ANNUAL MONITORING REPORT
2022

Prepared for:

LOWER MINNESOTA RIVER WATERSHED DISTRICT

By:

SCOTT SWCD

June 2023

Table of Contents

Introduction

This report focuses on the summary and comparison of water resources data from Eagle Creek collected by Scott Soil and Water Conservation District (SWCD) in 2022 and previous monitoring seasons for the benefit of the Lower Minnesota River Watershed District (LMRWD) and its constituents. Eagle Creek is a spring-fed creek located primarily in Savage, Minnesota. Like previous years, the monitoring work plan for 2022 included three water temperature logging locations in Eagle Creek and two around the watershed connected to Eagle Creek, one continuous water monitoring station in Eagle Creek (operated in conjunction with Metropolitan Council Environmental Service's (MCES) Watershed Outlet Monitoring Program (WOMP), ground water monitoring at 17 observation wells located in the Savage Fen and surrounding area, and one water monitoring station on the inlet to Dean Lake Inlet (DLI) (Figure 1).

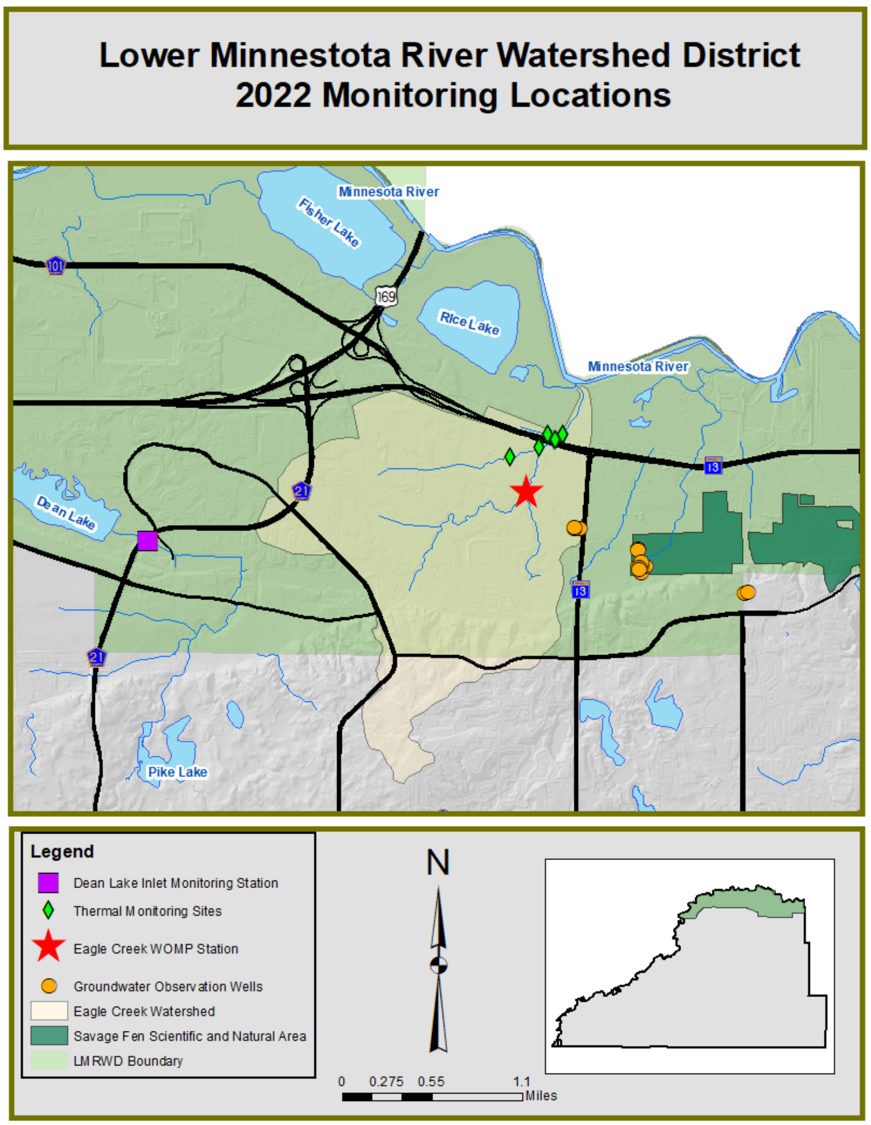

Figure 1. Monitoring locations around the Scott County portion of the Lower Minnesota River Watershed District for the 2022 monitoring season.

I. **Thermal Monitoring**

This study was initiated by the Lower Minnesota River Watershed District (LMRWD) to monitor the impact that storm water runoff from Highway 101 has on temperatures in Eagle Creek: a Minnesota Department of Natural Resources (MNDNR) designated trout stream and Class 2A waters designated for aquatic life and recreation. Brown Trout are very sensitive to changes in temperature as it impacts growth rate, habitat, and food resources. The optimal temperature range for adult brown trout is approximately 12.4 – 17.6^{o} Celsius (Bell, 2006).

Methods

Temperature loggers were placed upstream and downstream of Highway 101 in June of 2006 and have been recording stream temperature since that time. In October 2012, a midstream logger was placed just upstream of a pond tributary to monitor its impact on stream temperatures. Three additional loggers (Hwy 101 logger, Schroeder's Park logger and the Creek Way logger) have been placed on the outlets of the tributary adjacent to Eagle Creek in late July of 2018 (Figure 2). In 2021 the Creek Way logger was removed because it rarely saw any signs of water inundation and was only recording ambient temperatures. The additional tributary loggers monitor water temperatures leaving the tributaries, and they help identify potential sources of thermal warming. In late June 2021, METC staff added new equipment to the WOMP station which added continuous temperature sensing at the station. All five loggers and WOMP equipment record continuous temperature data in 15-minute intervals, and data from all loggers is collected quarterly.

Figure 2. Location of temperature loggers and WOMP station. The loggers added in 2018 are represented by the orange triangles. Thermal water data at the WOMP station is collected with METC monitoring equipment.

Results

Throughout the 2022 monitoring season, creek temperatures trended with atmospheric temperatures under most conditions. The downstream logger shows a deviation from the midstream and upstream loggers during the summer. A combination of atmospheric temperatures and the inflow of cold and warm water from the inlet near the Hwy 101 logger would influence the deviation.

Similar to other years, the general trend of the upstream logger continues to be the warmest during the winter and coolest in the summer of the three Eagle Creek loggers. The downstream logger shows the opposite trend as it is the warmest in the summer and coolest in the winter (Figure 3). During warm summer days, all three loggers recorded water temperatures that occasionally exceeded the optimal range for trout. This includes 16 times in the downstream logger, 15 times in the midstream logger, and 13 times in the upstream logger (Figure 4).

The upstream logger experienced higher temperature readings resembling atmospheric temperature between August 8 and August 11 likely caused by human disturbance of the logger. Those false spikes are notated on Figure 3. Maximum daily temperatures never exceeded the optimal range at the Eagle Creek WOMP site.

A separation in water temperatures is noticed after rain events, but this correlation was less drastic in 2022 due to low precipitation and low water levels (Table A1).

Since the start of the Eagle Creek water temperature monitoring project, consistent trends of daily maximum creek temperatures can be observed (Figure 4). The number of days that the maximum temperature exceeds 17.6°C is always highest at the downstream logger. The midstream and downstream loggers have the most significant relationship with annual precipitation totals while the upstream logger looks to have an inverse relationship with precipitation.

The two loggers outside of the creek's main channel—Schroeder's Park outlet and the Hwy 101 pond inlet—are more reactive to atmospheric temperature fluctuations (Figure 3). Schroeder's Park and Hwy 101 loggers showed several degrees separation with one another in the winter and summer months.

A slight increase in creek temperatures is seen between the WOMP station and the upstream logger during the summer months especially when the Schroeder's Park logger values are the highest (Figure 3). Fluctuations in all loggers are also observed with changes in atmospheric temperatures and rain events.

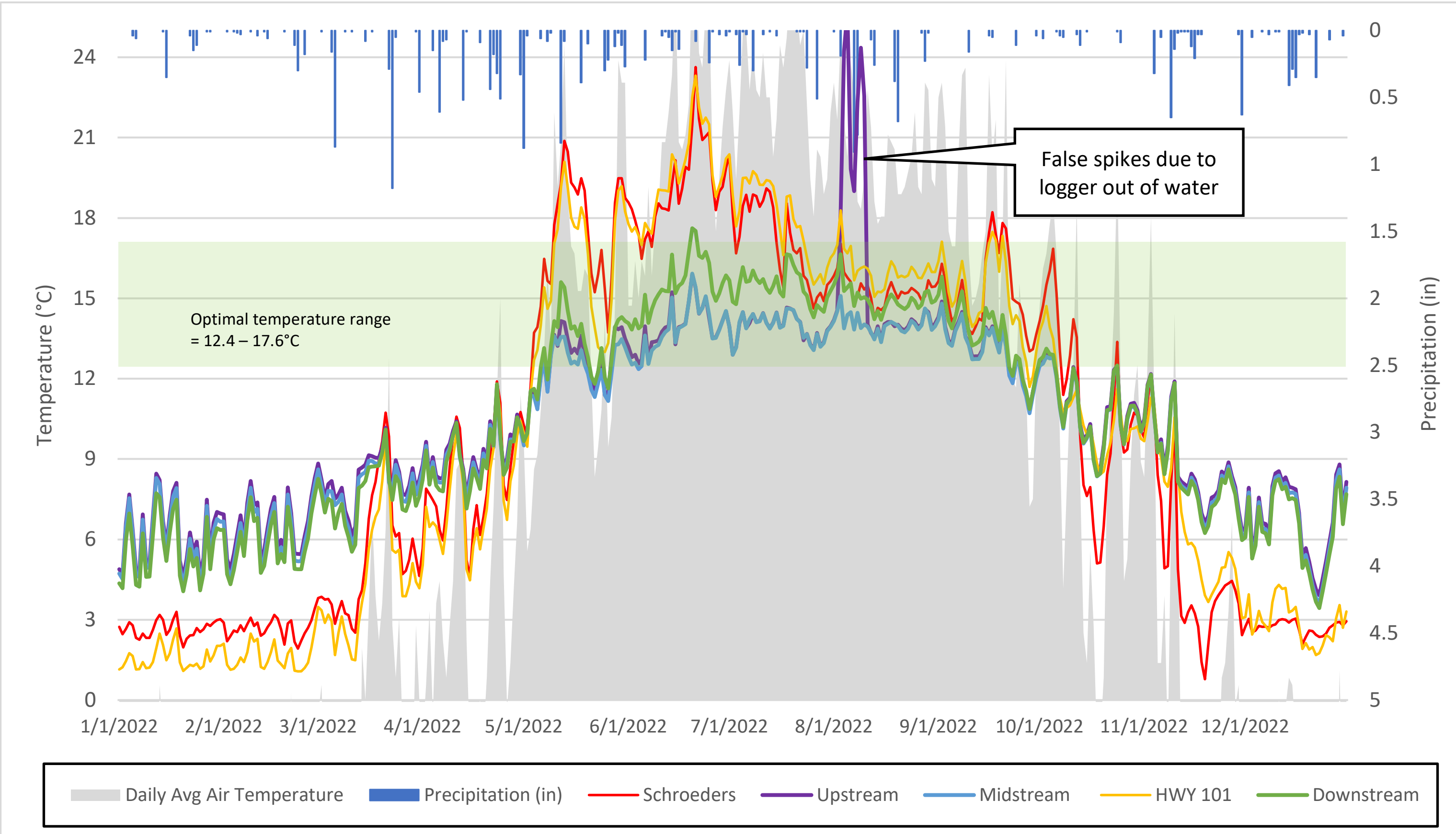

Figure 3. 2022 Average daily water temperatures in Eagle Creek compared with annual atmospheric temperature and annual precipitation.

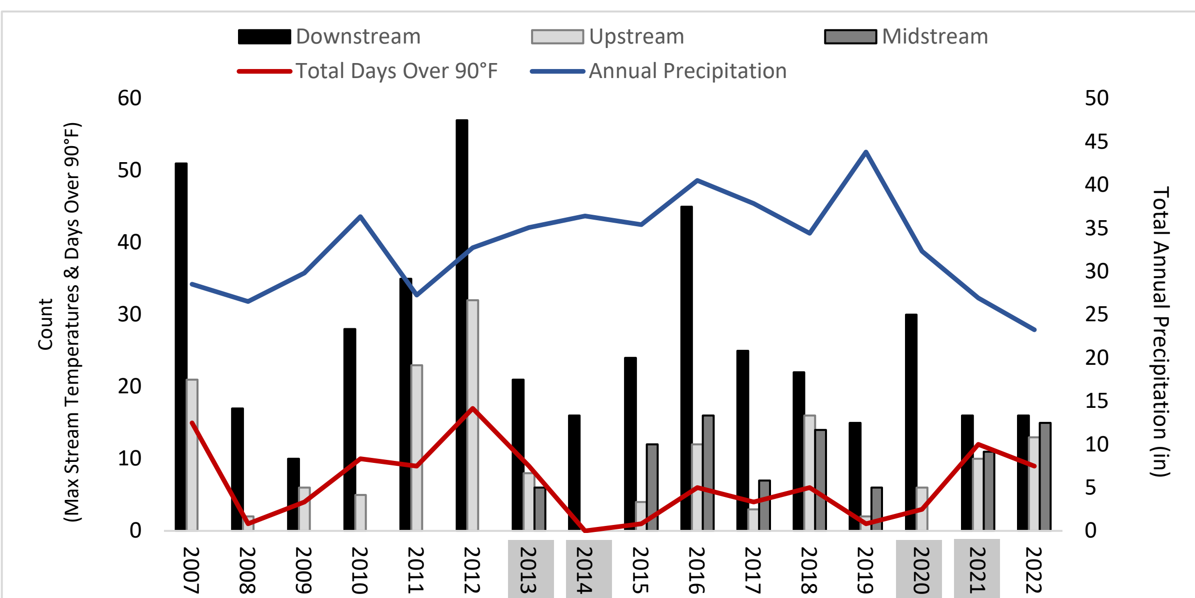

Figure 4. Total number of days maximum water temperature exceeded 17.6°C and air temperatures exceeded 90°F. Annual precipitation is the total received at the NOAA Chanhassen WSFO station. Shaded years have some missing or incomplete data associated with one or more of the thermal loggers.

Discussion

All loggers responded to atmospheric and tributary influences as seen in previous monitoring data. Minimal flooding in the spring did not appear to have any significant impacts to stream temperatures. Large precipitation events create instantaneous spikes in temperature, while a lack of precipitation creates longer and more sustained warmer temperatures that are likely due to increased air temperatures. This was observed in 2022 as Minnesota experienced a significant drought throughout the summer and into the fall.

The downstream loggers tend to peak higher and for an extended period of time when compared with the upstream logger, which is likely due to surface runoff from the stormwater inlets under Hwy 101 and increased side channel flow from the inlet at the Hwy 101 logger location.

Examining how these side channel tributaries influence the main channel of Eagle Creek, it is likely that the Hwy 101 tributary has some influence to rising temperatures at the downstream logger. The largest separation in temperatures between the upstream and downstream logger is observed after water passing the Hwy 101 logger enters the main channel and passes the downstream logger.

The Schroeders Park logger recorded slightly higher temperatures than the Hwy 101 logger. The park's pond is highly eutrophic and has the ability to absorb more radiational heat from the sun increasing the temperatures at the outlet. Schroeders Park funnels through several wetlands before entering Eagle Creek just upstream of the upstream logger location.

Being a groundwater fed stream, Eagle Creek's temperatures often track with ambient temperatures, but its base flow from groundwater flow keeps the stream warmer in cold months and cooler in warm months. Other factors that show influence to fluctuating Eagle Creek temperatures include spring flooding and precipitation events. Flooding usually occurs as early as March and can last until June. This can increase or suppress temperature fluctuations during those periods. Additionally, precipitation events are seen to impact logger temperatures, especially in the midstream and downstream loggers. These loggers have the greatest potential for influence from highway runoff and pond overflow discharge.

Continuous temperature monitoring of Eagle Creek and the adjacent tributaries will allow the tracking of temperature shifts. It also supplies historical background for past and future restoration projects. An unexpected geomorphic shift occurred in the streambed during 2020 which created sediment build up and deep pools between the Hwy 101 culvert and the downstream logger. The creek is very sandy and unstable in this section, and it is reasonable to assume the stream channel could change in this manner. The rate of this change was a somewhat unexpected, though, especially with no significant hydrogeologic influences observed throughout the year.

The METC's addition of the continuous water temperature data at the Eagle Creek WOMP location provides valuable insight as to the potential impact of the Schroeders Park pond discharge. Prior to the WOMP data there was no continuous data upstream of the confluence where the park water would enter the creek. Now there is a baseline temperature record to compare against the rest of the loggers downstream of the WOMP station.

II. Eagle Creek Water Quality Monitoring

Eagle Creek is a Class 2A self-reproducing trout stream, a unique water resource in the metropolitan area. The Creek originates at the Boiling Springs—an area considered sacred by the Mdewakanton Sioux Community—and outlets into the Minnesota River approximately 2.4 miles downstream. Significant measures have been taken over the past couple decades to prevent degradation of Eagle Creek, including diverting storm water from the stream, the establishment of a 200-foot natural vegetative buffer along each side of the bank, and most recently in 2013, a habitat improvement project along the west branch of Eagle Creek. These and other steps have helped to significantly minimize impacts from this rapidly growing suburban area.

Eagle Creek is located in the North Central Hardwood Forest (NCHF) ecoregion. There are seven ecoregions in Minnesota. Ecoregions are classified by geographic areas with similar plant communities, land use, soil, and geology. Each ecoregion has unique water quality goals as determined by historical monitoring of representative and minimally impacted reference streams within that ecoregion.

The Eagle Creek monitoring station began in 1999 as part of the Metropolitan Council's Watershed Outlet Monitoring Program (WOMP). This program was designed and currently managed by the Metropolitan Council for the primary purpose of improving pollutant load calculations from the Minnesota River. The LMRWD is the local funding partner for this station, and contracts with the Scott SWCD to perform field-monitoring activities. The monitoring station is located in the City of Savage near Highway 13 and Highway 101, approximately 0.8 miles upstream of the confluence with the Minnesota River (Figure 1).

Methods

In-stream field measurements of dissolved oxygen, temperature, turbidity, pH, and conductivity were taken every two weeks using an YSI EXO 1 multiparameter Sonde. Many parameters are also recorded every 15 minutes at the Eagle Creek WOMP station including stage, velocity, conductivity, precipitation, and stream temperature. Samples are collected and analyzed for multiple water quality parameters (Table 1, Table 2) during base flow conditions and storm events. Base flow samples are taken bi-weekly during periods of time unaffected by rainfall or snowmelt events. Samples are taken directly from the stream and then transported to the Metropolitan Council Environmental Services Laboratory for analysis. In 2021 the site was upgraded with an automated sample collector designed to collect individual samples throughout the rise, peak and fall of the stream during a precipitation event. The event samples are treated similar to base flow samples and are brought to the lab for analysis. The site was visited, and samples were collected 29 times during the 2022 monitoring season, three of which were event-based samples.

There are two means of measuring stage and flow at the WOMP station: A WaterLOG bubbler system and Sontek Argonaut Shallow Water (SW) system. The bubbler system has been used since 1999 to measure stage. To determine the amount of flow related to stage, flow measurements are taken manually by MCES staff with a flow meter while the creek is at different stages, and a rating curve is developed. With this data, a stage-flow relationship can be applied to the datalogger program, which then calculates continuous flow values as determined by the measured stage.

The Sontek Argonaut-SW was installed by the Metropolitan Council in 2008. This equipment calculates instantaneous flow based on the cross-section area, stage, and velocity of the water. This equipment was determined necessary because of occasional backwater conditions caused by beaver dams or flooding of the Minnesota River. The bubbler system is not able to determine that the water is moving slower, so it automatically calculates higher flow as the stage rises. The Argonaut is able to adjust the flow as velocity changes, making the flow values more accurate during backwater conditions.

Results

The range of sampled water quality parameters are reported in Table 1 and Table 2. State standards, comparable ecoregion ranges, or means are recorded for comparison purposes. Individual TSS and E. coli samples are plotted in figures 6 and 7 respectively. The site was visited, and samples were collected 27 times during the 2022 monitoring season, three of which were event-based samples.

Table 1. *In situ* water quality measurements for Eagle Creek taken by YSI EXO 1 multi-probe mini sonde during 2022 sampling.

Parameter	Min	Median	Avg	Max	N	Notes
Temp (deg C)	5.24	11.03	10.40	14.38	27	
DO (mg/L)	7.62	8.56	8.55	9.72	27	Standard = > 7 mg/L
pH	7.13	7.53	7.50	7.76	27	Standard = 6.5-8.5
Conductivity (umho/cm)	671.2	683.4	682.8	688.3	27	Freshwater system range = 200-1000 µS/cm

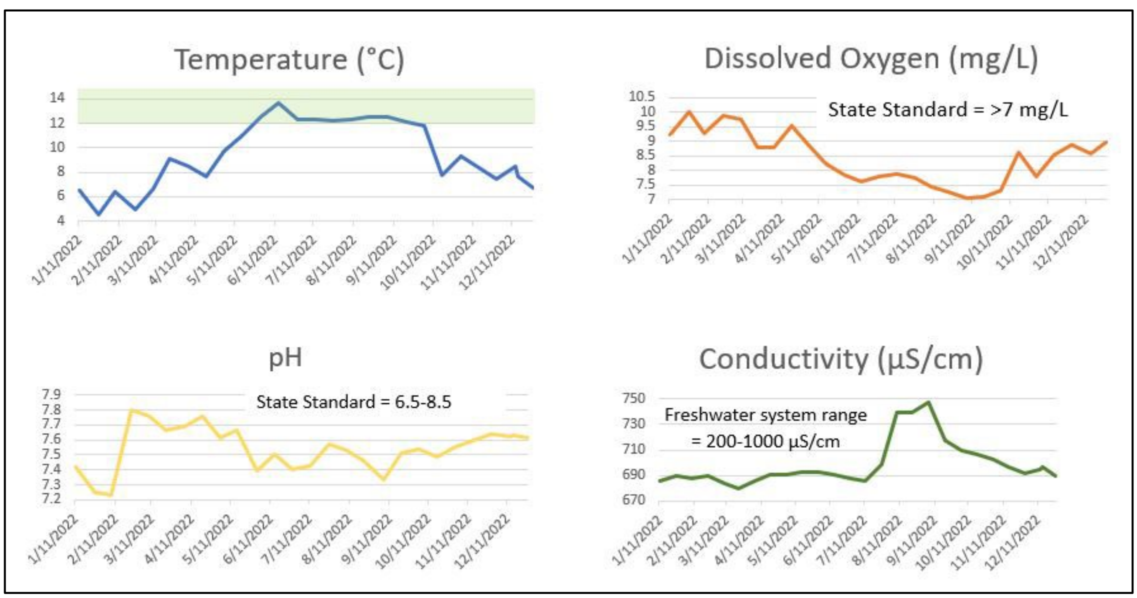

Figure 5. Time series graphs of in-situ water parameters for Eagle Creek collected with the YSI EXO1 sonde during site visits in 2022.

Table 2. 2022 Water quality preliminary lab results for Eagle Creek. Red text indicates exceedance of the noted standard limit.

Parameter	Min	Median	Avg	Max	N	Notes
Alkalinity (mg/L_CaCO3)	263	270	270	276	2	No standard. 20-200 mg/L typical
Ammonia (mg/L)	0.06	0.07	0.07	0.12	31	
Chloride (mg/L)	47.7	57	58.7	73.4	31	Standard = 230 mg/L
E. Coli (#/100ml)	11	130.5	259.7	1414	28	Standard = 126 CFU/100ml as geometric mean
Nitrate + Nitrite (mg/L)	0.2	0.2	0.21	0.31	31	Ecoregion mean = 0.04-0.26 mg/L
Ortho Phosphate (mg/L)	0.01	0.01	0.01	0.03	28	
Sulfate (mg/L)	13.3	14.8	14.8	16.3	2	
Suspended Solids (mg/L)	3	6	10.1	42	31	Ecoregion mean = 4.8-16 mg/L Standard = 10 mg/L
Total Kjeldahl Nitrogen (mg/L)	0.16	0.27	0.31	0.71	31	
Total Organic Carbon (mg/L)	2.2	2.25	2.25	2.3	2	
Total Phosphorus filtered (mg/L)	0.02	0.02	0.02	0.04	31	Ecoregion mean = 0.06-0.15 mg/L EPA recommends < 0.1 mg/L
Total Phosphorus unfiltered (mg/L)	0.02	0.04	0.05	0.18	31	Ecoregion mean = 0.06-0.15 mg/L EPA recommends < 0.1 mg/L
Volatile Suspended Solids (mg/L)	3	3	4.16	14	31	

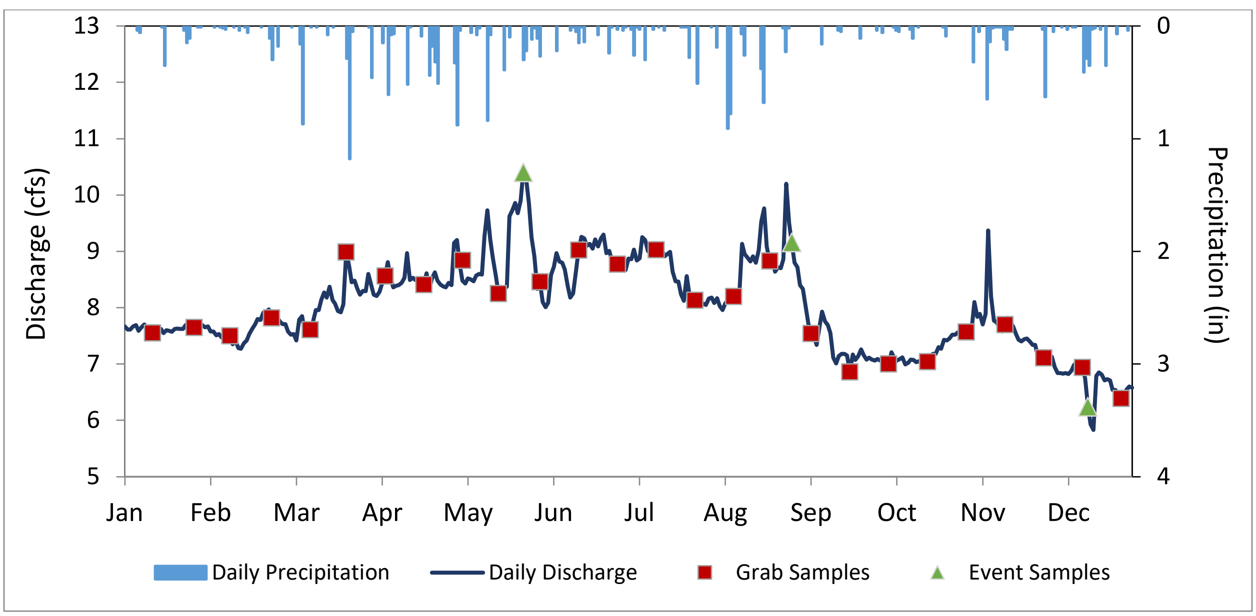

Figure 6. 2022 Eagle Creek WOMP discharge, precipitation, and samples collected. Discharge data is provided by METC. Precipitation data obtained from the NOAA Jordan 1SSW site.

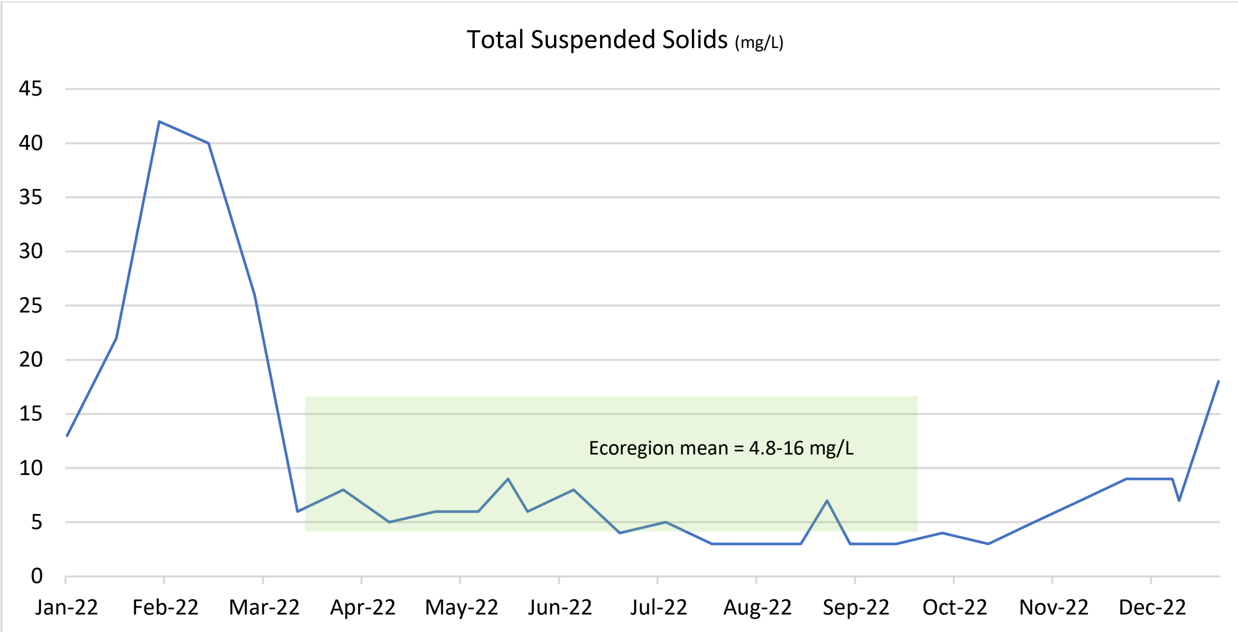

Figure 7. Total Suspended Solids (2022). State Standard for Class 2A Waters = 10 mg/L (indicated by the red line and the shaded areas in the graph) with no more than 10% exceedance between 1 April and 30 September.

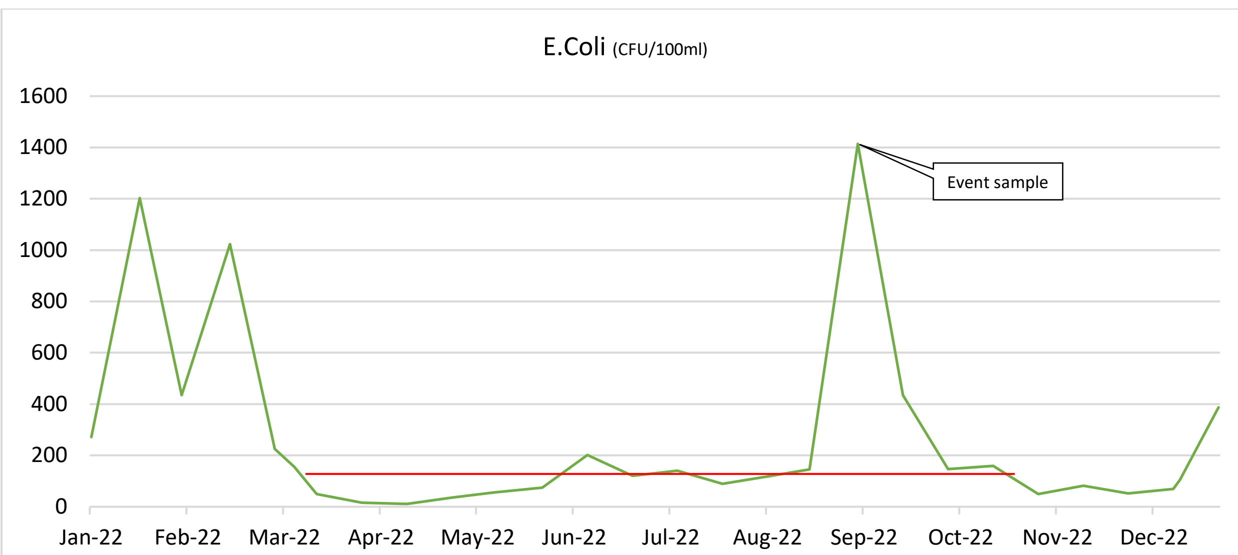

Figure 8. *E. coli* samples (2022). *E. coli* state standard for class 2A waters is not to exceed 126 organisms/100 ml (indicated by the red line) as a geometric mean of not less than 5 samples representative of conditions within any calendar month. Nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 ml. The standard applies only between April 1 and October 31.

Discussion

In general, the monitoring data suggests that Eagle Creek consistently meets state water quality standards and ecoregion means, with the exceptions being E. coli bacteria and total suspended solids (TSS) (Figure 6, Figure 7, and Table 3).

The E. coli standard is applicable from April 1 – October 31 and is exceeded when greater than 10% of the samples exceed 1260 Colony Forming Units (CFU's) per 100 ml or the geometric mean of no fewer than five samples in a calendar month exceed 126 CFU's. One sample exceeded 1260 CFU's from April through October in 2022. Additionally, 7 out of 15 samples exceeded the 126 CFU threshold from April through October.

The elevated levels of E. coli bacteria and suspended solids in winter are a result of the creek being spring fed and not freezing over in the winter. The open water attracts a large number of waterfowl and other animals, which results in historically higher bacteria, sediment, and turbidity levels than observed in summer months. Elevated levels during the summer are a result of continual animal use and runoff from significant rain events.

The TSS standard for Class 2A waters state that no more than 10% of samples shall exceed 10 mg/L between April 1 and September 30. Throughout 2022, TSS samples from Eagle Creek exceeded 10 mg/L in 6 of 29 (21%) lab samples, which is down 21% from 2021 (Figure 6). However, no samples collected from April thru September exceeded the state standard. The six samples that exceeded the 10 mg/L were during the winter months when waterfowl is constantly seen using the creek.

The watershed area experienced an extreme drought, as classified by the US Drought Monitoring Network, throughout the latter part of the growing season (USDM, n.d.). The lack of precipitation reduced watershed runoff and flows in the creek, resulting in less disturbance of the creek channel and fewer suspended solids.

III. Dean Lake Inlet Monitoring

Dean Lake Inlet was on the Minnesota Pollution Control Agency (MPCA) 303 (d) list of impaired waters from 2006-2016. It was impaired for aquatic recreation due to excess nutrients causing eutrophication. In 2016 the lake was re-assessed and reclassified as a wetland in the MPCA's Lower Minnesota River Watershed Monitoring and Assessment Report dated June 2017. Although reclassification removed the body of water from the 303 (d) list, Scott SWCD continues to conduct monitoring at the inlet to document nutrient loading. The monitoring site is located where CR21 passes over the Prior Lake Outlet Channel to the southeast of Dean Lake. The Scott SWCD monitors water chemistry and continuous stage and flow at this location. This site has been monitored since 2014.

Methods

In-stream field measurements of dissolved oxygen, temperature, turbidity, pH, and conductivity were taken using an YSI EXO 1 multiparameter Sonde. Field transparency is measured with a 1-meter secchi tube. Bi-weekly scheduled samples and additional event grab samples after rain events were taken while the stream channel is open (March-November). In 2022, 16 base grab samples and 2 event grab samples were collected totaling 18 samples. In addition to water quality samples, periodic flow measurements are typically taken throughout the monitoring season. No flow measurements were taken in 2022 due to the over-abundance of invasive aquatic vegetation near the flow monitoring location and the lack of flow from drought conditions. With flow measurements from previous years a discharge rating curve is developed for the site. This rating curve is applied to the continuous 15-minute stage measurements collected by Campbell Scientific SR50 Ultrasonic Distance Sensor and CR1000 data logger to calculate continuous discharge data at the site (Figure 8).

Results

During the 2022 sampling season, samples were collected eighteen (18) times, two of which were event-based samples. The 2022 monitoring data suggest that the inlet to Dean Lake continues to fall outside of ecoregion mean and EPA recommendations for phosphorus, nitrate, and suspended solids (Table 4). Historically, the inlet has seen spikes in nitrate and phosphorus.

Dean Lake Inlet's total unfiltered phosphorus exceeded the EPA's recommended level in six out of 18 samples. This is a 1% increase compared to 2021. Nitrate levels exceeded the Ecoregion high five out of 18 samples, which is a 25% decrease from 2021. Total suspended solids went above the Ecoregion high in two samples. One sample showed values above the state standard of 30mg/L.

Finally, a total of four out of 18 dissolved oxygen measurements fell below 5 mg/L (acceptable limits for most aquatic life) (Table 3). Low dissolved oxygen levels were also observed in 2021 when eight measurements fell below the threshold and in 2018 when two measurements fell below the threshold.

Table 3. 2022 *In situ* water quality measurements taken by a YSI EXO1 multi-probe mini sonde for Dean Lake Inlet. Red text indicates deviation from the state standard.

Parameter	Min	Median	Avg	Max	N	Notes
Temperature (deg C)	2.28	17.53	15.31	23.03	18	Ecoregion mean = 2-21
Dissolved Oxygen (mg/L)	2.22	5.42	6.59	12.55	18	Standard = >5 mg/L
pH	7.02	7.62	7.56	8.07	18	Ecoregion mean = 7.9-8.3
Conductivity (umho/cm)	570.8	683.40	692.73	869	18	Freshwater system range = 200-1000
Transparency Tube (cm)	48	77	77.89	100	18	

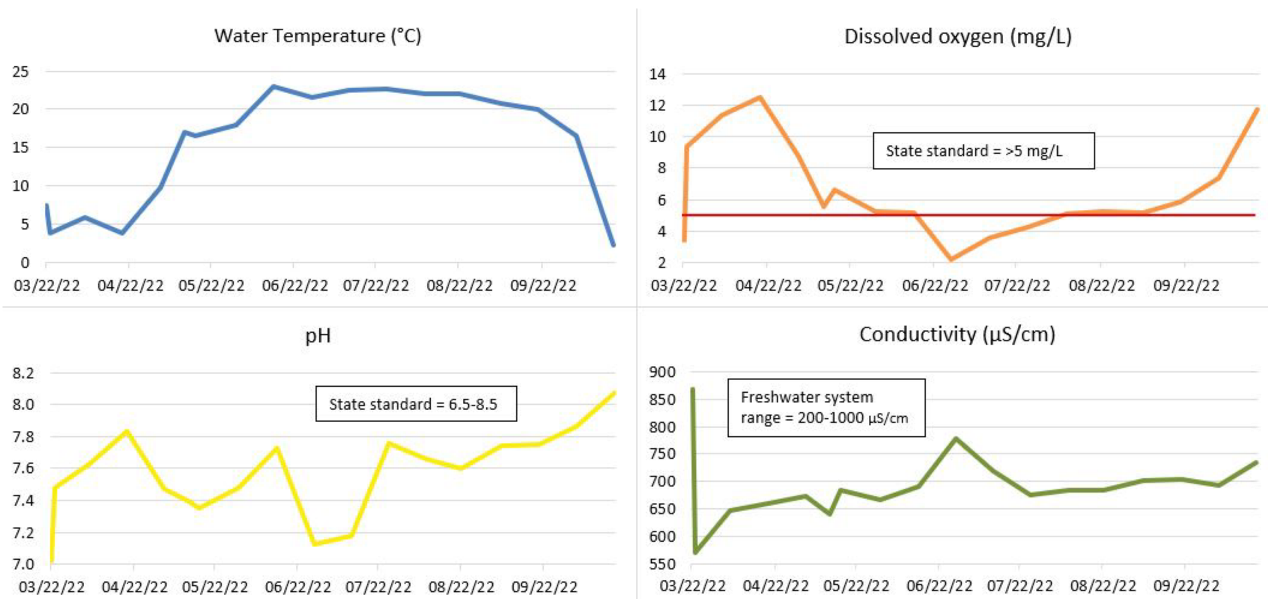

Figure 9. Time series graphs of in-situ water parameters collected at Dean Lake Inlet with the YSI EXO1 sonde during site visits in 2022.

Table 4. 2022 water quality data from Dean Lake Inlet. Red text indicates exceedance of the state standard, North Central Hardwood Forest ecoregion means, or EPA recommendations.

Parameter	Min	25th %	Median	Avg	75th%	Max	N	Notes
Chloride (mg/L)	54.1	56.75	62.20	66.17	72.80	89.80	18	Standard = 230 mg/L
Nitrate (mg/L)	0.20	0.20	0.20	0.33	0.37	1.13	18	Ecoregion mean = 0.04-0.26 mg/L
Nitrite (mg/L)	0.06	0.06	0.06	0.06	0.06	0.06	18	Ecoregion mean = 0.04-0.26 mg/L
TKN (mg/L)	0.34	0.49	0.89	0.86	1.13	1.40	18	
Total P (NUT) (mg/L)	0.03	0.05	0.09	0.09	0.12	0.19	18	Ecoregion mean = 0.06-0.15 mg/L EPA recommends < 0.1 mg/L
Total P (mg/L)	0.02	0.02	0.03	0.03	0.05	0.06	18	Ecoregion mean = 0.06-0.15 mg/L EPA recommends < 0.1 mg/L
TSS (mg/L)	3.00	4.00	6.00	9.78	13.25	50.00	18	Ecoregion mean = 4.8-16 mg/L Standard = 30 mg/L
VSS (mg/L)	3.00	3.00	3.50	4.67	5.25	15.00	18	

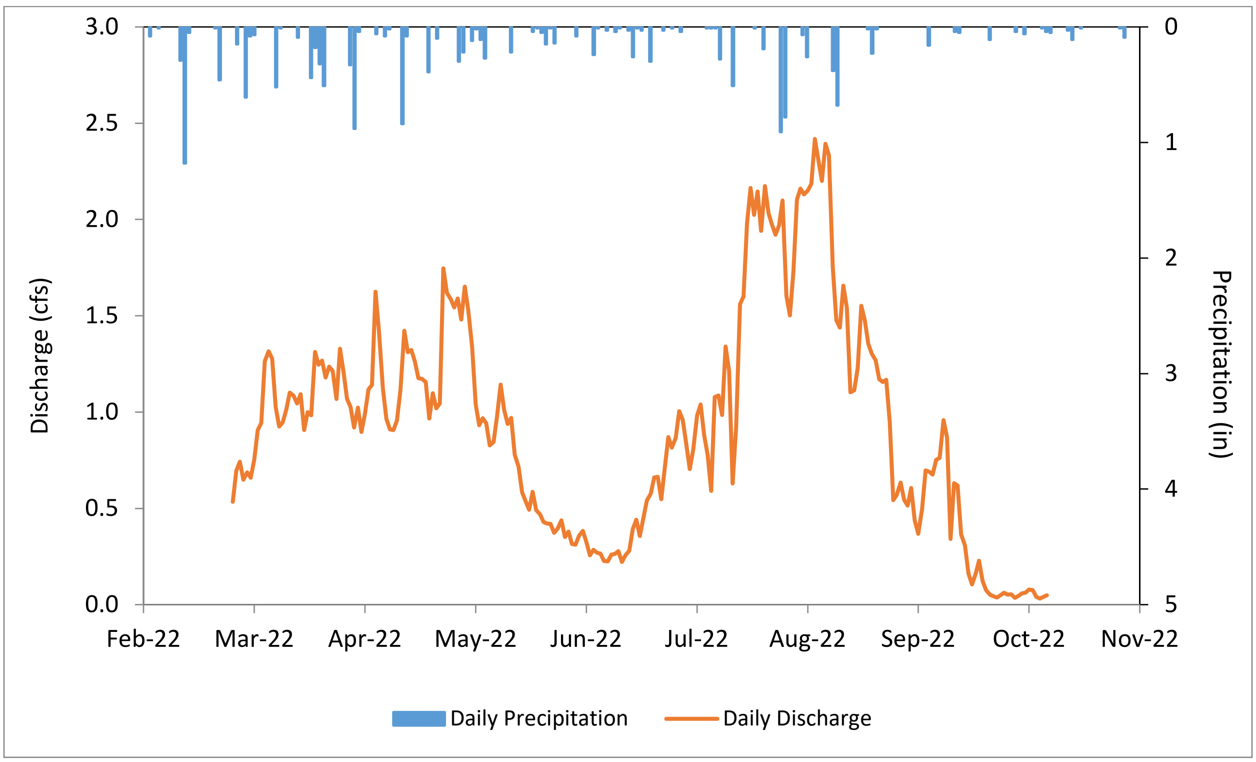

Figure 10. Dean Lake Inlet continuous 15min discharge data in 2022. Discharge data is provided by CR1000 data logger. Precipitation data obtained from the NOAA Jordan 1SSW site.

Discussion

The discharge at the Inlet mostly trended with precipitation and atmospheric trends. Due to the dry season, no water flowed from the Prior Lake Outlet Channel into Dean Lake in 2022. Even though Dean Lake is now considered a wetland, it is still beneficial to compare annual water quality results to its previous standards to track any water quality improvements or degradations at the site. Minnesota still requires that the quality of wetlands be maintained even if it does not follow previously identified lake standards. The majority of measured water quality parameters at the Dean Lake Inlet are within the recommended standards and ecoregion averages. With all exceeding measured parameters, most occur after precipitation events, droughts, or due to seasonal influences. In the observed instances of low dissolved oxygen readings, the most likely cause includes high algal growth combined with low water level exacerbated by the 2022 drought. Monitoring these levels should continue to track any potential increases or decreases in these levels in order to take proactive measures to avoid negative impacts to wildlife.

Throughout the monitoring years, general trends can be observed in several of the parameters monitored. For example, chloride concentrations appear to track diurnally with annual precipitation totals, and total concentrations have been increasing throughout the years. In general nitrate levels also follow this pattern. Phosphorus levels have been more inconsistent with increased concentrations observed in the routine samples throughout the years and a decrease in event-based samples. The turbidity and total suspended solids are typically driven by precipitation amounts and event frequency which can be observed throughout the monitoring years. Although Dean Lake Inlet is no longer on the 303 (d) list because of its reclassification, it is important to track the amount of nutrients at the site to maintain historical data and track nutrient/pollutant loading downstream.

IV. Well Monitoring

In 2005 the LMRWD contracted with Scott SWCD to collect groundwater measurements from 13 wells in the Savage Fen, and four wells in the Eagle Creek area. Additionally, two artesian wells are located in the Fens and are a part of the MNDNR's observation well (OBWELL) program. Well recording data is used to assess groundwater resources, determine long-term trends, and interpret the impacts of pumping and climate. The Savage Fen wells were installed by the MNDNR to monitor development effects that water usage from the City of Savage had on the water level in the Fen. All well data is entered into the DNR's groundwater level database.

The Savage Fen is a rare wetland complex at the base of the north-facing bluffs in the Minnesota River Valley--the largest calcareous fen of its kind in Minnesota. Calcareous fens host plant communities of wet, seepage sites with an internal flow of groundwater rich in calcium, magnesium bicarbonates and sulfates. This results in a thick peat base that supports a unique diversity of plants. More than 200 various plant species have been found in the Savage Fen, some of which are rare.

Methods

The Scott SWCD is contracted to monitor 13 wells in the Savage Fen monthly between March and October. Additional well levels were recorded into December at three of the wells from outside agencies as part of their requirements for adjacent construction/maintenance projects near the Fens. The Fen's water levels fluctuate throughout the year and the artesian wells record water levels above ground level. Field measurements of the artesian wells record values in pounds per square inch (psi). The psi measurements are converted to feet of head by multiplying the psi value by -2.31, which represents how high the water would shoot up in the air if the well was not capped. The eleven "normal" and two artesian wells are reported in this annual report.

In the past, the SWCD monitored two additional wells in the Savage Bluff area and four wells monitored in the Eagle Creek portion of Savage Fen on the other side of highway 13. The Bluff wells were sealed during the 2019 season and are no longer accessible, but well measurements can be found in annual monitoring reports up to 2019. The four wells on the other side of highway 13 were sealed in August of 2022 due to disrepair. Well measurements for that site can be found up until August in this report, and complete measurements can be found in annual monitoring reports up to 2021. The MNDNR continually assesses the validity and necessity of monitoring wells around the state and is currently investigating the need for several Savage Fen wells.

There are two MNDNR observation wells (70024 & 70025) that are roughly 300ft southwest of the bluff wells that will continue to monitor groundwater levels in that area but will not be analyzed in this report.

In total, the SWCD recorded 136 water level measurements for the LMRWD in 2022 from the 17 wells.

Results

The Savage Fen water levels showed a consistent drop in water levels throughout the 2022 summer and started to rebound at the end of the monitoring season (Figure 11). Overall, the average water levels for the non-artesian wells decreased 0.17 feet throughout 2022, with some wells dropping more than others. Historically, the Fens have shown signs of fluctuation, and have generally been slightly increasing in water levels to recover from a dip in 2012. Recently with warmer temperatures and less precipitation over the growing season, water levels are once again declining (Figure A1). In 2022, a slight majority of six of the Savage Fen wells showed a decrease in water levels when compared with 2021, and all eleven wells decreased over the 10-year average (Figure 11, Figure 12).

All figures in this section are reported in depth to water (DTW) which is a product of the wells measuring point elevation minus the elevation of the recorded observed elevation, or feet above ground for the artesian wells.

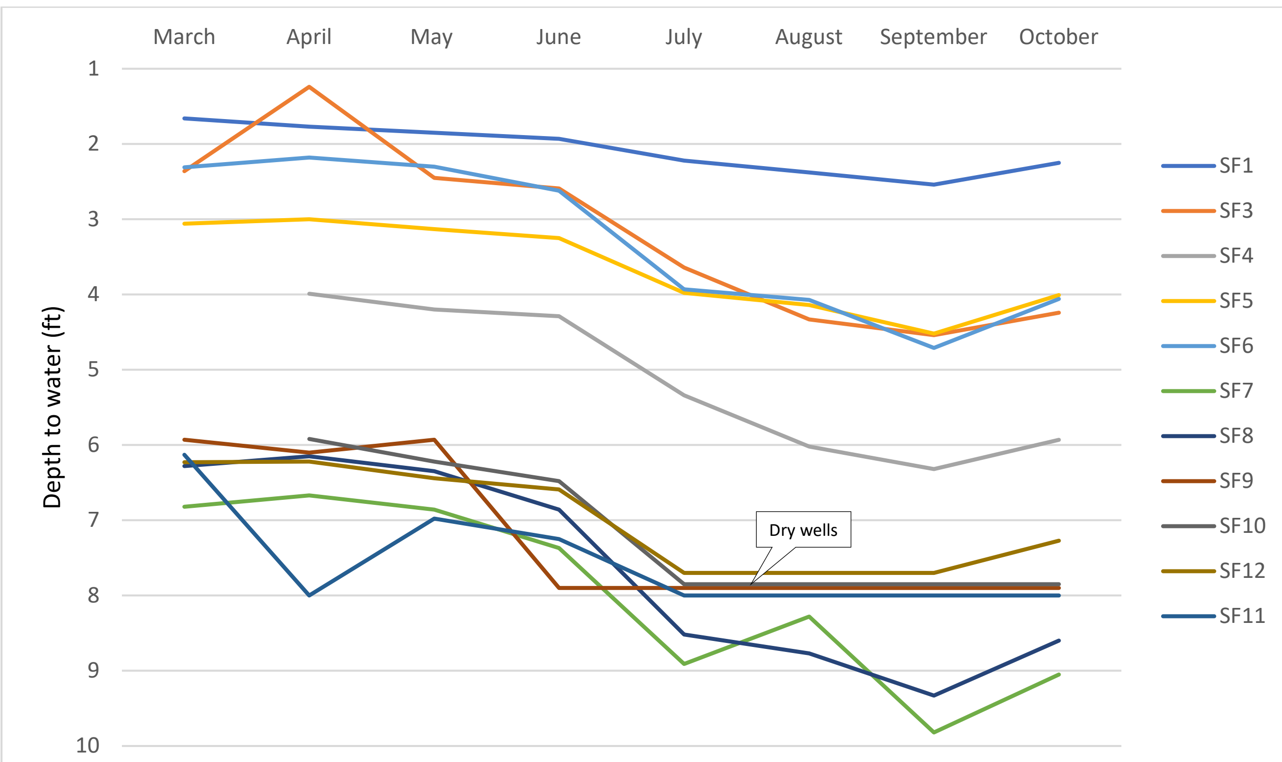

Figure 11. Savage Fen Wells (2022). Straight lines indicate dry hold readings.

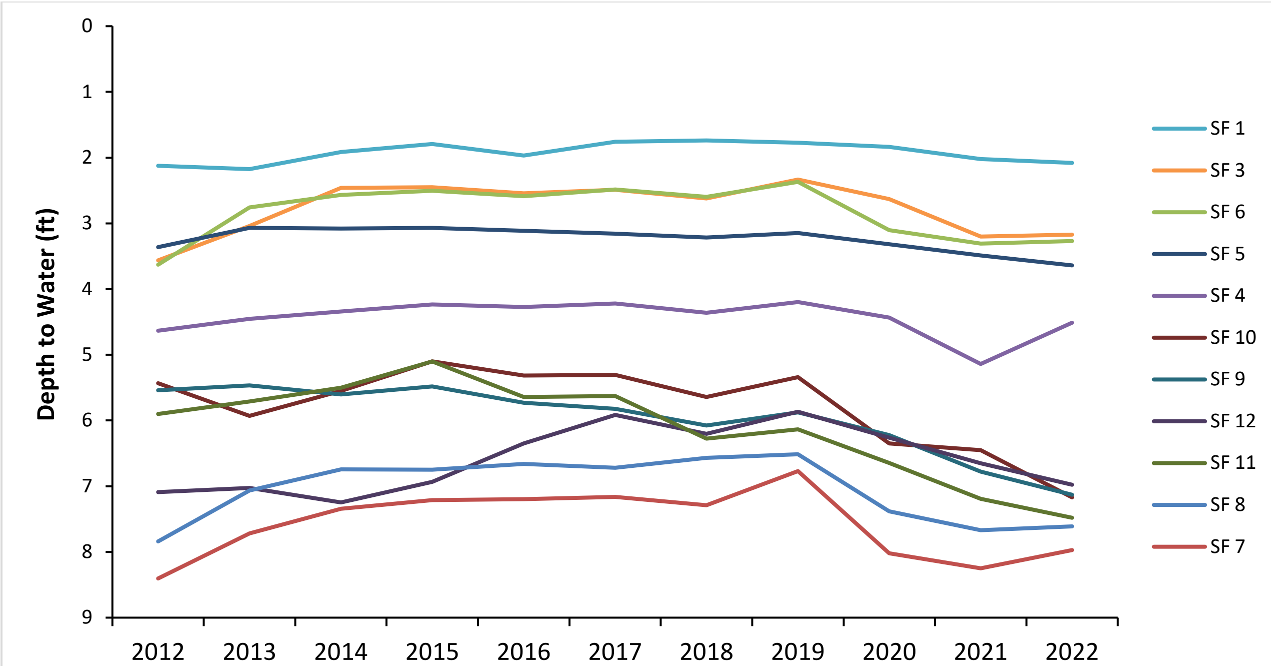

Figure 12. Average annual water level in Savage Fen wells (2012-2022). Averages include all observations in a calendar year.

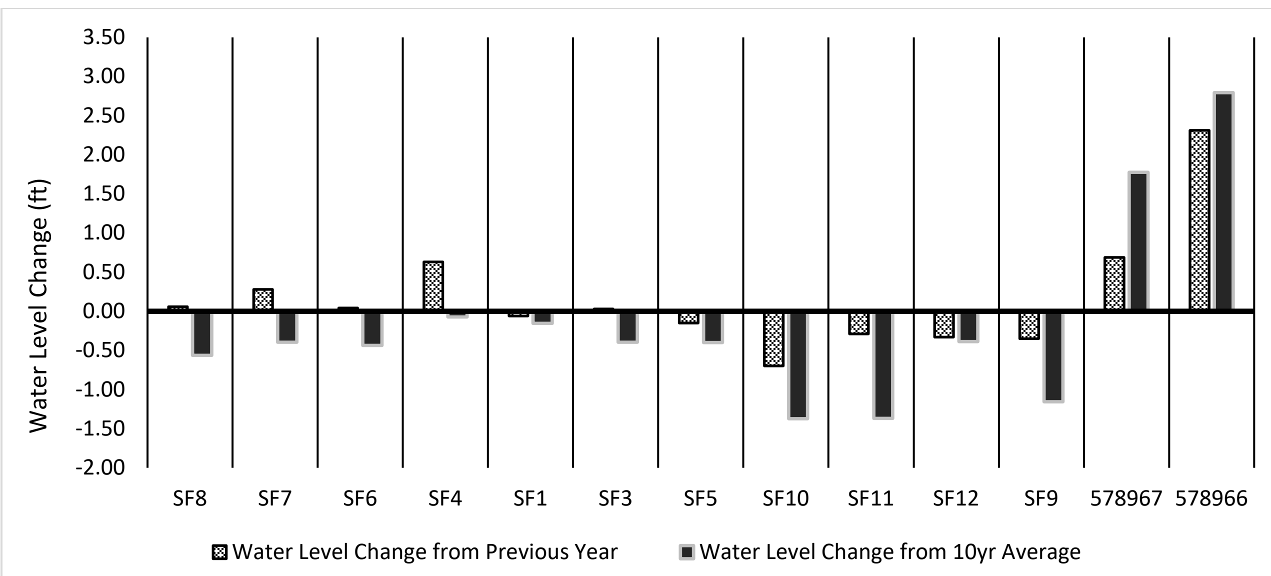

Figure 13. The water level changes at each Savage Fen well when compared with the previous year and the 10yr average depth to water. Average 2022 depth to water levels were used to compare with average 2021 values and 10yr historical average.

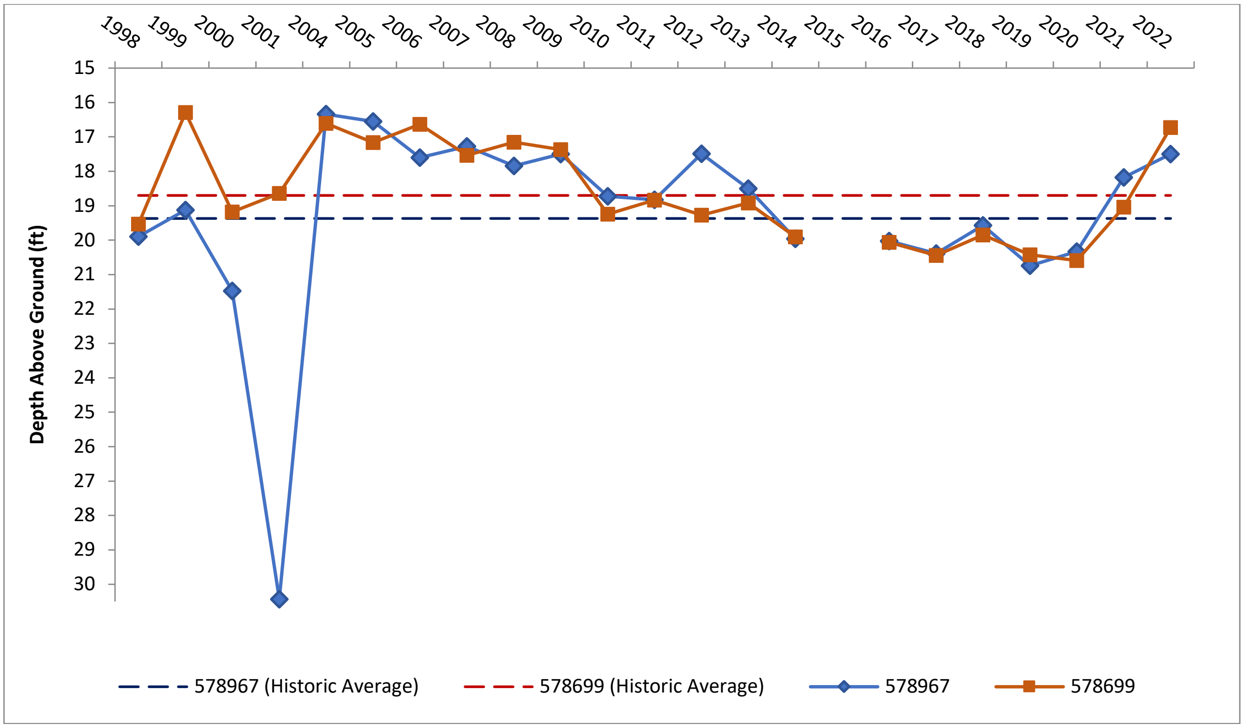

Figure 14. Average annual water level for the Savage Fen artesian wells (1998-2022). Averages include all observation in a calendar year. Historic averages are an average of all years sampled. Values are represented in feet above ground.

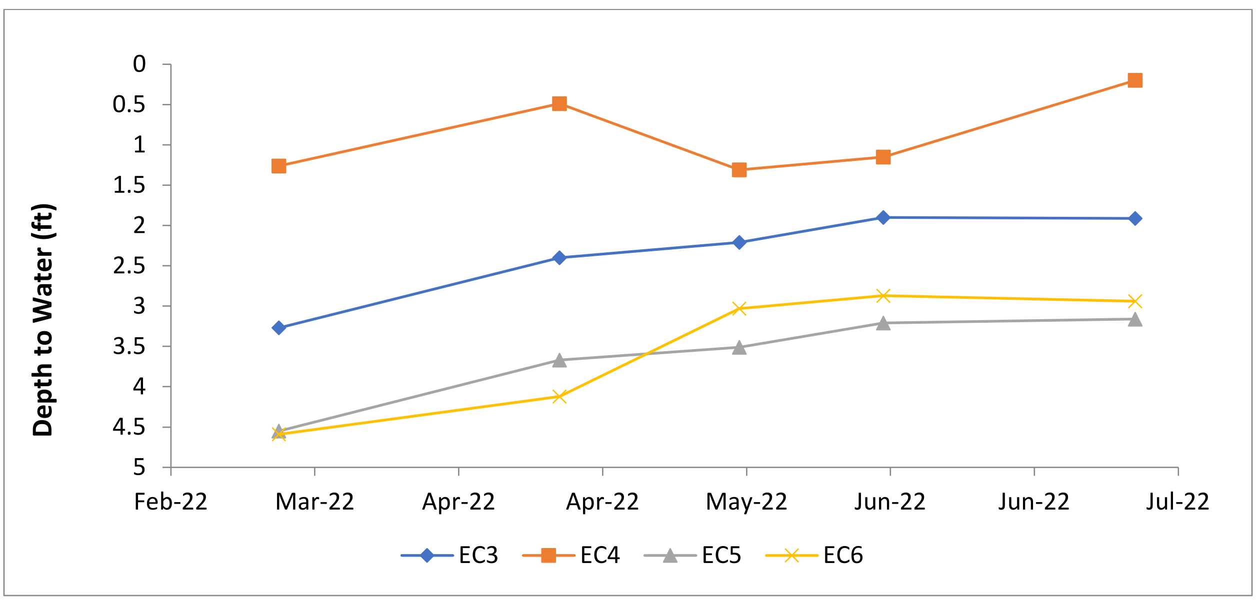

Figure 15. Eagle Creek groundwater wells (2022). Values are represented in feet above the ground.

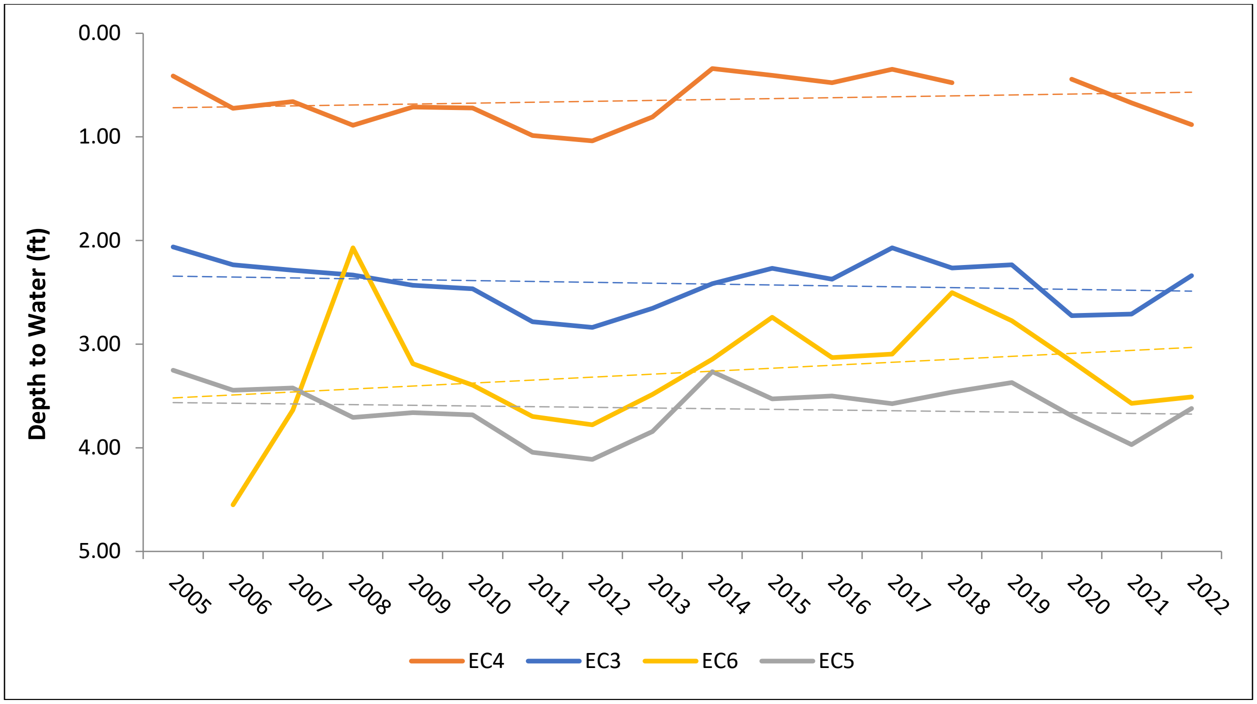

Figure 17. Average annual water level for the Eagle Creek groundwater wells (2005-2022). Averages include all observation in a calendar year. Historic averages are an average of all years sampled.

Discussion

Similar to previous years, the monitoring season in 2022 was seasonably dry which led to a continued decrease in water levels in all of the monitored wells (Figure 11). Total precipitation values increased near the end of the monitoring season, allowing wells to recharge slightly prior to the winter freeze. Although lower seasonal precipitation values can show a change in surface wells, decreased groundwater levels can amplify lower levels observed in wells. A continual annual increase in the wells from 2012 allowed for the drop in 2021 and 2022 without having significant implications to historical groundwater levels (Figure 12, Figure 13). While the majority of wells continued to decrease in groundwater levels from 2021 to 2022, five out of the eleven total wells increased their levels during the monitoring period when compared to the previous year.

There are many factors that can impact groundwater levels in northern Scott County. Seasonally, the amount of snowpack and precipitation throughout the year will determine recharge levels and rates. Other factors such as groundwater withdrawals for public supply and other consumptive uses and surface water redirection can also impact groundwater levels. Continued monitoring of groundwater levels in both shallow and deep wells in the LMRWD area will help inform water managers about whether current trends continue and whether conditions remain sufficient for supporting the unique characteristics and rare plant communities of the Savage Fen.

V. References

Bell, John M. 2006. The Assessment of Thermal Impact on Habitat Selection, Growth, Reproduction, and Mortality in Brown Trout (*Salmo trutta*): A Review of the Literature.

Hintz, W. D. & R. A. Relyea. 2017. Impacts of Road Deicing Salts on the Early-life Growth and Development of a Stream Salmonid: Salt type matters. Environmental Pollution. 223: 409-415.

SEWRPC Community Assistance Planning Report No. 316. 2013. Acute Toxicity of Sodium Chloride to Freshwater Aquatic Organisms. Appendix E: 1-14.

Minnesota Pollution Control Agency (MPCA). EDA: Guide to Typical Minnesota Water Quality Conditions. https://www.pca.state.mn.us/quick-links/eda-guide-typical-minnesota-water-quality-conditions

Minnesota Pollution Control Agency (MPCA). Minnesota's Impaired Waters List. https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list

Minnesota Pollution Control Agency (MPCA). Salt and Water Quality. https://www.pca.state.mn.us/water/salt-and-water-quality. Visited 6/29/2018.

VI. Appendix

Table A1: *Monthly total precipitation values for 2022, along with a historical average, minimum and maximum for comparison.*

Month	2022 Precipitation Jordan* (inches)	Historical Record**		
		Average	Minimum	Maximum
March	3.09	1.72	0.34	4.26
April	3.3	2.95	0.42	7.51
May	3.53	4.48	1.08	11.08
June	0.99	5.1	1.14	12.3
July	1.48	3.97	0.87	8.48
August	3.54	5.14	1.11	10.86
September	0.4	2.83	0.21	6.88
October	0.39	2.66	0.52	5.83
Total	**16.72**	**28.85**	**5.69 (2000)**	**67.20 (2014)**

* Precipitation data obtained from the NOAA Jordan 1SSW site

** The historical record (normal) is from 1992-2022, NOAA Jordan 1SSW site. The lowest minimum value was recorded in 2000 and highest maximum was recorded in 2014.