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2023

Prepared for:

LOWER MINNESOTA RIVER
WATERSHED DISTRICT

By:

SCOTT SWCD

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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 2023 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 2023 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 12 observation wells located in the Savage Fen and surrounding area, and one water monitoring station on the Dean Lake Inlet (DLI) channel (Figure 1).

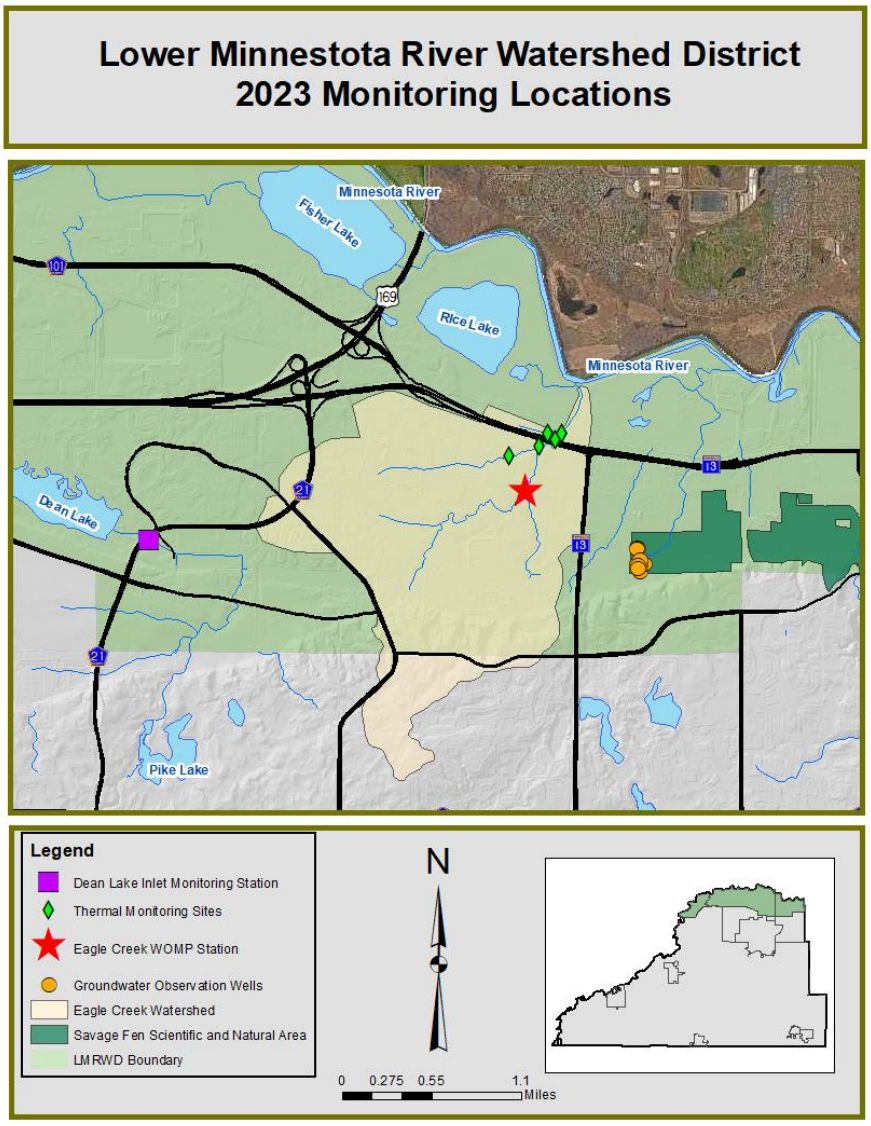

Figure 1. Monitoring locations located in the Scott County portion of the Lower Minnesota River Watershed District for the 2023 monitoring season.

I. **Thermal Monitoring**

This study was initiated by the LMRWD to monitor the impact that storm water runoff from Highway 101 has on stream 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 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, MCES 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 MCES monitoring equipment.

Results

Throughout the 2023 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 could influence the higher temperature fluctuation seen in that logger.

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, while also trending very closely with the midstream logger during the summer months. The downstream logger shows the opposite trend as it is the warmest in the summer and coolest in the winter (Figure 3). A separation in water temperatures is noticed after rain events, but this correlation was less drastic in 2023 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. During warm summer days, all three loggers recorded water temperatures that occasionally exceeded 17.6°C: the optimal range for trout. This includes 10 times in the downstream logger, 22 times in the midstream logger, and 21 times in the upstream logger (Figure 4). The number of days that the maximum temperature exceeds 17.6°C is historically highest at the downstream logger. The downstream logger likely would have recorded more high-temperature days in 2023, but the logger went offline likely due to either turbulent water damage or a dead battery from 6/9/23 - 9/18/23 when a new logger was replaced on site.

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 when compared with the three main channel loggers in 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.

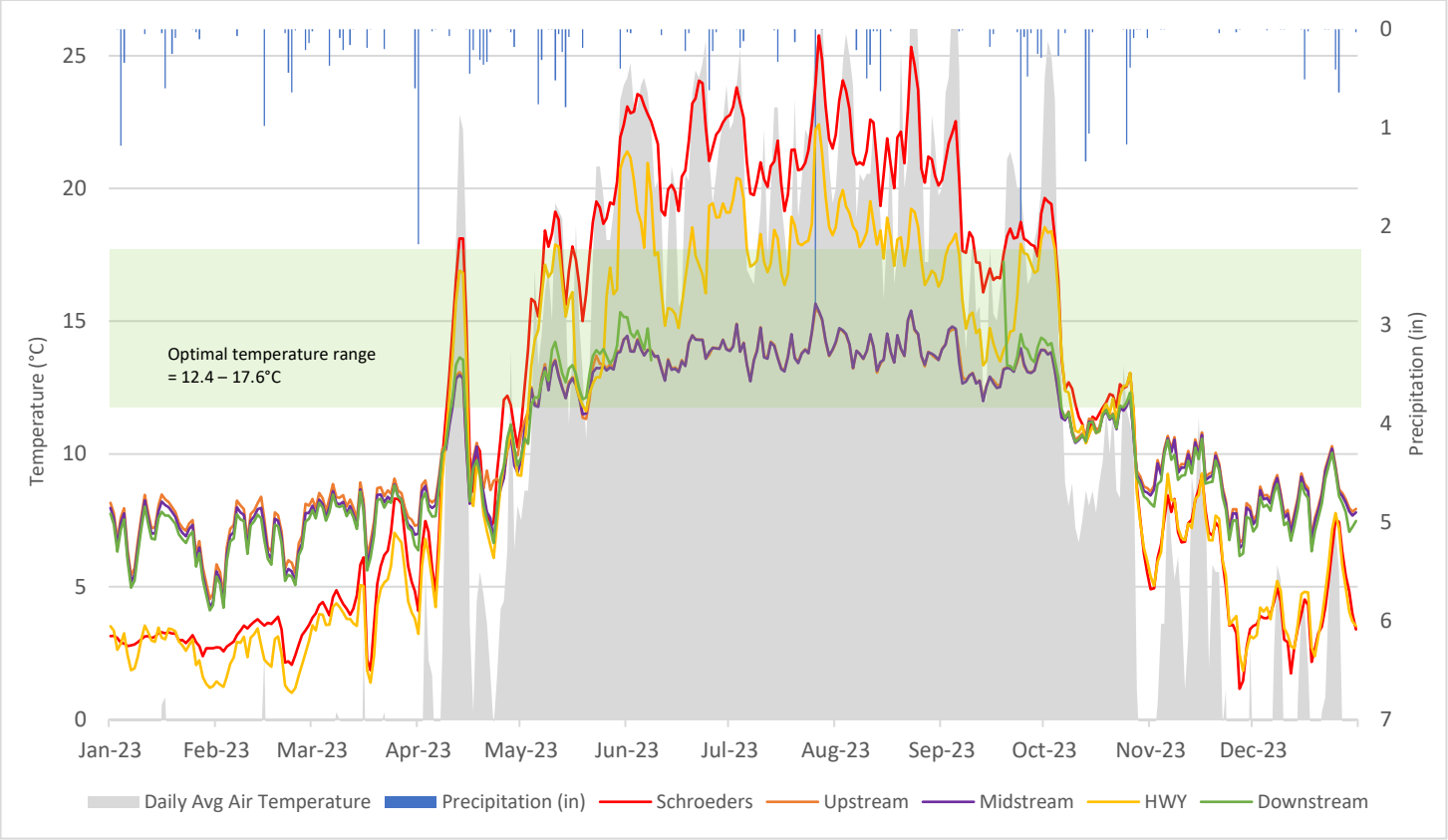

Figure 3. 2023 Average daily water temperatures in Eagle Creek compared with annual atmospheric temperature and annual precipitation.

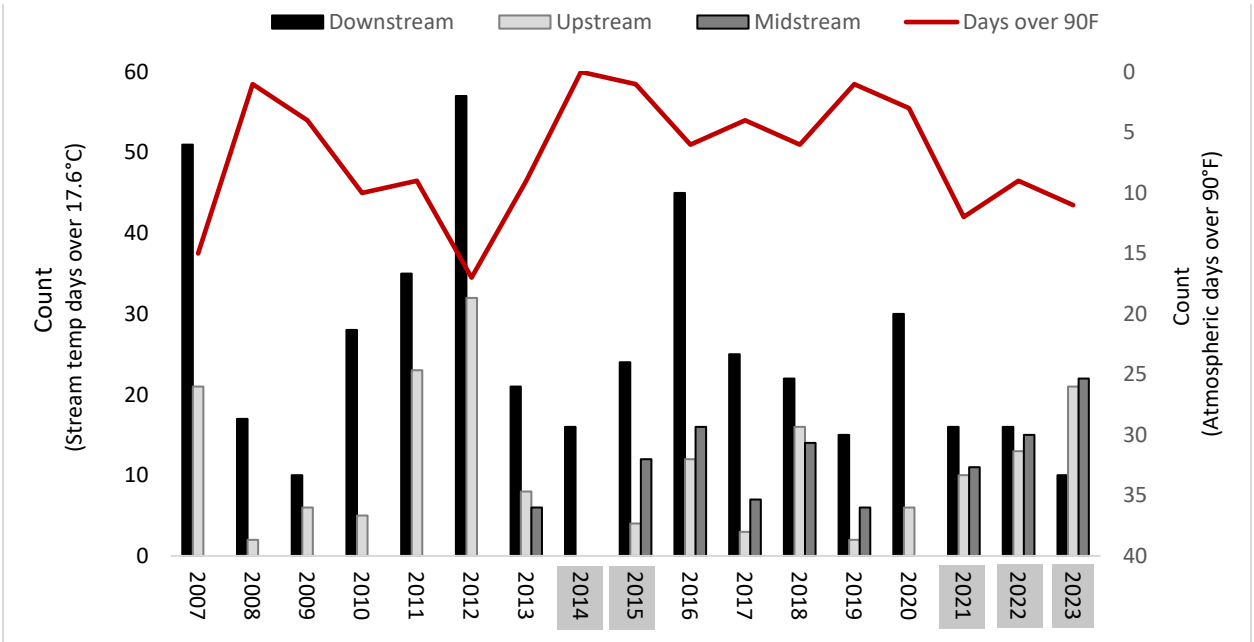

Figure 4. Total number of days maximum water temperature exceeded 17.6°C and air temperatures exceeded 90°F. Shaded years have some missing or incomplete data associated with one or more of the thermal loggers.

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 2023 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 Schroeder's Park logger recorded slightly higher temperatures—trending very closely with air temperatures—than the Hwy 101 logger, most significantly in the summer months. 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. 2023 saw long strings of hot weather days in the summer months, leading to higher recorded temperatures in Schroeder's Park and the Hwy 101 logger then seen in previous years.

Being a groundwater spring 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.

The MCES's addition of the continuous water temperature data at the Eagle Creek WOMP location provides valuable insight as to the potential impact of the Schroeder's 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 decades to prevent degradation of Eagle Creek, including diverting storm water from the stream, establishing a 200-foot natural vegetative buffer along each side of the bank, and installing a habitat improvement project along the creek's west branch. 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. 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 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 is designed and 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 Eagle Creek's 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 in 2023 using a YSI EXO 1 Multiparameter Sonde (Table 1). Many parameters are also recorded every 15 minutes at the Eagle Creek WOMP station including stage, velocity, conductivity, precipitation, and stream temperature (Table 2). Samples are collected and analyzed for multiple water quality parameters 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 transported directly from the stream 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.

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 or comparable ecoregion ranges are recorded for comparison purposes. Individual Total Suspended Solids (TSS) and Escherichia coli (E. coli) samples are plotted in Figures 7 and 8 respectively. Samples were collected 32 times (N) during the 2023 monitoring season, 7 of which were event-based samples.

Table 1. *In situ* water quality measurements for Eagle Creek during 2023 sampling.

Parameter	Min	Avg	Max	N	Notes
Temp (deg C)	5.67	10.22	13.41	32	Optimal Trout range = 12.4 – 17.6° Celsius
DO (mg/L)	7.19	8.28	9.59	32	Standard = > 7 mg/L
pH	7.42	7.65	7.78	32	Standard = 6.5-8.5
Conductivity (umho/cm)	683.4	712.6	746	32	Freshwater system range = 200-1000 µS/cm
T-Tube	47	89.9	100	32	

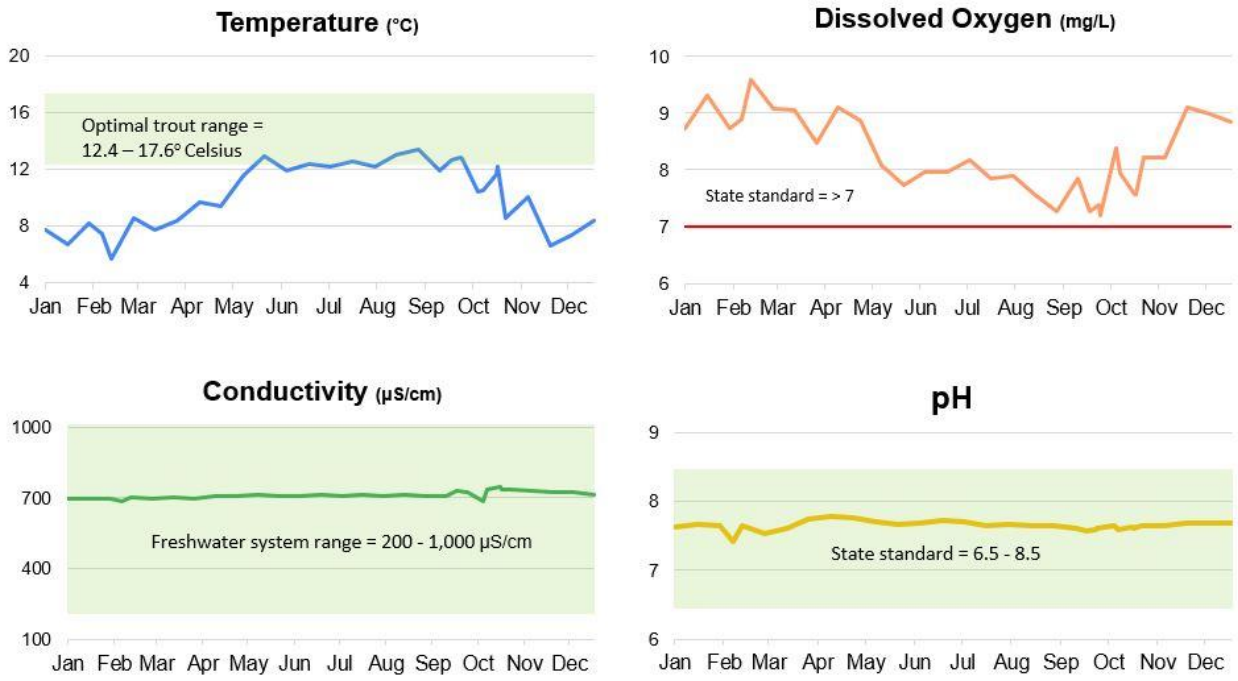

Figure 5. Time series graphs of *in-situ* water parameters for Eagle Creek during site visits in 2023.

Table 2. 2023 Water quality preliminary lab results for Eagle Creek. Red text indicates exceedance of the noted limits.

Parameter	Min	Avg	Max	N	Notes
Alkalinity (mg/L_CaCO3)	264	271.5	279	4	No standard. 20-200 mg/L typical
Ammonia (mg/L)	0.06	0.07	0.11	55	
Chloride (mg/L)	54.7	60.39	64.5	55	Standard = 230 mg/L
E. Coli (#/100ml)	24	681.4	12,200	31	Standard = 126 CFU/100ml as geometric mean
Nitrate + Nitrite (mg/L)	0.2	0.21	.38	55	Ecoregion mean = 0.04-0.26 mg/L
Ortho Phosphate (mg/L)	0.01	0.011	.038	47	
Kjeldahl Nitrogen (mg/L)	0.16	0.40	1	55	
Organic Carbon (mg/L)	1.8	1.93	2	4	
Phosphorus filtered (mg/L)	0.02	.044	0.05	54	
Phosphorus (mg/L)	0.02	0.07	0.18	54	Ecoregion mean = 0.06-0.15 mg/L EPA recommends < 0.1 mg/L
Suspended Solids (mg/L)	3	14	44	35	Ecoregion mean = 4.8-16 mg/L Standard = 10 mg/L
Volatile Suspended Solids (mg/L)	3	5.89	20	55	

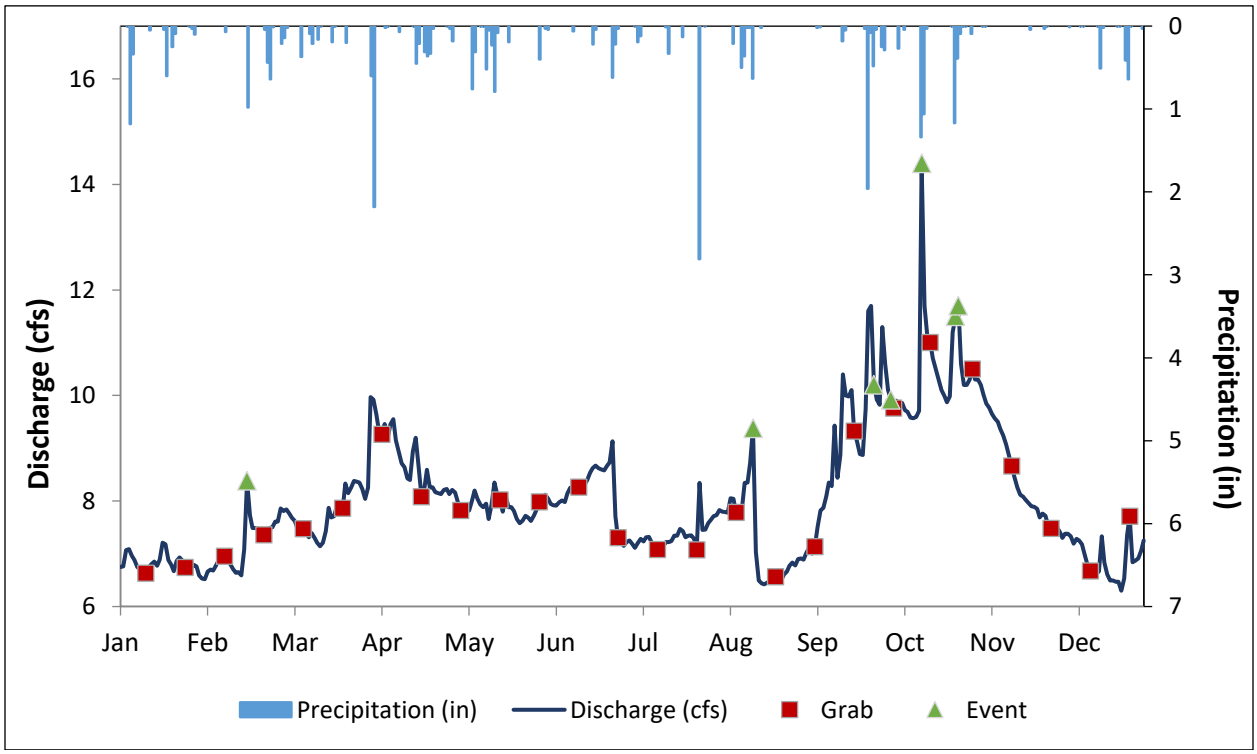

Figure 6. 2023 Eagle Creek WOMP discharge, precipitation, and samples collected. Discharge data is provided by MCES. Precipitation data obtained from the NOAA Jordan 1SSW site.

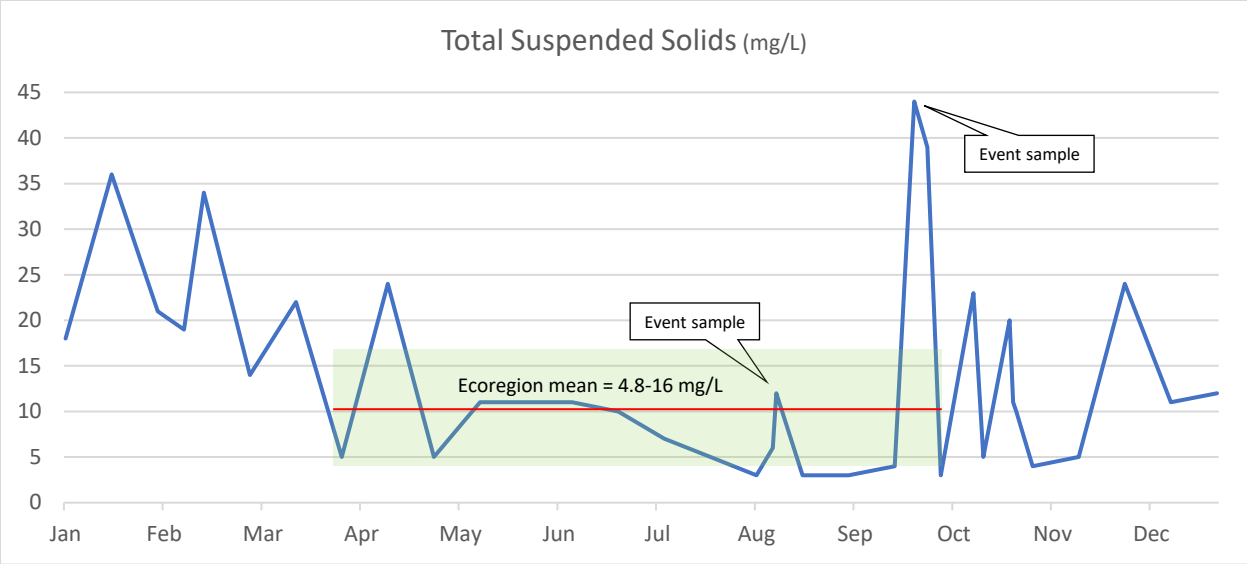

Figure 7. Total Suspended Solids (2023). State standard for Class 2A Waters = 10 mg/L (indicated by the red line and the shaded areas in the graph) require no more than 10% exceedance between 1 April and 30 September.

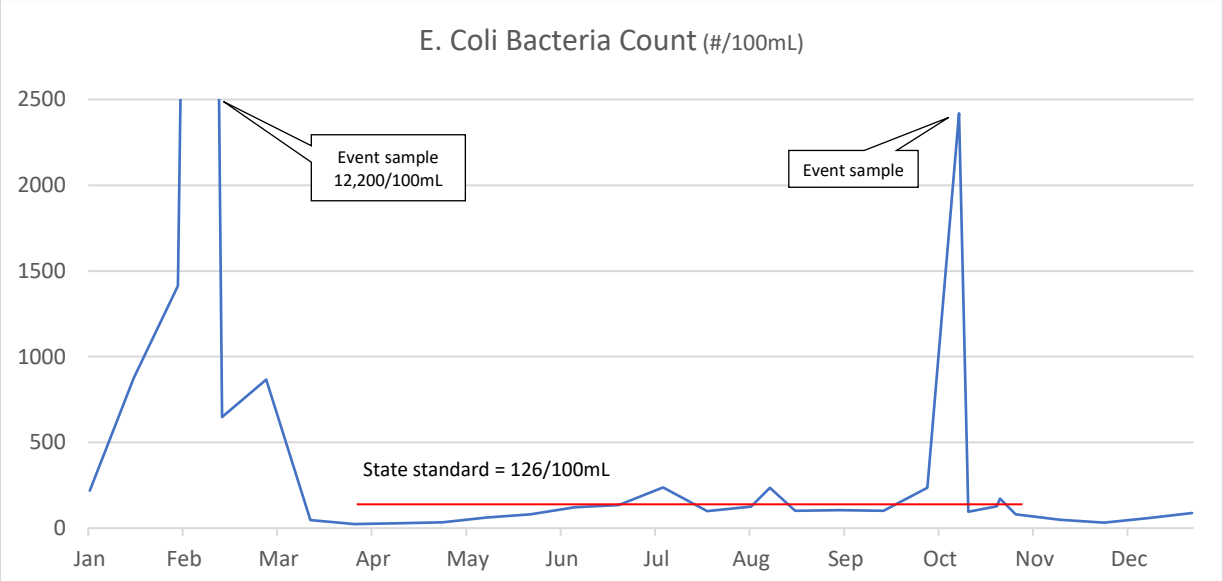

Figure 8. *E. coli* samples (2023). *E. coli* state standard for class 2A waters is not to exceed 126 organisms/100 ml (indicated by the red line) as a geometric mean of not less than 5 samples representative of conditions within any calendar month. Nor shall more than 10% of all samples taken during 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 2023 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 5, Figure 7, Figure 8, and Table 2).

The E. coli standard is applicable from April 1 – October 31 and is exceeded when greater than 10% of the samples exceed 1,260 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 2023. Additionally, 6 out of 20 samples exceeded the 126 CFU threshold from April through October, which is down 13% from 2022 (Figure 8).

Elevated levels of E. coli bacteria and suspended solids in winter are likely 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 may result in historically higher bacteria, sediment, and turbidity levels than observed in summer months. Elevated levels during the summer are likely 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 that time period in 2023, TSS samples from Eagle Creek exceeded 10 mg/L in 7 of 17 lab samples (Figure 7). In 2023, no samples within April-September exceeded the TSS standard. Recorded samples outside of the April-September timeframe that exceeded the 10 mg/L were during the winter months when waterfowl are constantly seen using the creek. There is also discussion ongoing with the Metropolitan Council theorizing that elevated TSS levels could be caused by localized erosion occurring underneath the bridge near the observation station. However, such observations are preliminary.

Figure 9. *Beaver activity pictured 40 ft. upstream of the Eagle Creek upstream thermal logger location.*

The increase of TSS could also be attributed to several other factors, including increased streamflow, and unexpected beaver activity throughout the monitoring season resulting in more disturbance of the creek channel and increased suspended solids (Figure 9). Regarding water level conditions, the beginning of the monitoring season trended with the end of the 2022 season with lower than average discharge, but due to a slight recharge in the latter half of the monitoring season, average daily discharge increased to slightly elevated levels when compared with 2022 (Figure 6). While drought conditions improved from 2022 to 2023, the watershed area still experienced a severe drought as classified by the US Drought Monitoring Network, throughout the latter part of the growing season (NIDIS, n.d.).

III. Dean Lake Inlet Monitoring

Dean Lake 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 County Road 21 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 was 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 was open (March-November). In addition to water quality samples, periodic flow measurements are typically taken throughout the monitoring season. One flow measurement was attempted after heavier rains on October 17, but due to sediment accumulation at the culvert, proper discharge readings were not possible. Using flow measurements from previous years a discharge rating curve was developed for the site. This rating curve was applied to the continuous 15-minute stage measurements collected by a Campbell Scientific SR50 Ultrasonic Distance Sensor and CR1000 data logger to calculate continuous discharge data at the site (Figure 11).

Results

During the 2023 sampling season, 20 routine grab samples (N) were collected, five of which were event-based. The 2023 monitoring data suggests that the inlet to Dean Lake continues to fall outside of ecoregion mean and EPA recommendations for nitrate, dissolved oxygen, pH, and water temperature (Table 3). Dean Lake Inlet's nitrate levels exceeded the ecoregion mean in six out of 19 samples, which is a 6% increase from 2022. No other lab-measured parameters recorded values higher than their respective state/EPA standards (Table 4). Notably, total unfiltered phosphorous levels, which have historically been high at DLI, showed a decrease in 2023, with no recorded samples exceeding the EPA recommendation of <0.1 mg/L.

Deviations from ecoregion means were observed in DLI's field measurements in 2023. A total of seven out of 20 dissolved oxygen measurements fell below 5 mg/L (acceptable limits for most aquatic life) (Table 3). Additionally, high air temperatures in July increased water temperatures to above ecoregion means in eight of 20 samples.

Discharge at DLI was low this year due to drought conditions, with values returning to historical normal for a brief period in later October after a series of heavy rain events. Gaps in discharge can be observed from 4/15 – 5/10 due to damage to the logger's sensor board and again from 9/13 – 9/24.

Table 3. 2023 *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	Avg	Max	N	Notes
Temperature (deg C)	4.0	17.0	25.2	20	Ecoregion mean = 2-21
Dissolved Oxygen (mg/L)	0.8	6.3	13.0	20	Standard = >5 mg/L
pH	7.4	7.7	7.9	20	Ecoregion mean = 6.5-8.5
Conductivity (umho/cm)	590	682	786	20	Freshwater system range = 200-1000
Transparency Tube (cm)	64	98	100	20	

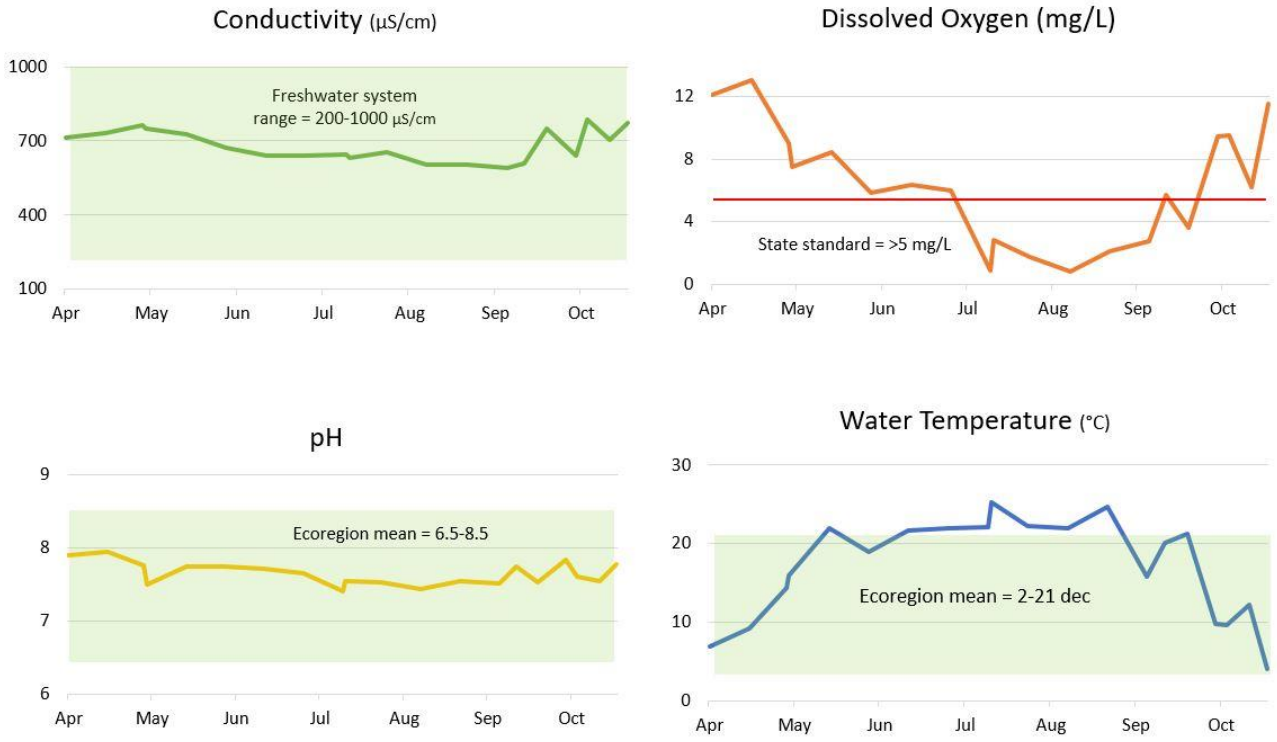

Figure 10. Time series graphs of in-situ water parameters collected at Dean Lake Inlet with the YSI EXO1 sonde during site visits in 2023.

Table 4. 2023 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	Avg	Max	N	Notes
Chloride (mg/L)	53	75	119	21	Standard = 230 mg/L
Nitrate (mg/L)	0.2	0.40	1.31	21	Ecoregion mean = 0.04-0.26 mg/L
TKN (mg/L)	0.34	0.60	1.10	21	
Total P (mg/L)	0.02	0.05	0.08	21	Ecoregion mean = 0.06-0.15 mg/L EPA recommends < 0.1 mg/L
TSS (mg/L)	3	5	9	8	Ecoregion mean = 4.8-16 mg/L Standard = 30 mg/L
VSS (mg/L)	2	3	5	8	

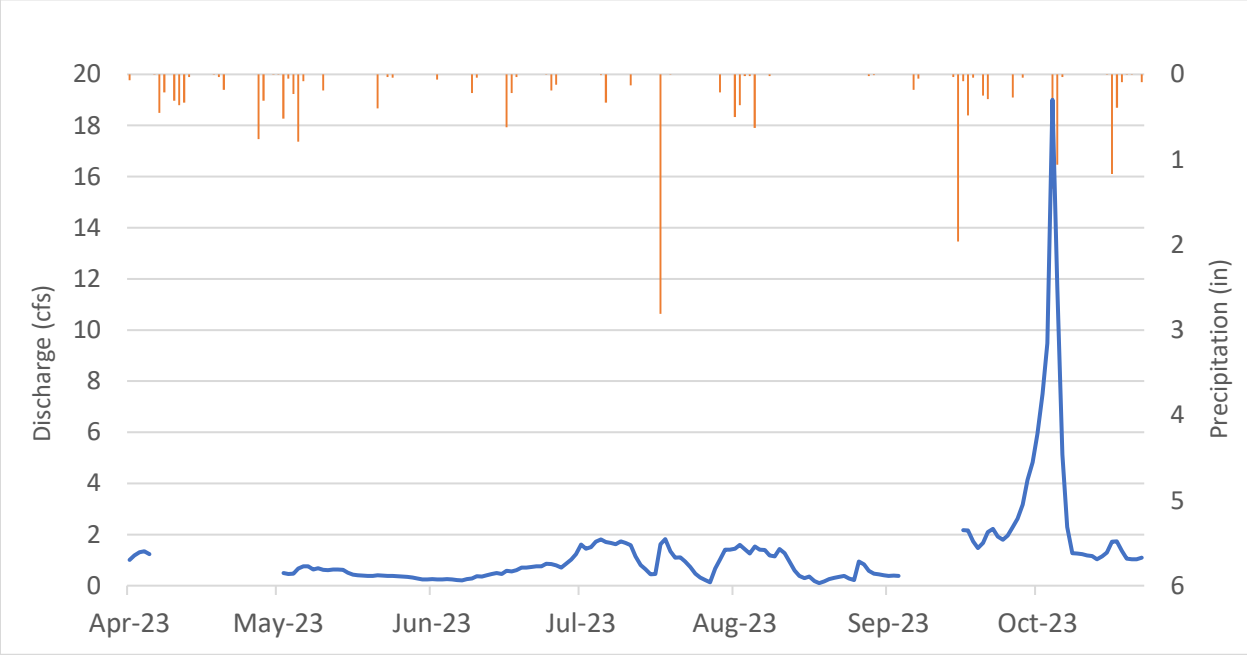

Figure 11. Dean Lake Inlet continuous 15min discharge data in 2023. Discharge data is provided by CR1000 data logger. Precipitation data obtained from the NOAA Jordan 1SSW site.

Discussion

The discharge at DLI mostly trended with precipitation and atmospheric trends. Due to the dry season, Prior Lake water levels did not reach the outlet weir level of 902.5 feet: the level at which water would begin to leave the lake. Therefore, the outlet structure on Lower Prior Lake did not discharge any water in 2023. While the outlet structure main gate was open all year, the low gate remained closed.

Although Dean Lake 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. 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. Most exceeding measured parameters 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 drought conditions. Monitoring should continue to track any increases or decreases in these levels in order to take proactive measures and avoid negative impacts to wildlife.

General trends can be observed in several of the parameters monitored over the years. 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, showing increased concentrations in the routine samples throughout the years and a decrease in event-based samples. Turbidity and total suspended solids levels are typically driven by precipitation amounts and event frequency, which can be observed throughout the monitoring years.

IV. Well Monitoring

Since 2005 the LMRWD has contracted with Scott SWCD to collect groundwater measurements from 11 shallow groundwater wells and 2 deep artesian wells in the Savage Fen located in the city of Savage, MN (Figure 12). Two deep artesian wells are located in the Fen and are 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 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—the largest calcareous fen of its kind on Minnesota—is a rare wetland complex at the base of the north-facing bluffs in the Minnesota River Valley. 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

Monthly monitoring of the 13 wells in the Savage Fen takes place 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 Fen. 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.

In the past, the SWCD monitored two additional wells in the Savage Bluff area and four wells in the Eagle Creek portion of Savage Fen on the west side of highway 13. The Bluff wells were sealed in 2019, but well measurements can be found in annual monitoring reports up to 2019. The four wells on the west side of highway 13 were sealed due to disrepair, and well measurements can be found in annual monitoring reports up to 2022.

In 2023, SF8 was sealed to avoid redundancy after an assessment from the DNR determined that the well was measuring the same aquifer at SF7. The relation of the two well measurements suggested a confining layer of only 20-30 ft deep between the two wells screens. The MNDNR continually assesses the validity and necessity of monitoring wells around the state.

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 81 water level measurements for the LMRWD in 2023 from the 13 wells.

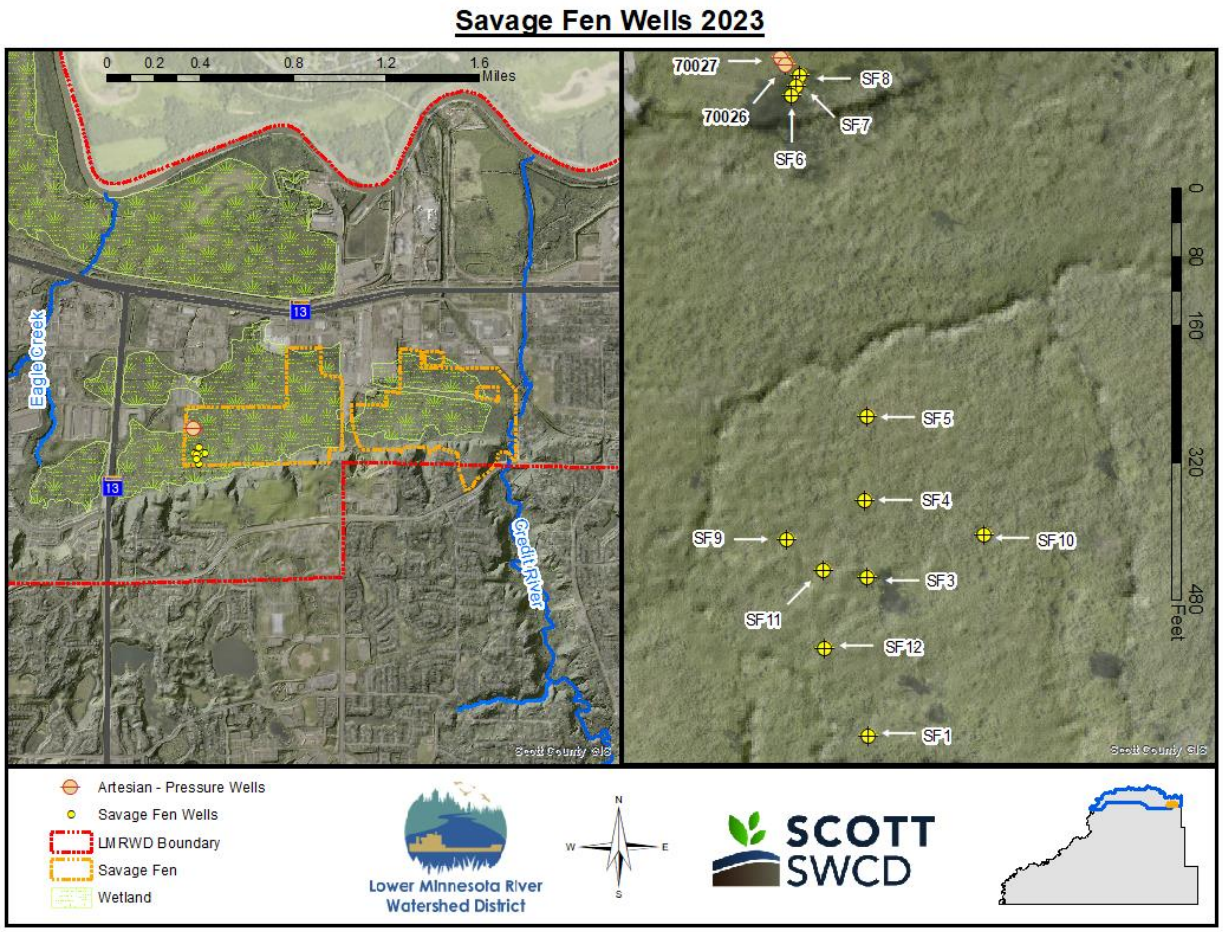

Figure 12: Map showing the location of active groundwater monitoring wells in the Savage Fen in Scott County, MN.

Results

The Savage Fen wells showed a consistent drop in water levels throughout the 2023 summer and started to rebound at the end of the monitoring season (Figure 13). Overall, the average water levels for the non-artesian wells decreased 0.21 feet throughout 2023, with some wells dropping more than others. Historically the Fen has shown signs of fluctuation, displaying a general increase in water levels from a dip in 2012. Since a slight spike in 2019, well levels have been steadily decreasing annually with warmer temperatures and less precipitation over the growing seasons (Figure A1). In 2023, ten of the Savage Fen wells showed a decrease in water levels when compared with 2022, and all eleven wells decreased over the 10-year average (Figure 14, Figure 15). However, because of late-season rainfalls, the wells have been able to consistently rebound annually back to early-season measurements over the past two years.

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.

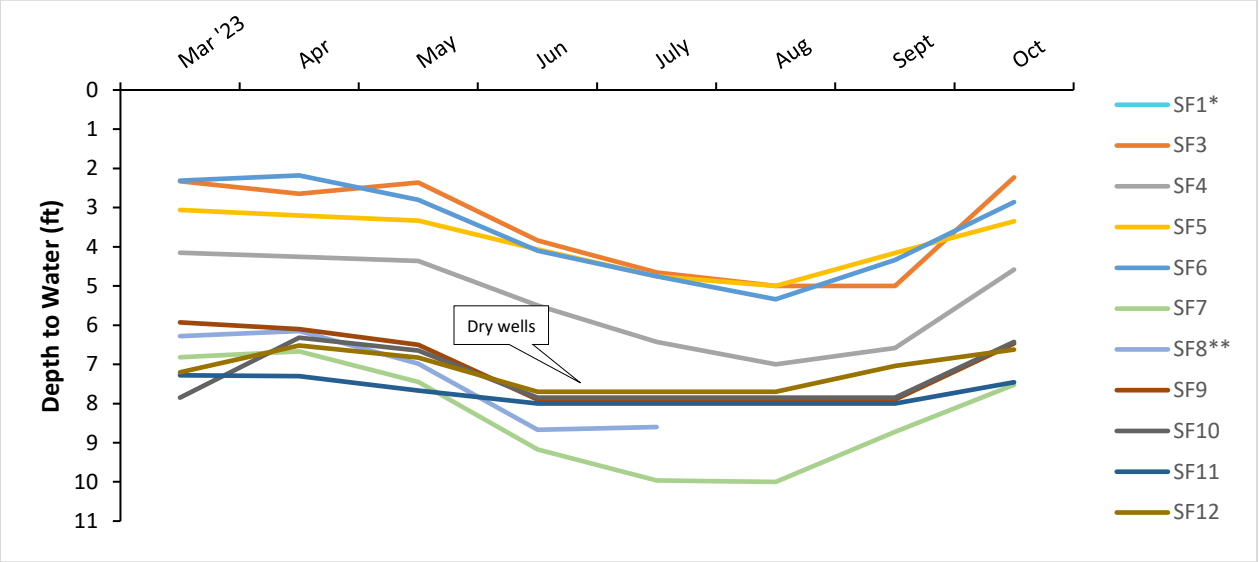

Figure 13. Savage Fen Wells (2023). Straight lines indicate dry hold readings. *SF1 was broken throughout the 2023 monitoring season. **SF8 was discontinued in July and permanently sealed on October 5.

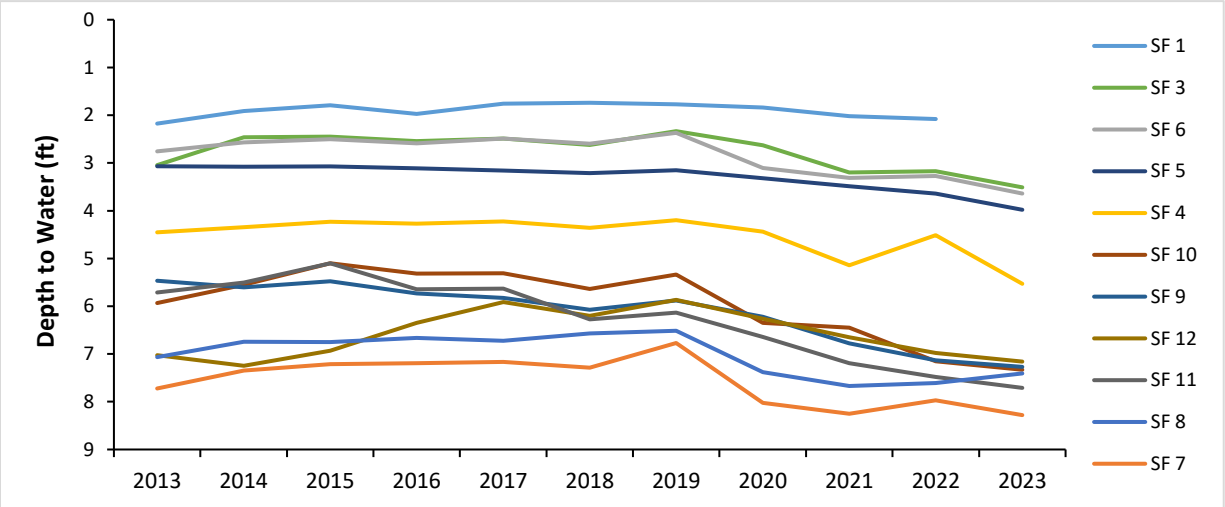

Figure 14. Average annual water level in Savage Fen wells (2013-2023). Averages include all observations in a calendar year.

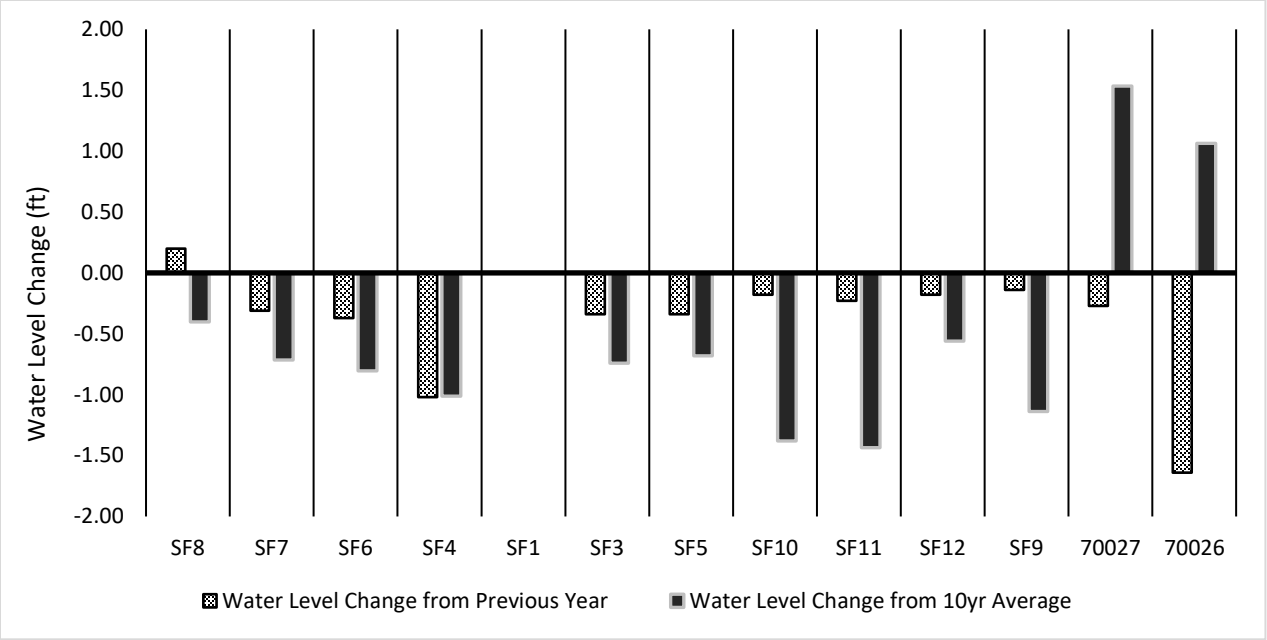

Figure 15. The water level changes at each Savage Fen well when compared with the previous year and the 10yr average depth to water. Average 2023 depth to water levels were used to compare with average 2022 values and 10yr historical average.

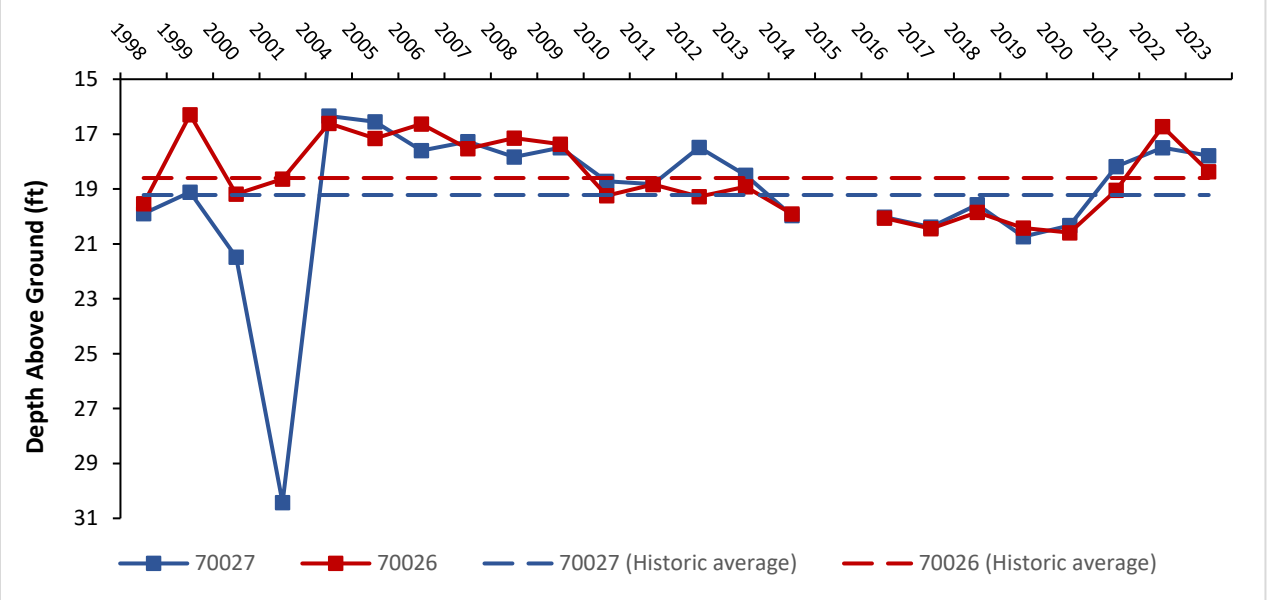

Figure 16. Average annual water level for the Savage Fen artesian wells (1998-2023). Averages include all observation in a calendar year. Historic averages are an average of all years sampled. Values are represented in feet above ground.

Discussion

Similar to 2020-2022, the monitoring season in 2023 was seasonably dry which led to a continued decrease in water levels in all of the monitored wells. Total precipitation values increased near the end of the monitoring season, allowing wells to recharge slightly prior to the winter freeze. All but one recorded well continued to decrease in groundwater levels from 2022 to 2023. Considering the single well that showed an increase in water levels—SF8—was discontinued before late summer drought conditions, it could be assumed that levels recorded in SF8 would have followed the pattern of other recorded wells had it been measured throughout the year.

While the two artesian wells have increased their observed levels over the last ten years, all ten shallow savage fen wells show decreased water levels over a ten-year average (Figure 16). Lower seasonal precipitation values and increased impervious surface development can show a change in surface wells, and decreased groundwater levels can amplify lower levels observed in wells.

There are many factors that can impact groundwater levels in northern Scott County. The fen depends on upwelling of groundwater to sustain it, and the same upwelling is responsible for maintaining baseflow for surface streams in and around the fen. The recharge of groundwater in the fen is replenished by the infiltration of precipitation upstream in the bluff. An increase of paved surfaces and water diversion to storm drains can also prevent runoff from infiltrating to the fen.

Seasonally, the amount of snowpack and precipitation throughout the year will determine recharge levels and rates. Other factors can also impact groundwater levels such as groundwater withdrawals for public supply, other consumptive uses, and surface water redirection. 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

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VI. Appendix

Table A1: *Monthly total precipitation values for 2023, along with a historical average, minimum and maximum for comparison.*

Month	2023 Precipitation Jordan* (in)	30 Year Record *		
		Average	Minimum	Maximum
January	2.682	0.98	0.08	4
February	2.53	0.93	0.001	2.53
March	1.842	1.76	0.34	4.26
April	4.173	3.01	0.42	7.51
May	3.332	4.35	1.08	11.08
June	1.26	4.85	0.99	12.3
July	3.592	3.8	0.87	8.48
August	1.76	4.83	1.11	10.86
September	3.39	2.63	0.21	6.88
October	4.483	2.68	0.39	5.83
November	0.073	1.43	0.001	4.99
December	1.626	1.32	0.001	3.4
Total	**30.743**	**33.17**	**22.12** (2022)	**41.99** (2019)

* Precipitation data obtained from the NOAA Jordan 1SSW site

** The historical record (normal) is from 1993-2023, NOAA Jordan 1SSW site. The lowest minimum value was recorded in 2022 and highest maximum was recorded in 2019.