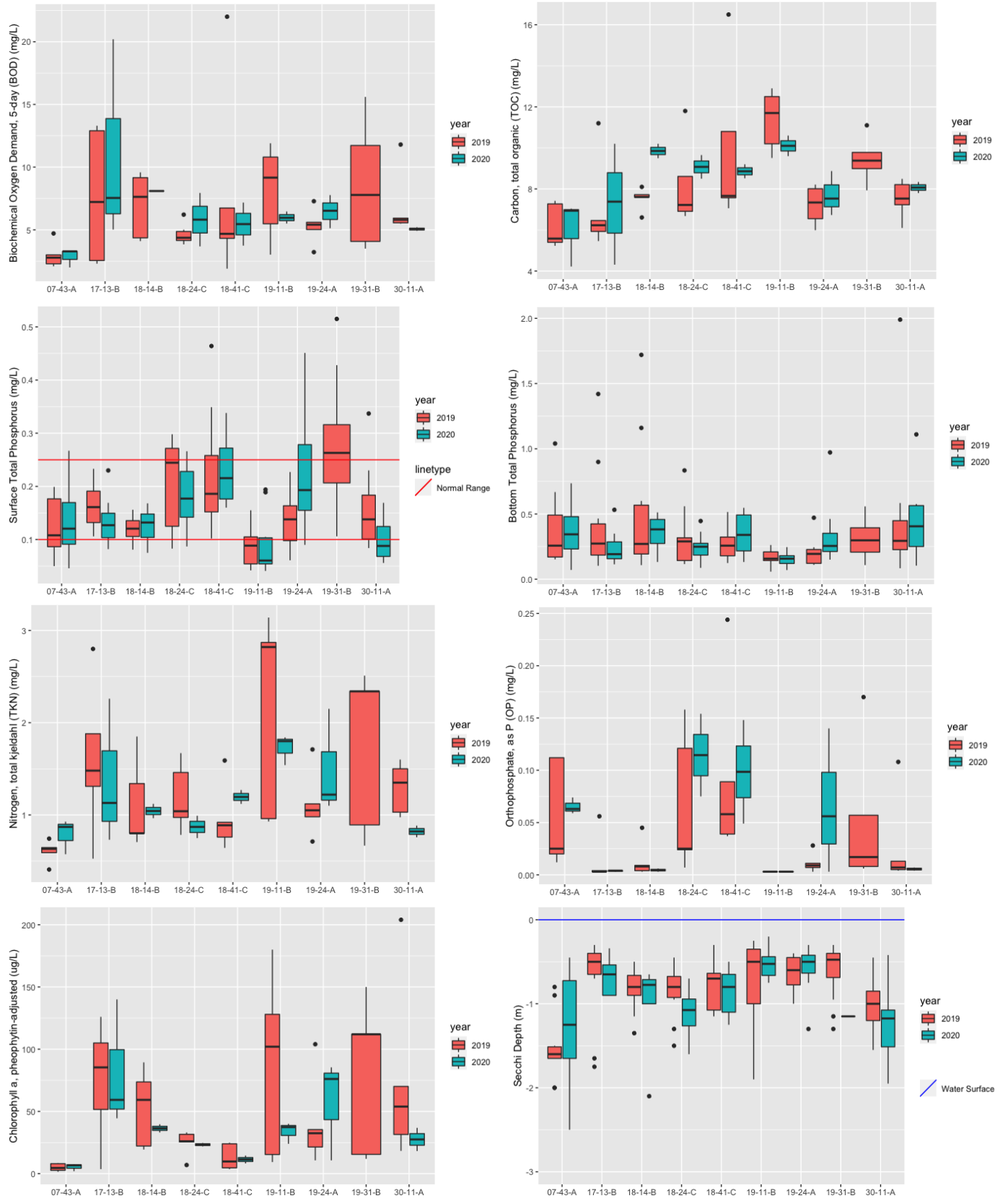
Joe Bischoff – Barr – RPBCWD Pond Assessment

- Pond phosphorous levels averaged concentrations around 200 ug/L but had maximum concentrations that were very high. This suggests levels are highly dependent on episodic events (i.e rain events or lack of). High phosphorus levels could be driven by high particulate seen within the ponds. Chl-a samples and phycocyanin levels indicate ponds have harmful algal blooms. All nine ponds sampled were anoxic significant portion of the year, even large ponds that should have a better chance of mixing. Sheltering around the ponds may be a main driver in reducing pond mixing and therefore increasing anoxia.
- Measured anaerobic phosphorous release in sediment cores and did not see much variation across all ponds including other pond studies that have previously been conducted in the area. Pond sediment phosphorous release rates were between 4-8 mg/m²/day and most phosphorous is iron bound.
- Overall, the ponds are still effective at removing P, but some are better than others and could be improved. The ponds with higher release rates could be targeted for BMP's to improve removal efficiencies. Need to develop framework to determine which ones are performing badly so we can target treatment.
- A CE-QUAL model has been developed to identify drivers of pond anoxia and develop hypotheses to determine the role of reaeration, biochemical oxygen demand (BOD), and sediment oxygen demand (SOD). This modeling, while not intended for scenario analysis, could develop hypotheses to manage drivers of anoxia- mainly BOD and SOD in larger ponds- and determine the role of sheltering- particularly in smaller ponds.

Potential Stormwater Pond Research

- [Creation of a Stormwater Pond Decision Tree](#)
- [Quick Assessment for Identifying High Risk Ponds](#)
- [More Efficient Stormwater Pond Function – Design and Retrofits/Mitigation](#)
- [Assessment/Revision of Current Nationwide Urban Stormwater Ponds \(NURP\) Standards](#)
- [Refinement of Current Stormwater Pond Modeling](#)
- [More Investigation of Biological and Sediment Oxygen Demands Role in the Functionality of Stormwater Ponds.](#)
- [Constructed Ponds vs Converted Natural Wetlands and the Relevance Sediment Plays](#)

Table 18 2019-2020 Stormwater Pond Summary



5 Aquatic Invasive Species

5.1 AIS Management

Due to the increase in spread of Aquatic Invasive Species (AIS) throughout the state of Minnesota, staff completed an AIS early detection and management plan in 2015. As part of the plan, an AIS inventory for all waterbodies within the District was completed and a foundation was set up to monitor invasive species that are currently established within District waters (**Table 20**). Early detection is critical to reduce the negative impacts of AIS and to potentially eliminate an invasive species before it becomes fully established within a waterbody. Effective AIS management of established AIS populations will also reduce negative impacts and control their further spread. The RPBCWD AIS plan is adapted from the Wisconsin Department of Natural Resources (WIDNR, 2015), Minnehaha Creek Watershed District (MCWD, 2013), and the Minnesota Department of Natural Resources (MNDNR, 2015a) Aquatic Invasive Species Early Detection Monitoring Strategy. The goal is to not only assess AIS that currently exist in RPBCWD waterbodies, but to be an early detection tool for new infestations of AIS. **Table 19** identifies AIS monitoring/management that occurred in 2020, excluding common carp management.

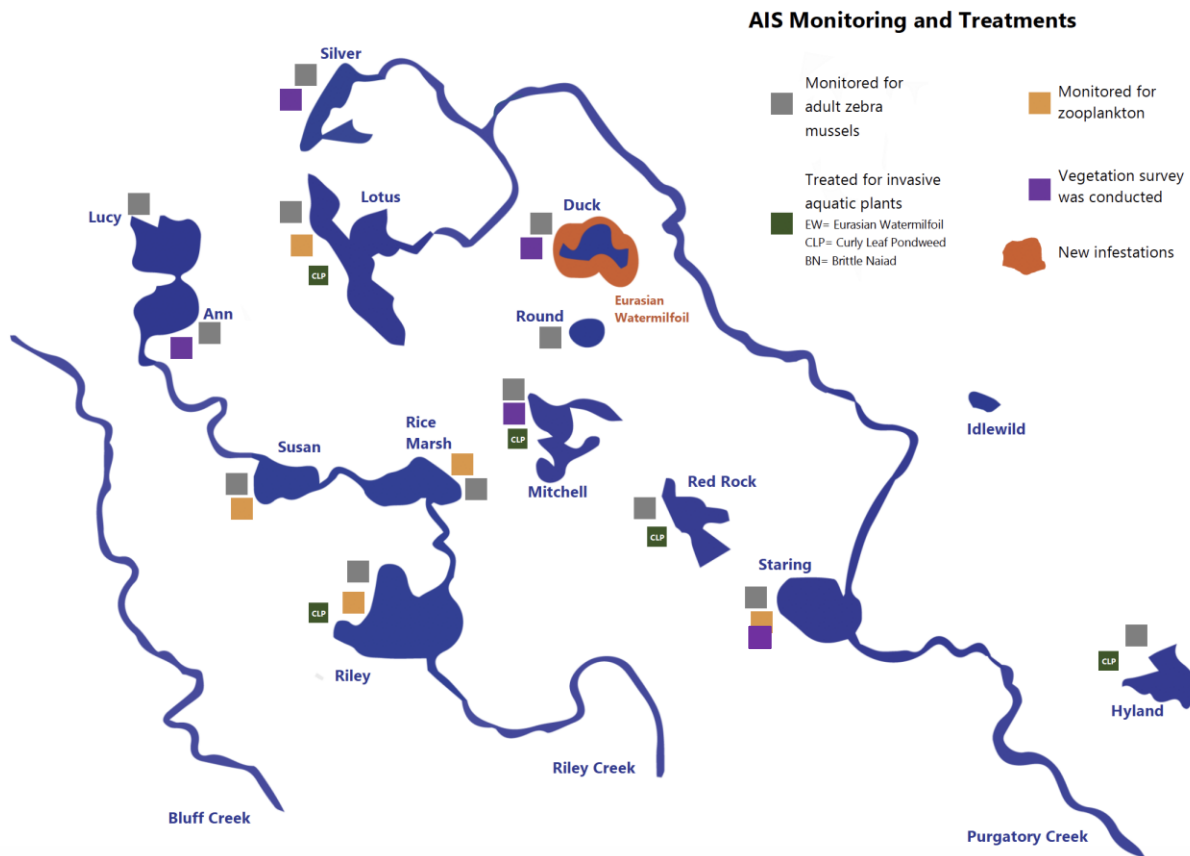


Table 19 2020 Aquatic Invasive Species Summary

Aquatic Invasive Species (AIS) work conducted in 2020 within the Riley-Purgatory-Bluff Creek Watershed District. Symbols indicate zebra mussel monitoring plates and/or monthly public boat launch scans (grey), zooplankton and phytoplankton sampling conducted (orange), herbicide treatments occurred (green), point intercept vegetation surveys (purple). The orange outline around a lake indicates a new AIS found. All lakes received juvenile mussel sampling; none were found by the District accept in Lake Riley.

Table 20 Aquatic Invasive Species Infested Lakes

Lake Names	Infested Waters	Brittle Naiad	Eurasian Watermilfoil	Curlyleaf Pondweed	Purple Loosestrife	Common Carp	Zebra Mussels
Ann	x	x	x	x	x	x	
Lotus	x	x	x	x		x	x
Lucy	x		x	x	x	x	
Red Rock	x		x	x	x		
Rice Marsh	x			x	x	x	
Riley	x		x	x	x	x	x
Silver	x			x	x		
Staring	x	x	x	x		x	
Susan	x	x	x	x	x	x	
Duck	x		x	x	x		
Mitchell	x		x	x	x		
Round	x	x	x	x			
Hyland	x			x			

X – Indicates new infestation.

5.2 Aquatic Plant Management

Aquatic plant surveys are important because they allow the District to map out invasive plant species for treatment, locate rare plants for possible protection, create plant community/density maps which evaluate temporal changes in vegetation community, identify the presence of new AIS within water bodies, and they can assess the effectiveness of herbicide treatments. Aquatic plant surveys have been conducted on a rotational basis within RPBCWD to ensure all lakes have received adequate assessments. As projects arise, or issues occur, additional plant surveys are conducted to aid in the decision-making process. The most comprehensive aquatic plant survey is called a point intercept method. This survey utilizes sample points arranged in a uniform grid across the entire lake which can vary in number depending on the lake size. At each designated sample location, plants are collected using a double-headed, 14-tine rake on a rope. For each rake sample, the rake is dragged over the lake bottom for approximately 5 ft before retrieving. Roving surveys are also used when species of concern are in question. This survey method involves driving around the lake, visually scanning the shallows, and marking every plant found using a handheld GPS device. Herbicide treatments have been shown to reduce and control aquatic invasive plants to a manageable level, which may in turn allow for native plants to increase in abundance.

In 2020, point intercept surveys were conducted Duck Lake (EP), Hyland (TRPD) Mitchell Lake, Lake Ann, and Silver Lake (RPBCWD). The District will continue to monitor the aquatic plant communities within our lakes and use herbicide treatments to manage aquatic invasive plants to sustain healthy aquatic communities into the future. In the early spring of 2020, herbicide treatments were carried out on Lotus Lake, Mitchell Lake, Riley Lake, Hyland Lake, and Red Rock for curly leaf pondweed. No Eurasian watermilfoil or brittle naiad treatments occurred.

Brittle Naiad

Brittle naiad (*Najas minor*) is a species native to Europe, western Asia, and northern Africa that has been introduced to the United States. The concern with Brittle Naiad is that it can form dense mats that can outcompete native plants. These dense communities can disrupt fish and waterfowl habitat, choking out plants which animals depend on for survival and potentially decreasing dissolved oxygen levels upon its decomposition. Brittle naiad is a resilient plant; it can survive in some polluted and eutrophic waters and can reproduce by fragmentation. The plant is most apparent in late summer/early fall when many recreational boaters are off the water. With that said, brittle naiad is a very new AIS and not much is known about its effects in Minnesota. So far the plant has appeared in small, dispersed stands across the infested lakes, but has had limited expansion to date. The exception is in the Lower Purgatory Creek Recreational Area where the plant has taken over. It may have been more successful in the LPCRA due to the good water clarity, shallow and uniform depths, highly organic sediments, and the highly fluctuating water levels. The highly fluctuating water levels make it difficult for many native plants to establish, which does not occur in relatively stable lake water levels. In the RPBCWD, Lotus, Ann, Staring, and Susan were scanned for the plant. District staff have been monitoring brittle naiad population since it is new to MN and its potential damage is unknown. The results from these surveys can be seen in this section.

Lake Ann Brittle Naiad

Freshwater Scientific Services, LLC surveyed the aquatic plant community of Lake Ann on August 2, 2017 using the point-intercept survey method. During the 2017 survey Brittle Naiad was discovered at one location in the northeast corner of the lake near the public swimming beach and dock. The immediate area surrounding where the plants were found was surveyed intensively to identify if there were more plants present, however none were found. The District immediately treated the 0.25 ac area as part of the rapid response plan in attempt to slow or stop the plant from spreading. On September 28th, 2018 RPBCWD staff conducted another brittle naiad roving survey to assess treatment results (). During the

scan staff drove a shallow and deep lap around the lake and searched for the presence of the plant. Plants were found near the location of the swimming dock and beach, similar to where they were found in 2017, however multiple extensive stands were present. Additionally, plants were found along the west shoreline and near the public access, equipment rental dock, and public beach (southeast). The results of the assessment suggested that brittle naiad was more widely distributed than it was in the 2017 survey. In 2020, staff again conducted a roving survey and found similar results from the 2018. Overall, there

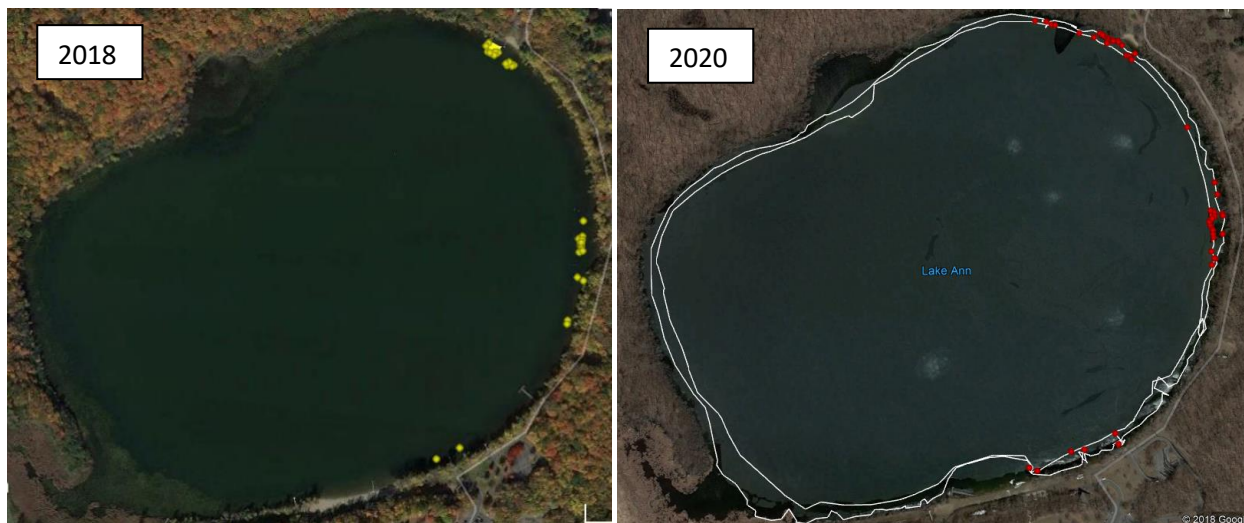


Figure 36 2018 & 2020 Lake Ann Brittle Naiad Maps.

were two main areas where brittle naiad was found: (1) NE corner on either side of the beach area and (2) along the western shore. While the overall number of plants appeared to be reduced, the two main areas were very robust and established stands. Unlike in other lakes in the District, the main stands were found in 6-8 feet of water. Staff will continue to monitor the population moving forward.

Lotus Lake Brittle Naiad

On September 26, 2017, Riley Purgatory Bluff Creek Watershed District staff found brittle naiad located on both sides of the public boat access on the south side of Lotus Lake. The plants were found during a routine aquatic invasive species (AIS) inspection of the boat launch. These inspections, conducted bimonthly, consist of staff searching the area around the boat launch for various types of aquatic invasive species for 5 minutes. The searches are conducted at each regular water quality sampling event. Since most AIS enter a lake through the public access this is the most likely location to find AIS. Staff immediately reported the occurrence of brittle naiad to Aquatic Invasive Species Specialist of the Minnesota Department of Natural Resources. Staff extended the inspection to a full scan of the lake, mapping the position of every observed brittle naiad occurrence with a handheld GPS device. An effective treatment area was determined in the fall, an herbicide was applied to the lake in an area totaling 2.42 acres across.

On September 24th and 26th of 2018, RPBCWD staff conducted brittle naiad roving surveys to determine the effectiveness of the herbicide and to see if the plant had spread throughout the lake. Results of the survey can be seen in **Table 21**. Based on the 2018 brittle naiad scan, it appeared the overall plant distribution had been reduced in the treatment areas. Plants were found on both sides of the public access, similar to where stands of plants were most dense in 2017, however the number and area occupied by the plants was reduced considerably. Additionally, no rooted plants were found on the southwest side of the lake. More plants were found scattered along the south east shoreline and into the east bay which may

have been missed during the 2017 survey. Brittle naiad was observed growing between 0.5 to three feet of water. Its absence from deeper water was likely due to limited water clarity in Lotus Lake.

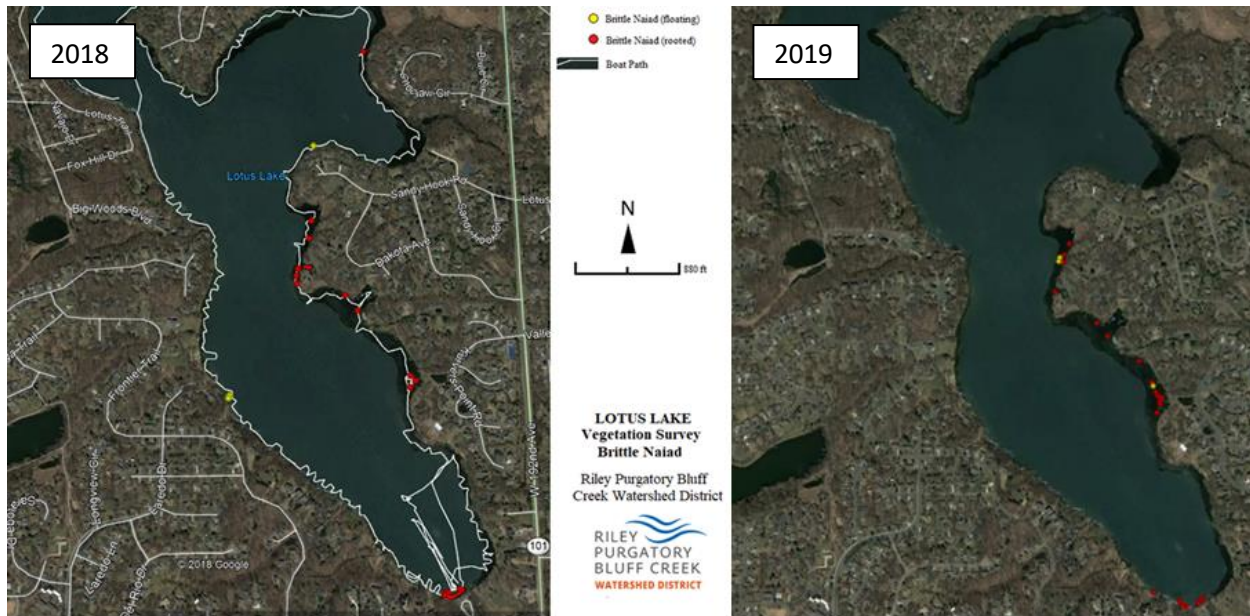


Table 21 2018 & 2019 Lotus Lake Brittle Naiad Maps

District staff again carried out the visual roving survey in 2019, marking each plant discovered. The results of the scan can be seen in **Table 21**. Overall, the 2019 results were very similar to what was seen in 2018. The plant was found in almost all areas where it was found in 2018, however it again appeared to be reduced in density. It has not been determined what would cause reductions in density. Staff did not conduct a scan in 2020 but did notice very few plants near the boat launch where it had been previously the densest on the lake. Carver County staff did conduct a point intercept survey early on July 8th, 2020 and only found a single plant.

Staring Lake Brittle Naiad

In 2015 Brittle Naiad was first discovered on Staring Lake at a single location along the northwest corner of the lake as indicated in **Figure 37**. It is not surprising that this occurred due to the fact that the species was found extensively in Purgatory Creek Recreation Area which is located upstream of Staring Lake. This fact, combined with the increased water clarity due to carp control may have allowed the plant to become established. After the discovery, the immediate area was treated in attempt to eliminate the plant from the lake. The following years after the lake was surveyed by the University of MN via point intercept survey and no brittle naiad plants were found.

In the fall of 2019, staff decided to conduct a roving survey as we had completed on multiple other lakes to see if we could detect brittle naiad. **Figure 37** shows the results of that survey. Staff did locate a number of plants scattered across the lake. The most brittle naiad was located in the northwest corner near the Purgatory Creek outlet and 2015 plant location. In this location the plant was the most abundant plant and was dense, limiting other native vegetation growth. It should be noted that the sediment found in this location was rich in organic matter which matches what can be seen in the Purgatory Creek Recreational Area where brittle naiad is dominant. In addition, there was a smaller location of dense plants located along the south shoreline. In 2020 staff went out and conducted another roving survey which was made difficult due to the shallow water and dense coontail and eurasian watermilfoil. During the survey staff only found brittle naiad plants in the south location and could not locate any single plants previously

found or in the northeast corner where it appeared most dense in 2019. From this year to year variability, brittle naiad may have trouble competing with other native vegetation due to its later emergence.

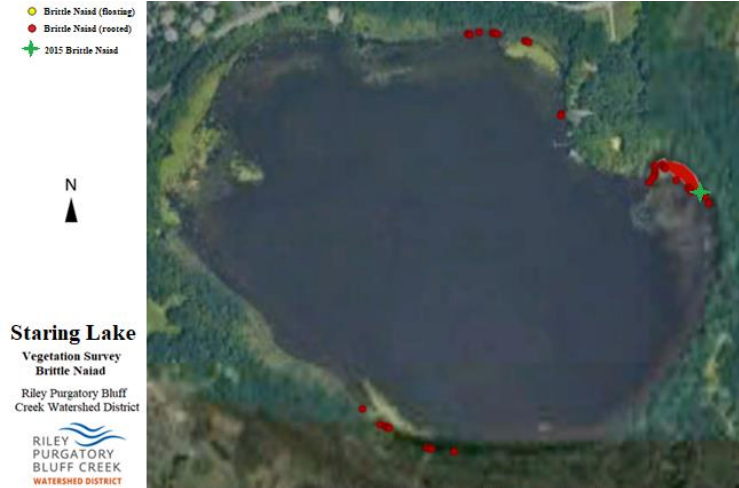


Figure 37 2019 Staring Lake Brittle Naiad Map

Lake Susan Brittle Naiad

During the University of MN 2019 August point intercept plant survey of Lake Susan, brittle naiad was detected at two points on Lake Susan. Both points were on the southern-most shore but relatively far apart (Figure 39). Later in September, RPBCWD staff went out and conducted a roving survey and searched to collect a voucher specimen in order to list the lake as infested with the MNDNR. Staff completed a survey and only found four small brittle naiad plants on the southwest location.

In 2020, staff conducted a roving survey Lake Susan to determine if any established areas of brittle naiad were missed or if the population expanded (Figure 38). During the survey staff found one additional location on the east side of the lake. In both locations, the plants seemed to be in less than 2 feet of water and were dense populations.

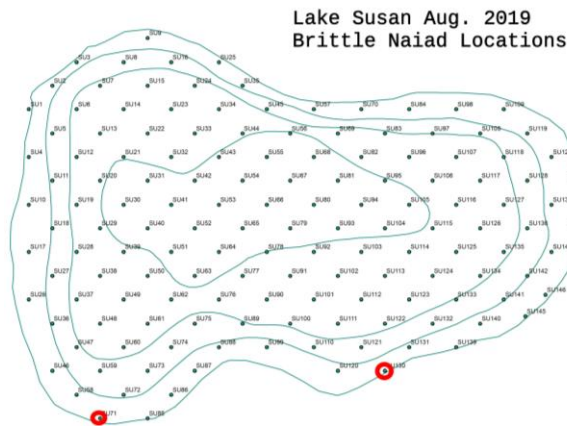


Figure 39 2019 Lake Susan Brittle Naiad Map



Figure 38 2020 Lake Susan Brittle Naiad Map

5.3 Common Carp Management

The RPBCWD, in cooperation with the University of Minnesota (UMN), (UMN), has been a key leader in the development of successful carp management strategy for lakes within the state of Minnesota. Following the completion of the Riley Chain of Lakes (RCL) Carp Management Plan drafted by the UMN in 2014 (Bajer et al., 2014), and the Purgatory Creek Carp Management Plan drafted in 2015 (Sorensen et al., 2015), the District took over monitoring duties from UMN. Carp can be detrimental to lake water quality. They feed on the bottom of the lake, uprooting aquatic plants and resuspending nutrients in the sediment. Adult carp are monitored within RPBCWD by conducting three, 20-minute electrofishing transects on each lake, three times each year between late July and early October (totaling three hours per lake). If the total biomass estimate of carp is above 100 kg/h, the population is considered harmful to lake water quality and the District would need to consider management. Young of the year (YOY) carp are monitored by conducting five, 24-hour small mesh fyke net sets between August and September. Capture of YOY carp during this sampling, suggests successful recruitment has occurred, and monitoring efforts should be increased on that water body. At that point, the District would also consider further management action.

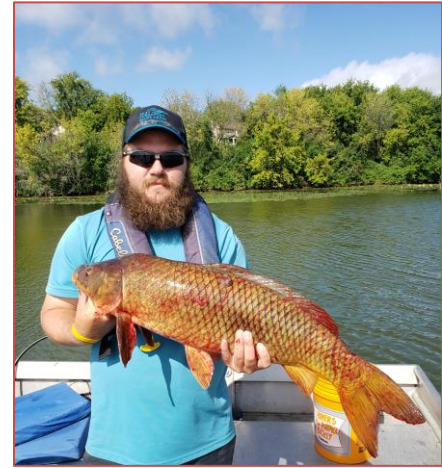


Figure 40 Captured Common Carp

Trap Netting

District staff completed trap net surveys on Staring Lake, Lake Lucy, Rice Marsh Lake, the Upper Purgatory Creek Recreational Area (UPCRA), and the Lower Purgatory Recreation Area (LPCRA) in 2020. As is true with many lakes during late summer located within the Twin Cities' metro area, the RCL and PCL inshore fish community was dominated by bluegill sunfish. Other species that were abundant included pumpkinseed sunfish, black crappies, and bullhead species. Of the lakes sampled in 2020, Rice Marsh Lake had the highest number of bluegills captured averaging 165 fish per net, which is slightly down from 234 fish/net in 2019. These numbers indicate a full recovery from the 2018/2019 winterkill (**Figure 41**). Additionally, catch per unit effort (CPUE) of bluegills in Lake Lucy of 79 bluegills/net in 2020 is down slightly from 2019 (CPUE=111.6), but also indicates a recovery from the winterkill that occurred in 2017/2018 (**Figure 41**). The LPCRA had the lowest bluegill abundance with only 3 bluegills/net captured. Additionally, both the total number of fish captured (from 2,169 in 2019 to 87 in 2020) and species (from 15 in 2019 to 10 in 2020) decreased in LPCRA indicating a winterkill most likely occurred (**Figure 41**).

Large predatory fish including northern pike and largemouth bass were also captured via fyke netting in low numbers across the lakes. The largest pike was captured in UPCRA and measured 39.85 inches. The most diverse fish population was observed in UPCRA where 11 different species were captured. A full summary table of the fish captured for each lake can be found in 8 Exhibits B. No YOY carp were captured in any of the lakes during fyke net surveys in 2020. The lack of young individuals captured in lakes indicates that 2020 was a poor recruitment year for common carp overall.

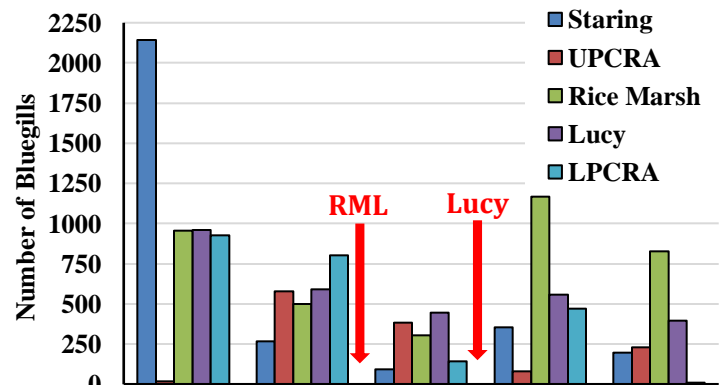


Figure 41 2016-2020 Bluegill Trap Net Catches
The red arrows indicate when winter kills occurred.

Overall, 17 YOY carp were captured during fyke netting on the LPCRA as compared to five in 2019. This increase in YOY carp indicates some recruitment did occur, however the number captured is still well below the numbers seen at the beginning of carp management in PCL.

Electrofishing

Lake Susan, Lake Riley, Lake Susan Park Pond (LSPP) were the lakes electrofished from the RCL in 2020. Staring Lake, and the Purgatory Recreation Area were surveyed via electrofishing in 2020. Lake Riley was sampled but only on one date which yielded no common carp. Since 2012, Lake Riley has consistently seen biomass estimates less the 50 kg/ha (Table 22). In 2020, the common carp biomass estimate was 42 kg/ha in Lake Susan (Table 23), which is up from 2016 (31 kg/ha) and 2017 (24 kg/ha). Comparing the past three years of available electrofishing data (Table 22), the carp population estimates have remained low and stable, with only slight year to year variability. Lake Susan Park Pond was again electrofished in 2020 and continues to be a congregation area for common carp within the RCL system. In 2017 the biomass estimate for carp was 404 k/ha and in 2020 it was 336 kg/ha. Fish are moving into LSPP during spring high water and become trapped as water levels recede. This has presented a management opportunity within the RCL lakes as carp in LSPP are more easily captured due to the shallow nature and limited area carp have to escape. This also is most likely an explanation as to why the biomass estimates are so high and suggests that the population in the pond is most likely being overestimated. The pond is deep enough as to prevent winterkill and has an established bluegill population to prevent carp recruitment via egg predation. The District will continue monitoring and removing carp from LSPP in addition to the recommended management actions established RCL management plan.

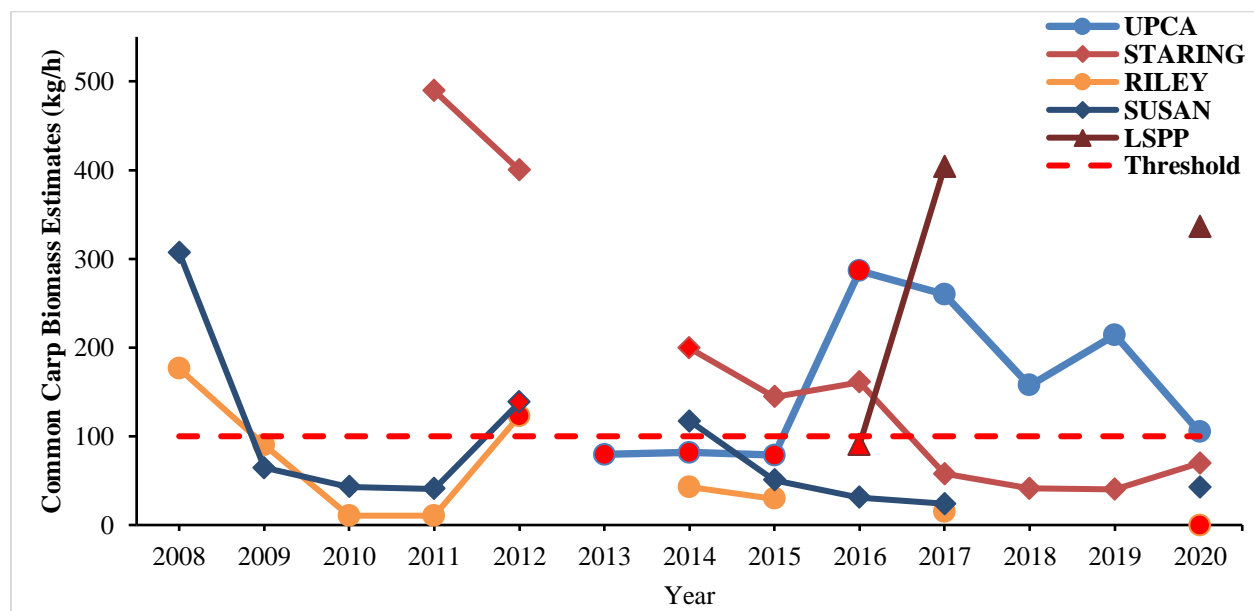


Table 22 2020 Common Carp Biomass Estimates

Of the PCL lakes, Staring Lake and the Purgatory Recreation Area were surveyed via electrofishing in 2020. As seen in (Table 22), the adult common carp biomass estimates have been decreasing in Staring Lake over the past four years. In 2017 the carp biomass estimate was below the threshold at 62 kg/ha. In 2018, it was lower still at 41 kg/ha and in 2019 the estimate was 40 kg/h. In 2020, the population estimate did increase to 69 kg/ha (Table 23). These fish captured consisted of individuals from the 2014/2015-year class, which was the last major recruitment year for common carp in the system. Electrofishing has not occurred in the LPCRA the past few years due to access issues and the amount of brittle naiad present in

the system. In 2020, the UPCRA again had a carp biomass estimate that exceeded the biomass threshold but was greatly reduced to 105 kg/ha (**Table 23**). This number is down from the past three years 260 kg/ha-2017, 157 kg/ha-2018, and 214 kg/ha in 2019 (**Table 22**). Since the UPCRA area is essentially the top of the system (fish cannot travel to Silver Lake and Lotus Lake), and has a deeper-water refuge, fish move to this location. The fluctuations in Staring and UPCRA can be explained by removals happening in the system and fish migrating between the systems. Due to the shallowness of the system, winter seining would have limited effectiveness at capturing carp in UPCRA and LPCRA. Additionally, winter seining may yield limited success in Staring Lake due to the low number of carp estimated in the system. Capture rates in the recreational area can be highly variable as the U of MN biomass estimates were based on lakes and not flow through wetlands. Staff will continue to monitor the carp population and remove fish in 2021.

Table 23 2019 Common Carp Biomass Estimates

Lake	Fish per Hour	Density per Hectare	Average Weight (kg)	Carp Biomass (kg/ha)
Lake Susan Park Pond	35.15	168.60	1.99	335.89
Riley	0	0	0	0
Staring	8.98	45.32	1.54	69.84
Susan	1.38	9.54	4.42	42.17
Upper Purg Rec Area	17.62	86.03	1.22	104.67

*Lower Purgatory Creek Recreational Area not sampled.

PCL Spring Removals

In 2020, the physical carp barrier on Purgatory Creek between Staring Lake and the LPCRA was closed later than usual in early June, due to Covid-19 and early June rain events. The later closure most likely allowed carp to move freely during the spring spawning event. The City of Eden Prairie opened, cleaned, and closed the fish barrier multiple times during the year due to high water levels in the Purgatory Creek Recreational Area. At times the barrier was held open for an extended period (up to 1 week). During this time, fish could move freely throughout the system.

During the spring of 2020 spawning run, staff utilized an electrofishing boat and a backpack electrofishing unit combined with block nets to remove common carp (**Figure 43**). Boat electrofishing was added in UPCRA because in 2019 carp were seen congregating in large groups. Backpack electrofishing and block nets were utilized in the channel upstream of the barrier and at the breach in the berm that separates the Upper and Lower Purgatory Creek Recreational Area. Most of the fish were captured via backpack electrofishing at the breached berm site. This breach allows water to short circuit the overflow



Figure 43 Common Carp Removal at the PCRA Berm

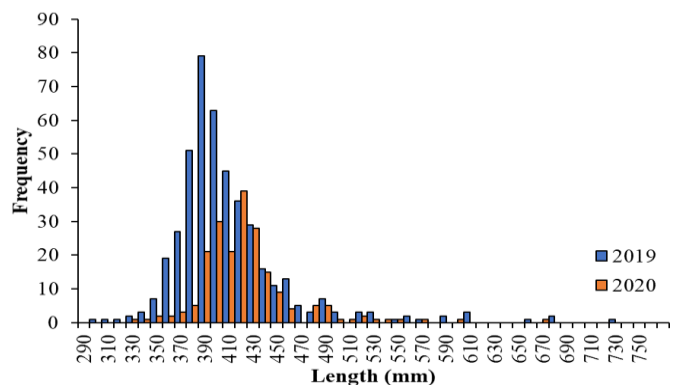


Figure 42 2019-2020 Length Frequency of PCRA Spring Removals

structure. Water is always flowing at this location which leads to carp concentrating in the shallow water near the breach before trying to move upstream. The sheet piling, combined with the consistent flow, has eroded the downstream side of the berm, causing a drop that impedes carp movement. A block net was anchored on the downstream side of the flow at the breach and then stretched around the congregating carp, trapping them against the berm and net. Staff used an electrofishing backpack to easily remove the trapped fish. During the heavy spawning run, staff repeated the process, sometimes up to three times a day, taking about an hour each time from installation of the net to completion of removal. Utilizing these gear types, a total of 201 carp were removed in 2020 vs 441 carp in 2019 and 1,901 carp in 2018. Most of the fish removed were from the 2015 year class, in which approximately 3000 YOY carp had entered Lake Staring from LPCRA and started to grow rapidly (Sorensen et al., 2015). This year class was a result of the last major recruitment event that occurred in the system thus far **Figure 42**. The major removal rate discrepancy between 2018 and 2020 can be attributed to the very low water levels seen in 2020 and the later installation of the barrier due to Covid-19. Low water levels prevent fish from congregating as much and the barrier being open allowed fish to move freely which may have reduced large podding. In 2019, most of the carp were removed on May 7th, when the water level at the barrier was 37.5 inches in depth (based on the installed staff gauge), and when the temperature was 17.2 degrees Celsius (**Table 24**). In 2020, the main carp removal event occurred on June 29th, when the water level was 39 inches and the water temperature was 22 degrees Celsius. District staff have been working with the City of Eden Prairie to stabilize the berm and correct/improve the regular overflow location to allow staff to utilize the location for future carp removal events. Staff may utilize electrofishing after dark in 2021 to improve capture efficiency.

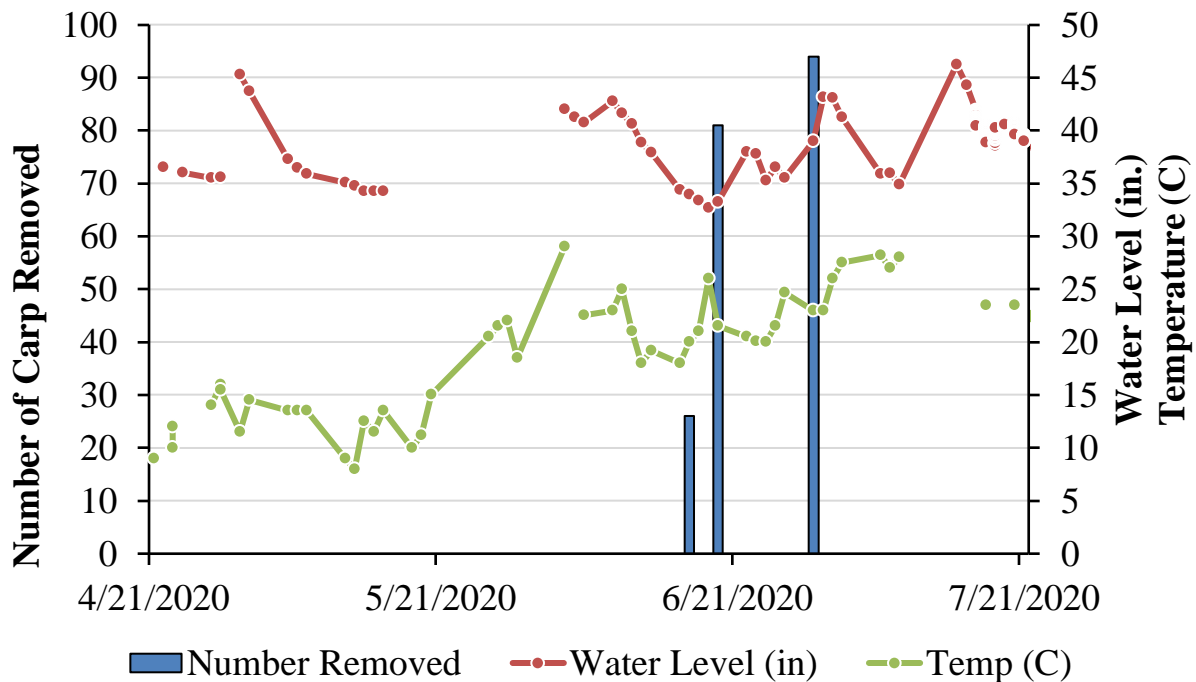


Table 24 Purgatory Creek Recreational Area Common Carp Removal vs Environmental Variables

5.4 Zebra Mussels

Zebra mussels are native to Eastern Europe and Western Russia and were introduced to the United States. Zebra mussels can cover equipment in the water, clog water intakes, cut bare feet, smother native mussels by covering them, and they can fundamentally change the food web of a lake by extensively filtering out phytoplankton to which many aquatic animals need (MNDNRb 2015). Treatment methods available to date are considered experimental and have not been effective in eradicating zebra mussels from a lake once they are introduced. The District continued to monitor for adult and veliger zebra mussels in 2020. The District conducted veliger sampling from June to July on 13 lakes and a high-value wetland to detect the presence of zebra mussels. Each lake was sampled once, apart from Lotus Lake which was sampled twice. RMB Environmental Labs processed the samples and found zebra mussel veligers on only lake Riley in 2020. Adult zebra mussel presence was assessed using monitoring plates that were hung from all public access docks, as well as some private docks of residents participating in the District's Adopt-a-Dock program. Monitoring plates were checked monthly and no mussels were found across all lakes except for lake Riley in 2020. Additionally, public accesses were scanned for approximately five to ten minutes during each regular water quality sampling period (bi-weekly). Staff visually searched rocks, docks, sticks, and vegetation for adult zebra mussels. Adult zebra mussels were only found at Lake Riley in 2020.

Riley

On October 22, 2018, RPBCWD staff confirmed zebra mussels on Lake Riley after a lake service provider discovered some zebra mussels while pulling docks and lifts. Previously, no zebra mussels had been found in the lake during the regular monitoring season, which included all the different monitoring efforts. The zebra mussels appeared to be widespread across the lake at low densities. Mussels were found of varying sizes suggesting that reproduction in Lake Riley had occurred. In 2019 zebra mussels were found on all plates deployed ranging in number from 69 mussels to 5,717 mussels/plate. This indicates a robust and expanding population that is well established across the lake. In 2020, adopt-a-dock volunteers captured zebra mussels of all sizes and the plates were fully covered in most cases. Actual zebra mussel counts/plate have not been completed.

Lotus

On August 30, 2019, 5 zebra mussel veligers were found in veliger tows collected by Carver County from the public access of Lotus Lake (**Figure 44**). No zebra mussel veligers were found in samples collected on June 20, 2019 or September 10, 2019 by the RPBCWD. Additional in-lake searching occurred on October 9, 2020 by RPBCWD staff. No adult zebra mussels were found during the search. An additional veliger tow was collected on October 10, 2019 and eDNA samples were taken at 4 locations. On October 24, 2019 staff from DNR, Carver County and the RPBCWD surveyed pulled docks on shore around the lake and found 5 zebra mussels ranging in size from 6-16 mm on a single boat lift footing in the east bay (**Figure 44**). After the October survey, the eDNA results were complete and indicated zebra mussel eDNA was present near the boat launch sample and the east bay sample near where the adults were captured. Based on the collected information, Lotus Lake was added to the Infested Waters List for zebra mussels for 2019. In 2020, veliger tows were again collected twice in the spring, but yield no zebra mussel veligers. Both boat launch and mussel plate checks (expanded to 11 plates) yielded no adult mussels.



Figure 44 2019 Lotus Lake Zebra Mussel Map

Staff visually searched for mussels twice in 2020, once in August and once in October after docks were pulled. No mussels were found. The eDNA results for 2020 were positive for the deep-water area near the boat launch only. Staff will continue to monitor for zebra mussels in 2021.

The chemical and physical makeup of a lake determines the suitability of that lake to support zebra mussels. Like many organisms, there is a wide range of suitable conditions in which zebra mussels can survive. Optimal conditions are conditions in which there are no limiting variables that are controlling an organism's ability to grow and reproduce within a system. **Table 25**, lists the different variables associated with zebra mussels that the District currently measured in 2018 for Lake Riley and in 2019 for Lotus Lake. In **Table 25**, the criteria used to determine the level of infestation by zebra mussels in North America (Mackie and Claudi 2010) with the variables being arranged from greatest to least importance for determining suitability for zebra mussels. For consistency, all variables included in the analysis were measured during the summer growing season (June-September) and include only the top two meters for the lakes. The different variables can be grouped into three categories:

- Chalk variables which are needed for shell formation.
- Trophic (nutrient) variables which are associated with growth and reproductive success.
- Physical variables or basic lake variables that limit where zebra mussels can live in a lake.

Calcium concentrations were estimated based on average monthly alkalinity samples. The estimated calcium concentrations in Lotus and Riley were similar to actual calcium concentrations collected from all other lakes in the Riley Chain. Comparing all lakes in the District with the calcium threshold established by Mackie and Claudi 2010, only Round and Hyland have less than optimal calcium concentrations (>30mg/L) for zebra mussels. Alkalinity and pH are associated with calcium concentrations and were both highly suitable for sustaining zebra mussels in both lakes. The nutrient variables for Lake Riley were at moderate levels for zebra mussel suitability, however both TP and Chl-a concentrations were near the upper end of the moderate infestation threshold. Lotus Lake nutrient data indicates minimal growth parameters for zebra mussel growth. This indicates the zebra mussel population may not be as significant. Steve McComas found Chlorophyll concentrations directly impacted zebra mussel populations in Lake Minnetonka bays. Areas of the lake with optimal chlorophyll conditions experienced significant reductions in chlorophyll concentrations after infestation. This was followed by a zebra mussel dieback, occurring three to four years after the first mussels were found (McComas 2018). Physical variables all scored high for zebra mussel suitability in Riley and Lotus. These variables all change with depth, however optimal conditions for each were present in both lakes. Hard structure suitability was estimated as moderately suitable for zebra mussels in both lakes. In 2016, it was found that 98% of the zebra mussel population in Lake Minnetonka were mostly juveniles and were found on submerged aquatic plants (McComas 2018). That said, it was hypothesized that many of those individuals died off and the main source of zebra mussel year to year recruitment may be from smaller, but dense groups of adults spread on isolated hard structure in slightly deeper portions of the lake. Hard structure in both lakes included predominantly rock and woody debris and is hypothesized to not be limiting for zebra mussels.

Based on the results in **Table 25**, the suitability of Lake Riley to support a robust and expansive zebra mussel population is high. These results were confirmed by mussel counts on adopt-a-dock volunteers. Once large zebra mussel populations become established, it is hypothesized that Chl-a and TP will decrease, and water clarity will increase due to zebra mussel filtering rates. In Lotus Lake **Table 25** indicates a slow growing or limited population to the minimal growth nutrient levels.

Table 25 Suitability for Zebra Mussels in Lake Riley and Lotus Lake

	LAKE	RILEY	LOTUS
Shell Formation	Calcium (mg/L)	43.9	53.6
	Alkalinity (mg/L)	111.5	157.5
	pH	8.69	7.88
Trophic Variables	TP (mg/L)	0.018	0.042
	Chl-a (ug/L)	2.79	34.3
	secchi (m)	4.64	1.2
Physical Variables	Temp (degC)	24.69	22.74
	DO (mg/L)	8.79	8.82
	Cond (uS/cm)	483.7	461.73
	Hard Structure	n/a	n/a

*Mackie and Claudi 2010

BLUE=Minimal Infestation Potential

ORANGE= Moderate Infestation Potential

RED=Massive Infestation Potential

6 Lake and Creek Fact Sheets

The Riley Purgatory Bluff Creek Watershed District has included in this report informational fact sheets for the lakes and creeks that were monitored during the 2019 sampling season (See 8 Exhibits E). The lake fact sheets include: Lake Ann, Duck Lake, Hyland Lake, Lake Idlewild (high value wetland), Lotus Lake, Lake Lucy, Mitchell Lake, Red Rock Lake, Rice Marsh Lake, Lake Riley, Round Lake, Silver Lake, Staring Lake, and Lake Susan. The creek fact sheets include: Bluff Creek, Purgatory Creek, and Riley Creek.

Each lake fact sheet includes a summary of the historical water quality data collected as related to the MPCA water quality parameters: Secchi Disk depth, Total Phosphorus, and Chlorophyll-a. Each creek fact sheet includes a summary of the most current Creek Restoration Acton Strategy assessment, which includes the analysis of infrastructure risk, water quality, stream stability/erosion, and habitat. Lake or creek characteristics, stewardship opportunities, and information about what the District is doing in and around local water bodies is also described in each fact sheet.

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8 Exhibits

Exhibit A	2018 & 2019 Lake Level Sensor Graphs
Exhibit B	2019 Fyke Net Summary Data
Exhibit C	2019 Zooplankton Summary Data
Exhibit D	2019 Phytoplankton Summary Data
Exhibit E	2019 Lake and Creek Fact Sheets

Exhibit A

2018 & 2019 Lake Level Sensor Graphs

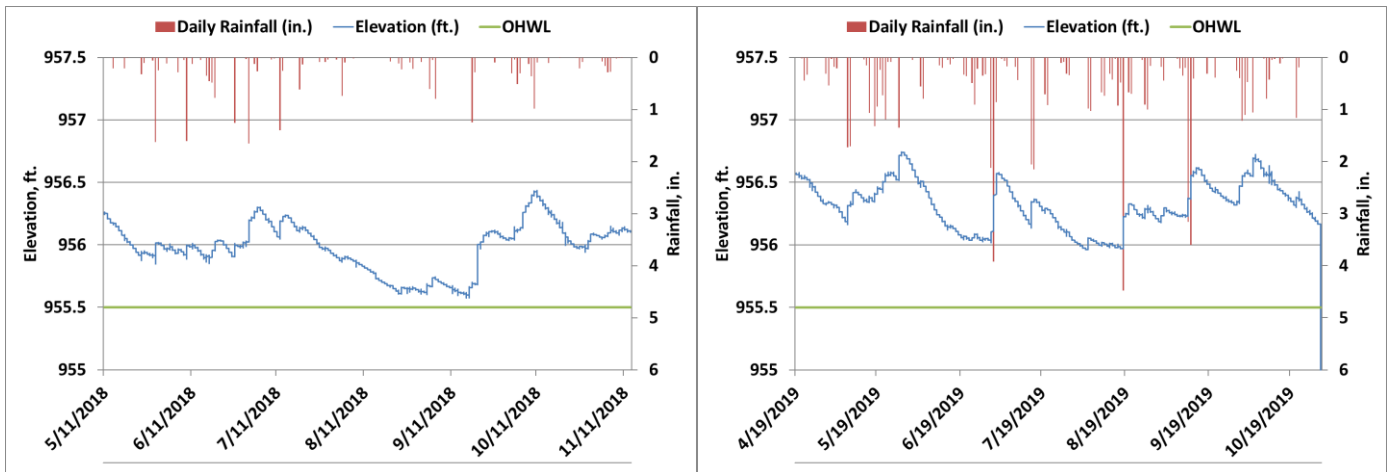


Figure A-1. **Lake Ann** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

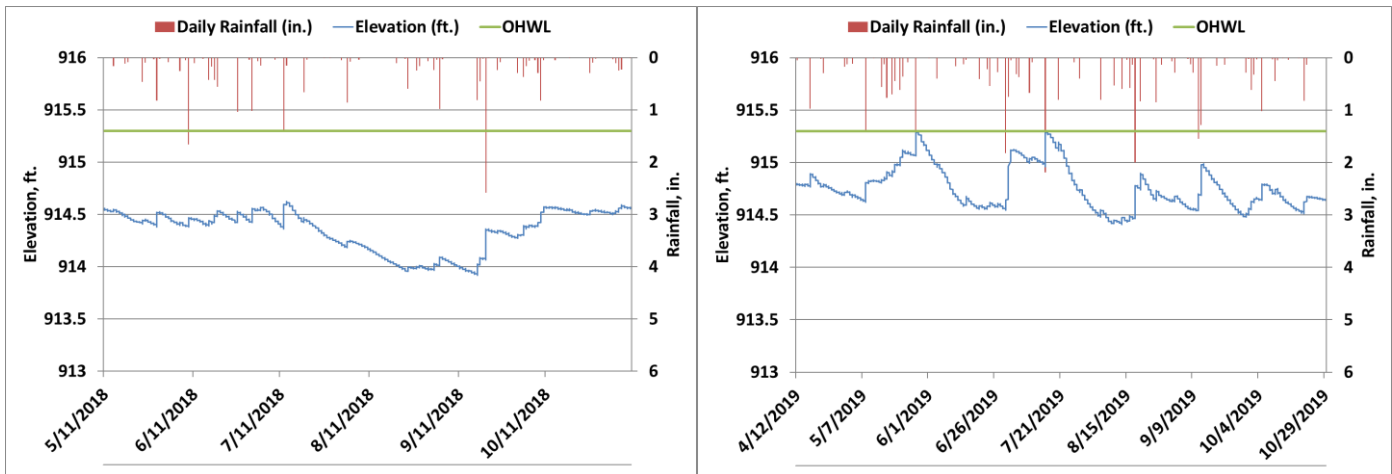


Figure A-2. **Duck Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

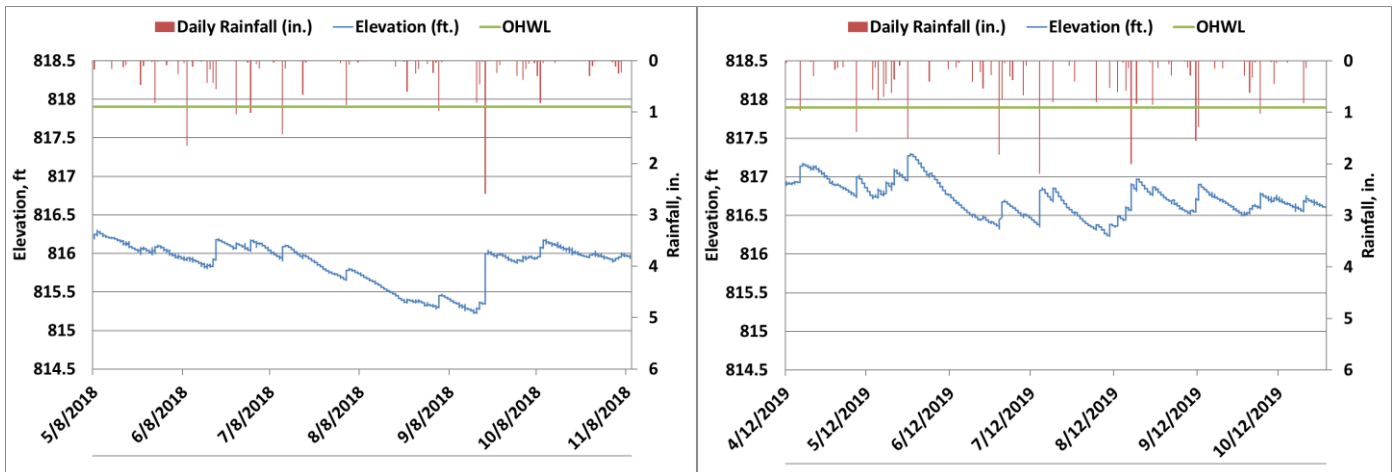


Figure A-3. **Hyland Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

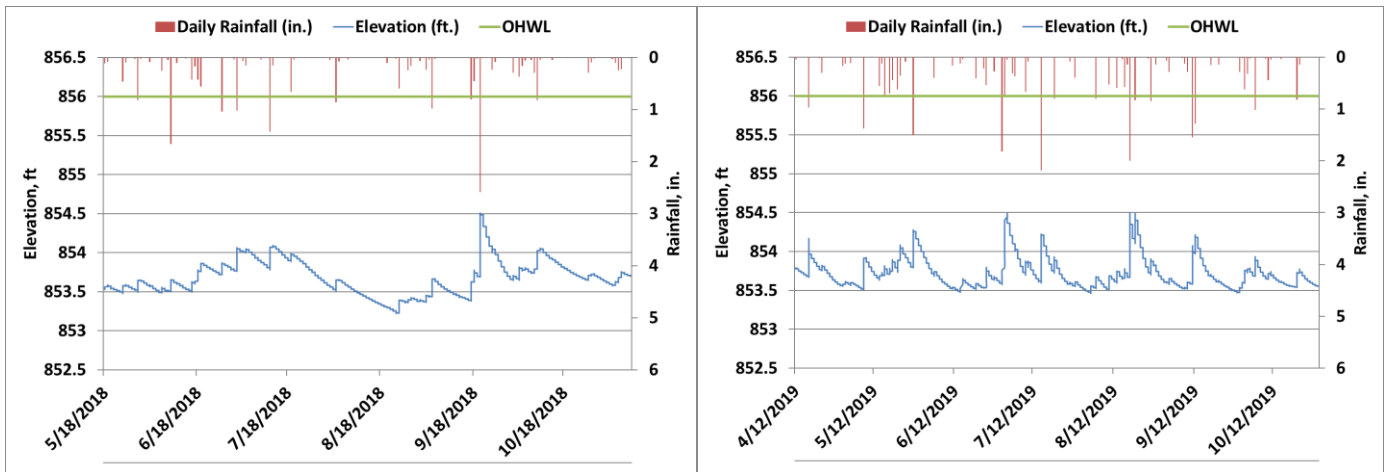


Figure A-4. **Lake Idlewild** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

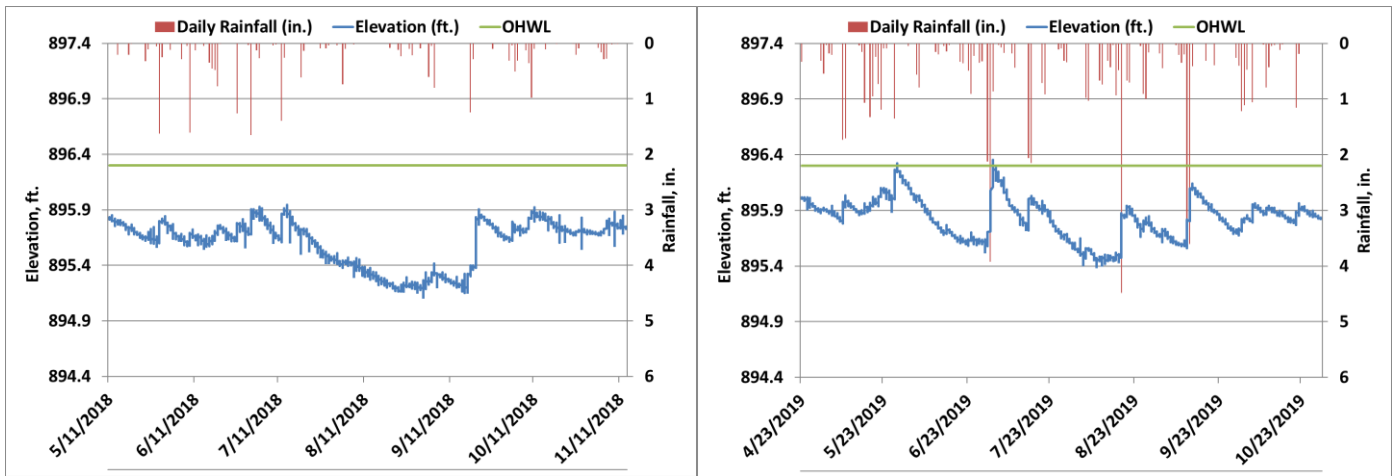


Figure A-5. **Lotus Lake** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

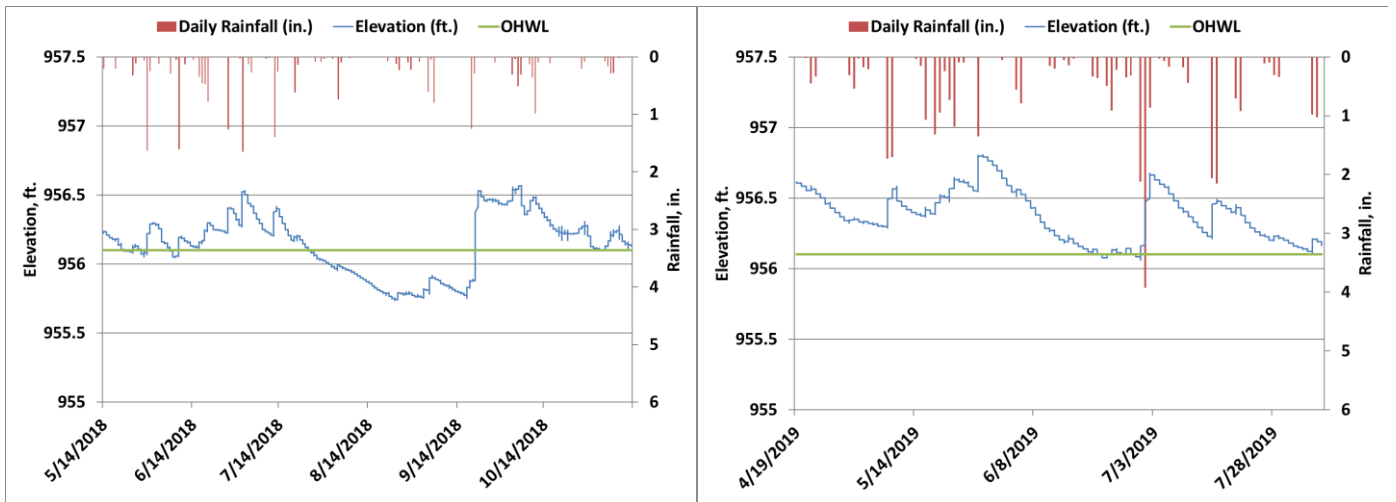


Figure A-6. **Lake Lucy** level elevation data (ft.) for 2018 and 2019 along with the lake's ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

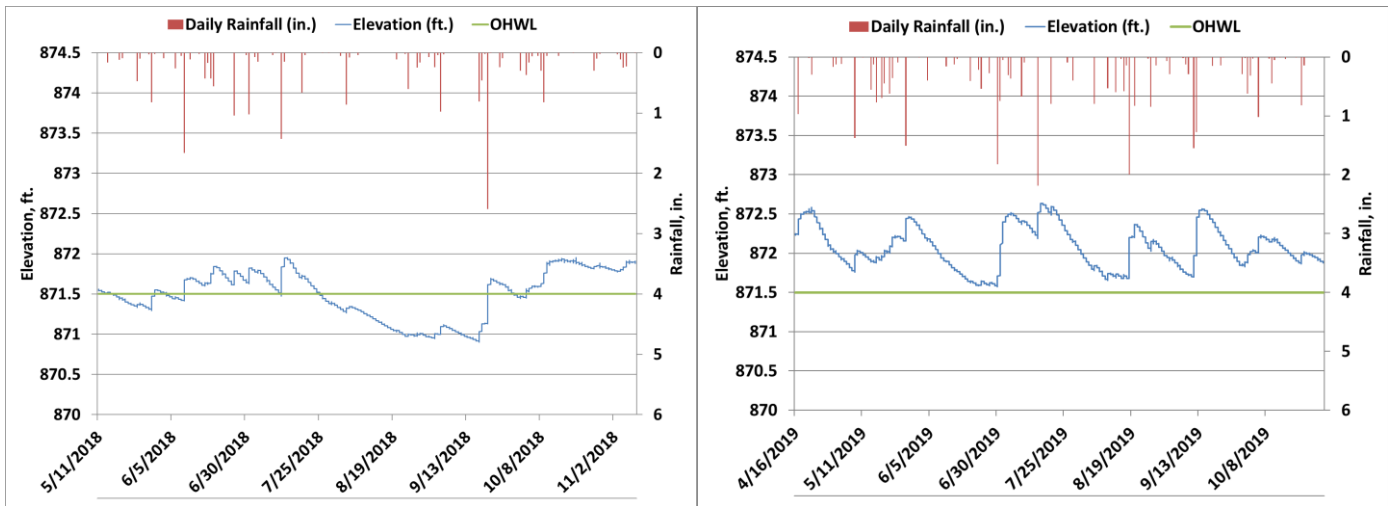


Figure A-7. **Mitchell Lake** level elevation data (ft.) for 2018 and 2019 along with the lake’s ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

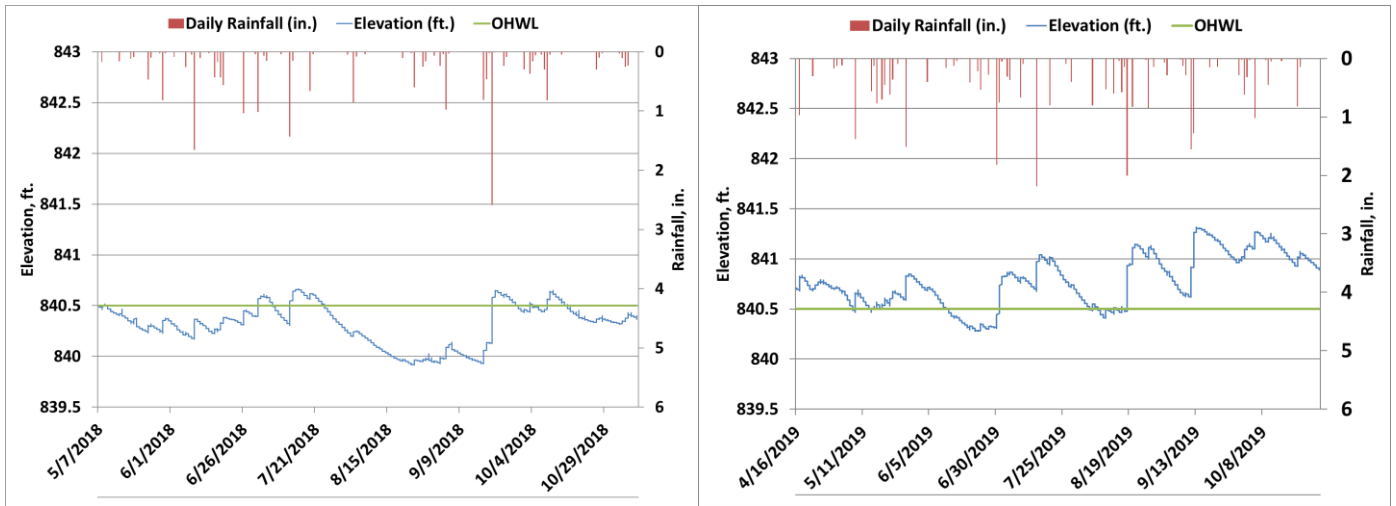


Figure A-8. **Red Rock Lake** level elevation data (ft.) for 2018 and 2019 along with the lake’s ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

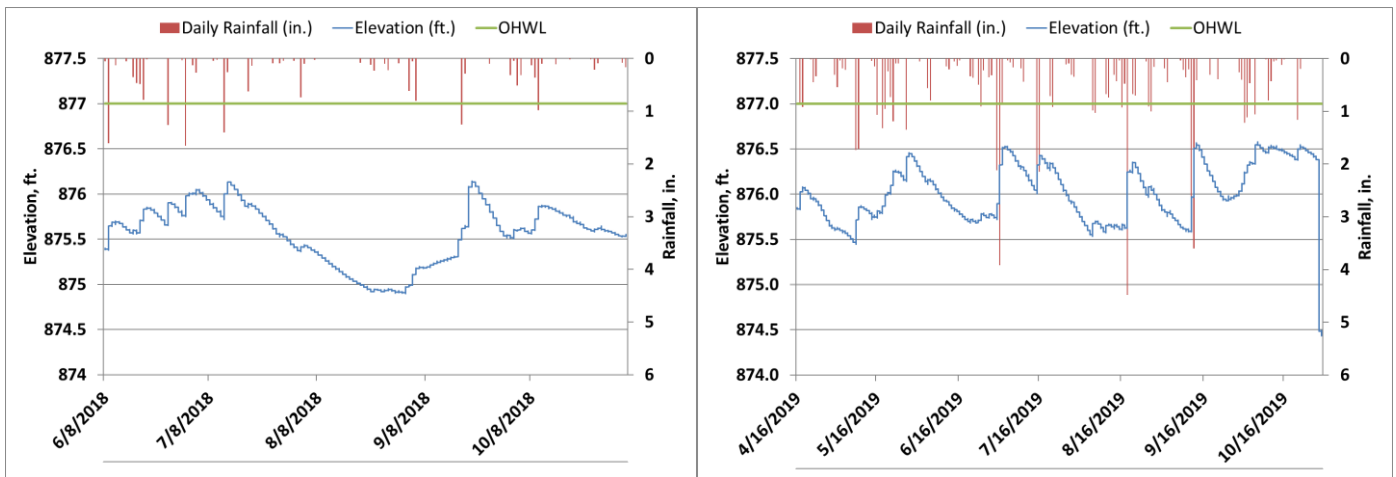


Figure A-9. **Rice Marsh Lake** level elevation data (ft.) for 2018 and 2019 along with the lake’s ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

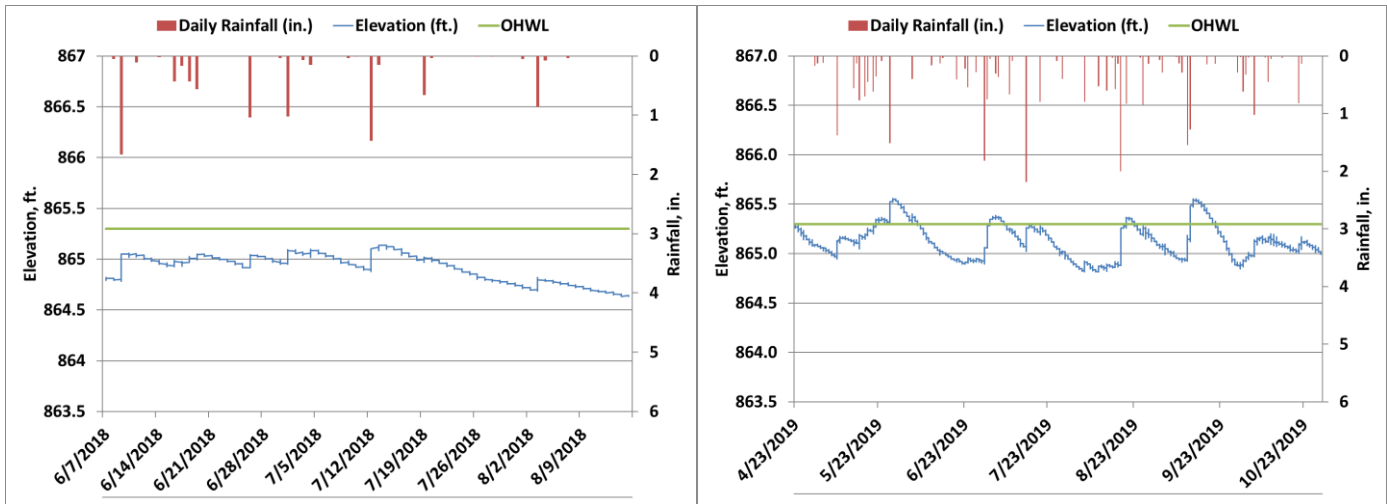


Figure A-10. **Lake Riley** level elevation data (ft.) for 2018 and 2019 along with the lake’s ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

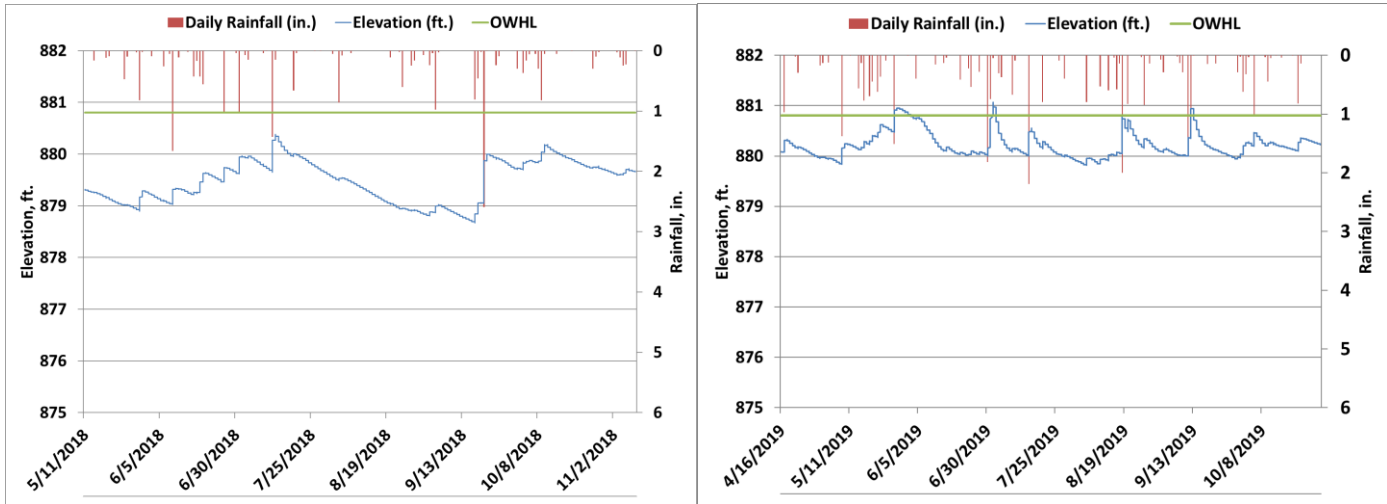


Figure A-11. **Round Lake** level elevation data (ft.) for 2018 and 2019 along with the lake’s ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

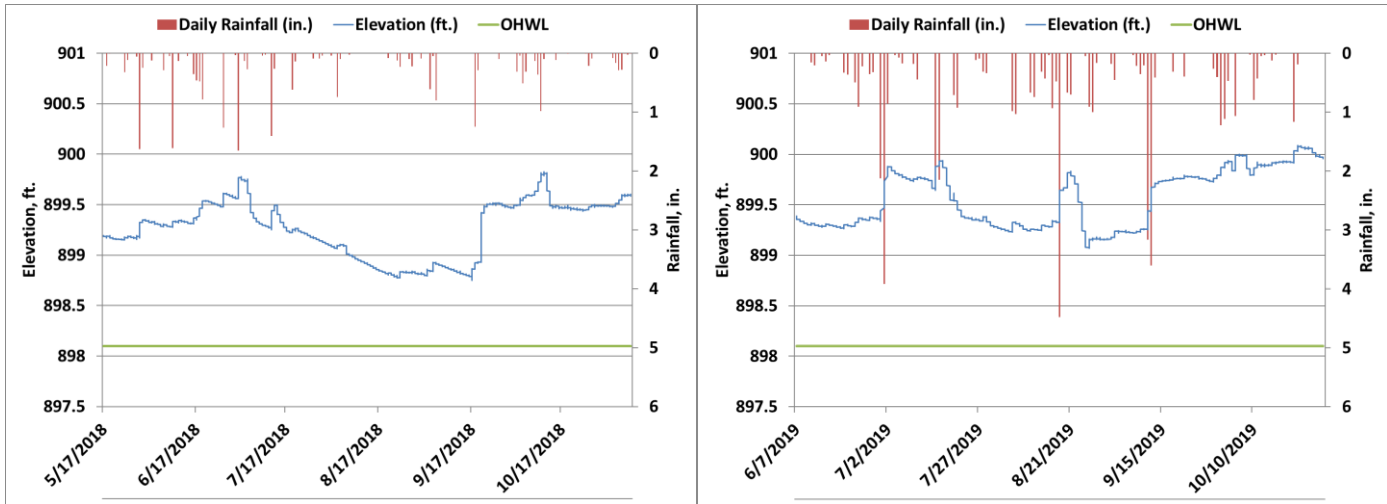


Figure A-12. **Silver Lake** level elevation data (ft.) for 2018 and 2019 along with the lake’s ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

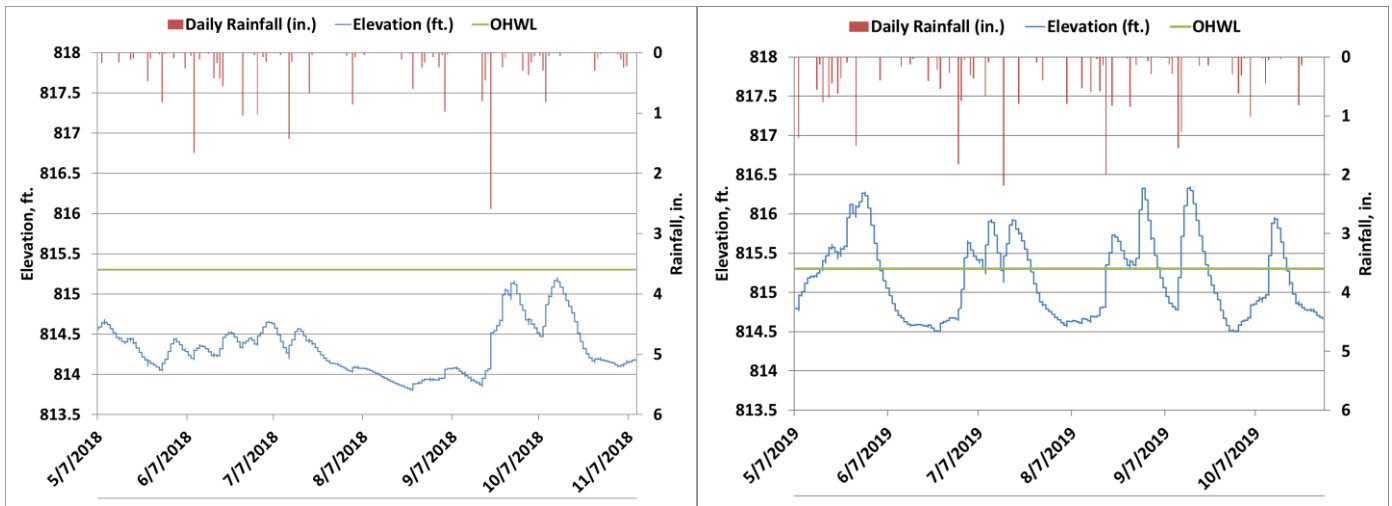


Figure A-13. **Staring Lake** level elevation data (ft.) for 2018 and 2019 along with the lake’s ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

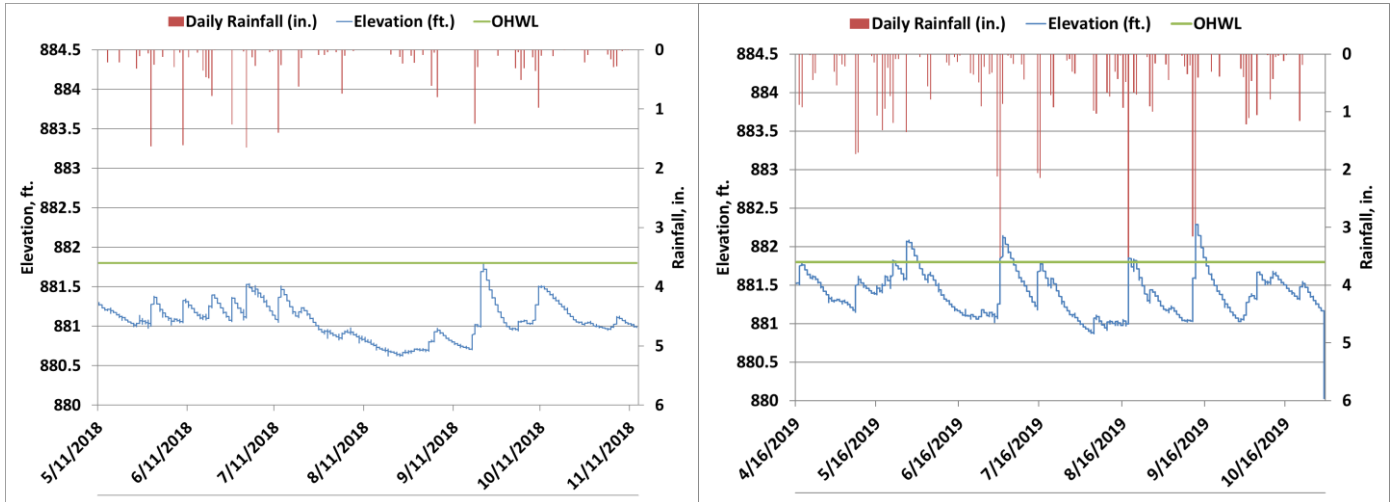


Figure A-14. **Lake Susan** level elevation data (ft.) for 2018 and 2019 along with the lake’s ordinary high-water level (OHWL). Daily rainfall (in.) is displayed along the top of the graph (NOAA).

Exhibit B

2020 Trap Net Summary Data

Table B3: 2020 **Lake Lucy** trap net data

Species	Number of fish caught in each category (inches)												2020 Fish/Net
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39	40-44	Total	
<i>Black Crappie</i>			4	3								7	1.4
<i>Bluegill Sunfish</i>	296	90	11									397	79.4
<i>Hybrid Sunfish</i>	4	7										11	2.2
<i>Largemouth Bass</i>	1											1	0.2
<i>Northern Pike</i>	1	1		2	3		3	2				12	2.4
<i>Pumpkinseed</i>	64	19	1									84	16.8
<i>Yellow Bullhead</i>	1	3	5	19	9							37	7.4
<i>Yellow Perch</i>	1	2		1	1							5	1

Table B4: 2020 **Lower Purgatory Creek Recreational Area** fyke net data

Species	Number of fish caught in each category (inches)												2020 Fish/Net
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39	40-44	Total	
<i>Black Bullhead</i>	2											2	0.5
<i>Bluegill Sunfish</i>	10	1										11	2.75
<i>Common Carp</i>	16	1										17	4.25
<i>Golden Shiner</i>	3											3	0.75
<i>Green Sunfish</i>	2											2	0.5
<i>Hybrid Sunfish</i>	8											8	2
<i>Largemouth Bass</i>	8											8	2
<i>Pumpkinseed</i>	34											34	8.5
<i>Yellow Bullhead</i>				1								1	0.25
<i>Yellow Perch</i>	1											1	0.25

Table B5: 2020 **Upper Purgatory Creek Recreational Area** fyke net data

Species	Number of fish caught in each category (inches)												2020 Fish/Net
	0-5	6-7	8-9	10-11	12-14	15-19	20-24	25-29	30-34	35-39	40-44	Total	
<i>Black Bullhead</i>	1	3	3									7	1.75
<i>Black Crappie</i>	117	26	10	1								154	38.5
<i>Bluegill Sunfish</i>	220	11										231	57.75
<i>Green Sunfish</i>	2											2	0.5
<i>Hybrid Sunfish</i>	2	1										3	0.75
<i>Largemouth Bass</i>	21	2			2							25	6.25
<i>Northern Pike</i>								1		1		2	0.5
<i>Pumpkinseed</i>	29											29	7.25
<i>White Sucker</i>					3							3	0.75
<i>Yellow Bullhead</i>	2	7	45	8								62	15.5
<i>Yellow Perch</i>	7											7	1.75

Table B6: 2020 **Rice Marsh Lake** fyke net data

Exhibit C

2019 Zooplankton Summary Data

Table C1: 2019 Lake Riley Zooplankton Counts (#/m²)

DIVISION	TAXON	5/20/2019 #/m2	6/4/2019 #/m2	7/10/2019 #/m2	8/8/2019 #/m2	9/5/2019 #/m2
CLADOCERA	<i>Bosmina longirostris</i>	0	0	0	0	0
	<i>Ceriodaphnia sp.</i>	0	0	0	0	0
	<i>Chydorus sphaericus</i>	120,544	11,904	0	0	0
	<i>Daphnia ambigua/parvula</i>	0	0	0	0	0
	<i>Daphnia galeata mendotae</i>	0	11,904	17,177	0	0
	<i>Daphnia pulex</i>	0	23,807	8,589	0	0
	<i>Daphnia retrocurva</i>	0	0	8,589	8,137	6,329
	<i>Diaphanosoma leuchtenbergianum</i>	0	0	0	0	0
	Immature Cladocera	0	0	0	0	0
	<i>Kindtii</i>	0	0	0	0	0
	CLADOCERA TOTAL	120,544	47,615	34,355	8,137	6,329
COPEPODA	<i>Cyclops sp. / Mesocyclops sp.</i>	45,204	71,422	34,355	0	0
	<i>Diaptomus sp.</i>	7,534	107,133	25,766	65,094	6,329
	Nauplii	180,815	178,555	188,952	65,094	151,885
	COPEPODA TOTAL	233,553	357,110	249,073	130,187	158,213
ROTIFERA	<i>Asplanchna sp.</i>	0	41,663	0	0	0
	<i>Brachionus sp.</i>	0	0	0	0	0
	<i>Filinia longiseta</i>	0	0	8,589	0	0
	<i>Lecane sp.</i>	0	0	0	0	0
	<i>Monostyla sp.</i>	0	0	0	0	0
	<i>Keratella sp.</i>	851,339	124,989	60,121	89,504	398,698
	<i>Keratella quadrata</i>	0	0	0	0	0
	<i>Kellicottia sp.</i>	0	309,496	0	0	6,329
	<i>Polyarthra sp.</i>	0	5,952	154,597	24,410	145,556
	<i>Trichocerca cylindrica</i>	0	0	0	0	0
	<i>Trichocera similis</i>	0	0	0	0	0
	<i>Trichocerca multirinis</i>	0	0	0	16,273	0
	<i>Conochilus sp.</i>	0	0	60,121	0	221,499
	<i>Noltholca</i>	0	0	0	0	0
	<i>UID Rot</i>	0	0	0	0	0
	ROTIFERA TOTAL	851,339	482,099	283,428	130,187	772,082
TOTALS		1,205,436	886,824	566,856	268,511	936,623

Table C2: 2019 Staring Lake Zooplankton Counts (#/m²)

DIVISION	TAXON	5/15/2019 #/m2	6/4/2019 #/m2	7/10/2019 #/m2	8/8/2019 #/m2	9/5/2019 #/m2
CLADOCERA	<i>Bosmina longirostris</i>	220,670	217,129	63,285	10,096	66,713
	<i>Ceriodaphnia sp.</i>	0	19,739	0	0	18,195
	<i>Chydorus sphaericus</i>	7,609	0	0	0	24,259
	<i>Daphnia ambigua/parvula</i>	0	0	0	10,096	0
	<i>Daphnia galeata mendotae</i>	15,219	108,565	23,732	0	72,778
	<i>Daphnia pulex</i>	0	0	0	0	0
	<i>Daphnia retrocurva</i>	0	29,609	0	0	36,389
	<i>Diaphanosoma leuchtenbergianum</i>	0	0	7,911	40,382	6,065
	Immature Cladocera	0	0	0	0	0
	<i>Kindtii</i>	0	0	0	0	0
	CLADOCERA TOTAL		243,498	375,041	94,928	60,573
COPEPODA	<i>Cyclops sp. / Mesocyclops sp.</i>	251,107	69,087	23,732	40,382	121,297
	<i>Diaptomus sp.</i>	7,609	39,478	31,643	20,191	84,908
	Nauplii	144,577	453,997	308,516	126,194	485,188
	COPEPODA TOTAL	403,294	562,562	363,891	186,767	691,393
ROTIFERA	<i>Asplanchna priodonta</i>	38,047	69,087	0	131,242	6,065
	<i>Brachionus sp.</i>	0	9,870	0	0	0
	<i>Filinia longiseta</i>	0	19,739	63,285	0	0
	<i>Lecane sp.</i>	0	0	0	0	6,065
	<i>Monostyla sp.</i>	0	0	7,911	0	0
	<i>Keratella cochlearis</i>	167,405	888,255	308,516	318,009	121,297
	<i>Keratella quadrata</i>	0	9,870	0	0	0
	<i>Kellicottia sp.</i>	30,437	187,521	0	0	66,713
	<i>Polyarthra sp.</i>	0	345,433	237,320	20,191	133,427
	<i>Trichocerca cylindrica</i>	0	0	0	0	6,065
	<i>Trichocera similis</i>	0	0	0	0	0
	<i>Trichocerca multirinis</i>	0	0	0	0	0
	<i>Conochilus sp.</i>	0	0	0	0	0
	<i>UID Rot</i>	0	0	0	60,573	333,567
ROTIFERA TOTAL		235,889	1,529,773	617,032	530,015	673,198
TOTALS		882,680	2,467,376	1,075,851	777,355	1,588,990

Table C3: 2019 Lotus Lake Zooplankton Counts (#/m²)

DIVISION	TAXON	5/16/2019 #/m ²	6/4/2019 #/m ²	7/10/2019 #/m ²	8/8/2019 #/m ²	9/5/2019 #/m ²
CLADOCERA	<i>Bosmina longirostris</i>	11678	0	48820	0	13184
	<i>Ceriodaphnia sp.</i>	0	0	0	0	0
	<i>Chydorus sphaericus</i>	0	0	16273	0	0
	<i>Daphnia ambigua/parvula</i>	0	6253	0	0	0
	<i>Daphnia galeata mendotae</i>	198520	25013	16273	0	0
	<i>Daphnia pulex</i>	0	0	0	0	0
	<i>Daphnia retrocurva</i>	0	0	8137	26369	243912
	<i>Diaphanosoma leuchtenbergianum</i>	0	0	0	13184	105476
	Immature Cladocera	0	0	0	0	0
	<i>Leptodora kindtii</i>	0	0	0	0	0
	CLADOCERA TOTAL	210198	31266	89504	39553	362572
COPEPODA	<i>Cyclops sp. / Mesocyclops sp.</i>	309458	81292	122050	26369	46146
	<i>Diaptomus sp.</i>	216037	68785	81367	19777	79107
	Nauplii	770725	212609	496338	118660	323019
	COPEPODA TOTAL	1296220	362685	699755	164806	448271
ROTIFERA	<i>Asplanchna sp.</i>	5839	62532	0	0	0
	<i>Brachionus sp.</i>	0	0	0	0	0
	<i>Filinia longiseta</i>	0	0	0	0	0
	<i>Lecane sp.</i>	0	0	0	0	0
	<i>Monostyla sp.</i>	0	0	0	0	0
	<i>Keratella sp.</i>	0	50026	16273	13184	171398
	<i>Keratella quadrata</i>	0	0	0	0	0
	<i>Kellicottia sp.</i>	110938	25013	0	0	217543
	<i>Polyarthra sp.</i>	0	18760	0	6592	0
	<i>Trichocerca cylindrica</i>	0	0	0	0	0
	<i>Trichocera similis</i>	0	0	0	0	0
	<i>Trichocerca multicornis</i>	0	0	0	0	0
	<i>Conochilus sp.</i>	0	0	0	0	0
	UID Rot	0	0	0	0	0
ROTIFERA TOTAL	116777	156330	16273	19777	388941	
TOTALS		1623194	550281	805532	224136	1199785

Table C4: 2019 Lake Susan Zooplankton Counts (#/m²)

DIVISION	TAXON	5/15/2019 #/m2	6/4/2019 #/m2	7/10/2019 #/m2	8/8/2019 #/m2	9/5/2019 #/m2
CLADOCERA	<i>Bosmina longirostris</i>	220,670	217,129	63,285	10,096	66,713
	<i>Ceriodaphnia sp.</i>	0	19,739	0	0	18,195
	<i>Chydorus sphaericus</i>	7,609	0	0	0	24,259
	<i>Daphnia ambigua/parvula</i>	0	0	0	10,096	0
	<i>Daphnia galeata mendotae</i>	15,219	108,565	23,732	0	72,778
	<i>Daphnia retrocurva</i>	0	29,609	0	0	36,389
	<i>Diaphanosoma leuchtenbergianum</i>	0	0	7,911	40,382	6,065
	CLADOCERA TOTAL	243,498	375,041	94,928	60,573	224,399
COPEPODA	<i>Cyclops sp. / Mesocyclops sp.</i>	251,107	69,087	23,732	40,382	121,297
	Nauplii	144,577	453,997	308,516	126,194	485,188
	<i>Diaptomus sp.</i>	7,609	39,478	31,643	20,191	84,908
COPEPODA TOTAL	403,294	562,562	363,891	186,767	691,393	
ROTIFERA	<i>Asplanchna priodonta</i>	38,047	69,087	0	131,242	6,065
	<i>Brachionus sp.</i>	0	9,870	0	0	0
	<i>Filinia longiseta</i>	0	19,739	63,285	0	0
	<i>Lecane sp.</i>	0	0	0	0	6,065
	<i>Monostyla sp.</i>	0	0	7,911	0	0
	<i>Keratella cochlearis</i>	167,405	888,255	308,516	318,009	121,297
	<i>Keratella quadrata</i>	0	9,870	0	0	0
	<i>Kellicottia sp.</i>	30,437	187,521	0	0	66,713
	<i>Polyarthra sp.</i>	0	345,433	237,320	20,191	133,427
	<i>Trichocerca cylindrica</i>	0	0	0	0	6,065
	<i>Trichocera similis</i>	0	49,348	0	0	0
	UID Rot	0	0	0	0	333,567
ROTIFERA TOTAL	235,889	1,579,121	617,032	469,442	673,198	
TOTALS		882,680	2,516,724	1,075,851	716,782	1,588,990

Table C5: 2019 Rice Marsh Lake Zooplankton Counts (#/m²)

DIVISION	TAXON	5/16/2019 #/m2	6/6/2019 #/m2	7/8/2019 #/m2	8/8/2019 #/m2	9/9/2019 #/m2
CLADOCERA	<i>Bosmina longirostris</i>	8,438	87,394	51,758	23,205	296,763
	<i>Ceriodaphnia</i> sp.	0	0	86,264	20,304	7,609
	<i>Chydorus sphaericus</i>	0	26,218	0	2,901	0
	<i>Daphnia ambigua/parvula</i>	0	0	0	0	0
	<i>Daphnia galeata mendotae</i>	210,951	0	0	0	0
	<i>Daphnia pulex</i>	50,628	0	0	0	0
	<i>Daphnia retrocurva</i>	0	0	0	0	0
	<i>Diaphanosoma leuchtenbergianum</i>	0	0	0	40,608	15,219
	Immature Cladocera	0	0	0	0	0
	Kindtti	0	0	0	0	0
	CLADOCERA TOTAL	270,018	113,612	138,022	87,017	319,591
COPEPODA	<i>Cyclops</i> sp. / <i>Mesocyclops</i> sp.	337,522	34,958	17,253	46,409	91,312
	<i>Diaptomus</i> sp.	84,380	0	103,517	23,205	53,265
	Nauplii	1,063,194	410,752	181,154	437,987	464,168
	COPEPODA TOTAL	1,485,097	445,710	301,924	507,601	608,745
ROTIFERA	<i>Asplanchna priodonta</i>	8,438	26,218	17,253	0	0
	<i>Brachionus</i> sp.	0	0	0	0	0
	<i>Filinia longiseta</i>	0	0	0	0	0
	<i>Lecane</i> sp.	0	0	0	5,801	0
	<i>Monostyla</i> sp.	0	0	0	8,702	0
	<i>Keratella cochlearis</i>	556,911	620,498	25,879	31,906	15,219
	<i>Keratella quadrata</i>	497,845	8,739	0	0	0
	<i>Kellicottia</i> sp.	2,826,747	0	0	0	0
	<i>Polyarthra</i> sp.	210,951	1,538,136	232,913	179,836	251,107
	<i>Trichocerca cylindrica</i>	0	0	0	0	0
	<i>Trichocera similis</i>	0	0	0	0	0
	<i>Trichocerca multicornis</i>	0	0	0	0	0
	<i>Platylabus patulus</i>	0	0	0	2,901	7,609
	<i>Euchlaris</i> sp.	0	0	0	0	0
	UID Rot	0	0	0	0	0
	ROTIFERA TOTAL	4,100,892	2,193,591	276,045	229,146	273,935
TOTALS		5,856,006	2,752,914	715,991	823,765	1,202,271

Exhibit D

2019 Phytoplankton Summary Data

Table D1: 2019 **Lotus Lake** Phytoplankton #/L

	5/16/2019	6/4/2019	7/10/2019	8/8/2019	9/5/2019
Class	#/L	#/L	#/L	#/L	#/L
Bacillariophyceae	230		57	172	
Chlorophyceae	574	1149		5054	2642
Cryptophyceae	919	574	1838	689	1149
Cyanophyceae	2354	2470	1436	38367	14244
Dinophyceae				230	1723
Total	4077	4193	3331	44513	19758

Table D2: 2019 **Staring Lake** Phytoplankton #/L

	5/15/2019	6/4/2019	7/10/2019	8/8/2019	9/5/2019
Class	#/L	#/L	#/L	#/L	#/L
Bacillariophyceae	4882	3159	689	230	115
Chlorophyceae	57838	1321	1608	6777	1436
Cryptophyceae	2527	1149	1264	1838	9017
Cyanophyceae	1608	57	4480	27339	
Dinophyceae				57	57
Euglenophyceae				57	
Total	66855	5686	8041	36299	10626

Table D3: 2019 **Lake Riley** Phytoplankton #/L

	5/16/2019	6/4/2019	7/10/2019	8/8/2019	9/5/2019
Class	#/L	#/L	#/L	#/L	#/L
Bacillariophyceae	56	57	115		57
Chlorophyceae	1418	1551	1551	11659	1551
Cryptophyceae		287	517	287	459
Crysophyceae	1668				
Cyanophyceae	2141	632	3102	7696	3791
Dinophyceae				57	172
Euglenophyceae		57			
Total	5284	2585	5284	19700	6031

Table D4: 2019 **Rice Marsh Lake** Phytoplankton #/L

	6/6/2019	7/8/2019	8/8/2019	9/9/2019
Class	#/L	#/L	#/L	#/L
Bacillariophyceae	172	115	459	230
Chlorophyceae	6490	3733	1608	6261
Cryptophyceae	402	517	1378	4939
Crysophyceae	57			
Cyanophyceae	517	1264	459	402
Dinophyceae		57		
Total	7639	5686	3906	11832

Table D5: 2019 **Lake Susan** Phytoplankton #/L

	5/16/2019	6/3/2019	7/10/2019	8/6/2019	9/11/2019
Class	#/L	#/L	#/L	#/L	#/L
Bacillariophyceae	287	57		5700	1920
Chlorophyceae	1378	2355	2125	11158	7406
Cryptophyceae	2412	1895	1781	2536	5943
Cyanophyceae	574	402	2527	34741	
Dinophyceae			230	85	30446
Euglenophyceae				85	366
Total	4652	4710	6663	54304	46080

Exhibit F

2019 Lake and Creek Fact Sheets