Fens Sustainability Gaps Analysis for Carver, Dakota, and Scott Counties, Minnesota

LOWER MINNESOTA RIVER
WATERSHED DISTRICT

Lower Minnesota River Watershed District

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Fens Sustainability Gaps Analysis for Carver, Dakota, and Scott Counties, Minnesota

prepared for

Lower Minnesota River Watershed District

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
BLS	below land surface
CGM	cooperative groundwater monitoring
DO	dissolved oxygen
FEMA	Federal Emergency Management Administration
GPD	gallons per day
HVRA	High Value Resource Area
KH	horizonal hydraulic conductivity
KV	vertical hydraulic conductivity
LMRWD	Lower Minnesota River Watershed District
MDH	Minnesota Department of Health
MLAEM	multilayer analytical element model
MNDNR	Minnesota Department of Natural Resources
MNDOT	Minnesota Department of Transportation
MP	measuring point
MSL	mean sea level, referenced to the National Geodetic Vertical Datum of 1929
MSP	Minneapolis–Saint Paul
NOAA	National Oceanic and Atmospheric Administration
PDC–J	Prairie du Chien–Jordan
pH	logarithm of the hydrogen ion concentration
SNA	Scientific and Natural Area
SWCD	Soil and Water Conservation District

Abbreviation	Term/Phrase/Name
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

Calcareous fens are among the rarest types of wetlands in the United States. They are characterized by a substrate of peat and are dependent on a constant supply of cold groundwater that is oxygen-poor but rich in calcium and magnesium bicarbonates. This ecosystem supports a unique plant community that sustains many rare and endangered plant species not found in other environments. In Minnesota, lands containing calcareous fens are defined in Minnesota Rules, part 8420.0935, subpart 2. These calcareous fens have been identified by the commissioner by written orders published in the State Register on March 14, 2005 (29 SR 1061-1065), June 2, 2008 (32 SR 2148-2154), August 31, 2009 (34 SR 278), December 7, 2009 (34 SR 823-824), and July 5, 2016 (40 SR 8).

In the Lower Minnesota River Watershed District (LMRWD), the fens are part of the High Value Resource Areas (HVRAs), which require special consideration and adherence to protection standards as specified in the 2018 LMRWD Watershed Plan (Plan). The HVRAs were an embraced management strategy, adopted as part of the 2018 Plan, that consisted of managing areas directly draining to calcareous fens and trout waters through the formation of HVRA overlay districts. The goals of the Plan and the corresponding HVRA overlay districts are to understand, preserve, protect, and restore unique natural resources while evaluating projects that propose to alter them.

Effectively managing and protecting these groundwater-dependent resources requires reliable and accessible information. This report's purpose is to review the findings of previous studies, identify gaps in existing information, suggest needs for enhanced data collection and information, and outline a long-term, comprehensive plan for monitoring the fens.

This report is the result of an effort to compile readily available monitoring data and information about calcareous fens in the Lower Minnesota River Watershed District (LMRWD) and to identify gaps in those data. The fen complexes discussed are the Gun Club Lake North Fen, Gun Club Lake South Fen, Nichols Meadow Fen, Black Dog Lake Fen Complex, Savage Fen Complex, and Seminary Fen, as shown in the overview map (**Exhibit 1**). The report also provides recommendations for filling data gaps. Resource managers can use this information to develop management plans that will sustain these high-value, groundwater-dependent resources.

Encroachment has affected each of the fens, but the fen conditions presently range from healthy to degraded. The following summarizes the data available for each of the fens, listed in order from east to west along the Minnesota River Valley.

Gun Club Lake North and South Fens: These fens are in located in the Cities of Mendota Heights and Eagan in Dakota County, over sandy alluvial deposits above dolomitic and calcareous bedrocks. Once a single fen complex, they were divided by the construction of Interstate 494. Previous vegetation surveys have identified a few calcareous fen indicators but have not been conducted frequently in the past, and there are no baseline vegetation data available to determine if the fens have a viable population of calciphytes. Groundwater level data show a mix of stable or increasing water levels and have not changed significantly since monitoring began in 2007. The most recent geochemical testing in 1998 confirmed expected high levels of calcium and magnesium cations but also suggested a transitional chemistry that would be expected in a confined aquifer with anoxic waters exposed to atmospheric pressures (Almendinger & Leete, 1998a and 1998b). It is recommended to continue monitoring groundwater levels at both fens in addition to increasing geochemistry sampling on an annual basis.

Nicols Meadow Fen: This fen is located above alluvial sand that overlies the Prairie du Chien formation in the City of Burnsville in Dakota County, downgradient of residential developments and the Seneca Wastewater Treatment Plant. Nicols Meadow Fen has been adversely affected by groundwater appropriations and increased stormwater runoff over many years and continues to show the adverse effects of those disturbances. Despite the number of disturbances, until as recently as 30 years ago, the fen still supported a healthy fen ecosystem. It is recommended that private lands within the fen complex be considered for conservation purchase to protect and restore the fen from future development.

Black Dog Lake Fen Complex: This fen complex is in the City of Burnsville in Dakota County, downgradient of light industrial and residential areas. There are various organic deposits beneath the fen, overlying flood plain alluvium, with silt and clay enriched by organics. According to vegetation surveys, two fens within the complex have no fen-indicator species, and one has remnants. The Minnesota Department of Natural Resources has speculated that pockets of the fen may remain, but there are concerns the fen complex may be extinct. Water levels vary up to 25 feet in certain areas, the result of high groundwater use by neighboring municipal well fields and industrial pumping activities. No geochemical data have been found to support determination of whether the calcareous fen hydrology still exists. The MNDNR will conduct a vegetation assessment to determine if the native calcareous fen vegetative community still exists at Black Dog Lake Fen. The outcome of this assessment will determine whether additional monitoring or efforts are recommended.

Savage Fen complex: These fens are within the City of Savage in Scott County, located on sedimentary glacial deposits overlying sandy dolomitic bedrock of the Shakopee Formation. They are below a plateau whose land use is agricultural and residential. Vegetation assessments going back to 1980 indicate the

presence of calciphiles with continued encroachment by invasive species. Well monitoring indicates that water levels are increasing. Geochemical samples in 1994 established that the groundwater is enriched in calcium and magnesium carbonates but young for groundwater, indicating the potential for pollutants to enter the fen ecosystem via stormwater infiltration upstream. Given the potential for adverse impacts of future land development on Savage Fen, it is recommended that consideration be given to the purchase of private fen land for conservation.

Seminary Fen: This fen is located in the City of Chaska in Carver County above the Tunnel City Group sandstones that include calcareous materials, with glaciofluvial deposits full of carbonates in between. Various encroachments have disturbed this fen over the years, including agricultural tile drains, peat mining, and urbanization. Vegetation assessments in 2008 found the presence of fen indicator species, but they were not the dominant vegetation. Some of the groundwater monitoring wells show 6-foot water-level variations within a year; others have less fluctuation. Water samples from 2006 had calcium and alkalinity values that met the requirements for calcareous fens. Overall, Seminary Fen is thought to have some of the finest characteristic fen features, including a prominent peat dome and an excellent community of native fen plant species, despite its history of disturbances.

The following are tasks recommended:

1. **Land Conservation**

    - Continue to enforce the District Rules and complete project reviews on all proposed developments within the fens' HVRA overlay districts.
    - Consider purchasing private lands for conservation adjacent to Savage Fen and Nicols Meadow Fen estimated at $2.2M and $296,000, respectively.
    - Determine the viability of Black Dog Lake Fen before any conservation practices can be recommended.

2. **Vegetation Surveys**

    - Conduct qualitative vegetation surveys to document the presence or absence of fen indicator species at the fen once every 2 to 3 years and a quantitative relevé every 5 to 7 years to verify whether fens are thriving or degrading.
    - Manage invasive species in the fens using techniques such as manual removal or other environmentally sound practices that will not damage the fens.

3. Groundwater Monitoring

- Establish a routine, uniform groundwater monitoring for all the fens determined to be viable.
- At Gun Club Lake North Fen, maintain the existing wells and continue hand-monitoring activities. Consider installing of a new shallow and new deep well with instrumentation near the Union Pacific railbed, further removed from the influence of the Minnesota River and within healthy fen habitat.
- Analyze well records at Gun Club Lake South Fen for wells 482155, 482156, and 484653 to determine whether these wells should be maintained.
- At Nicols Meadow Fen, maintain existing wells and consider outfitting them with instrumentation.
- At Black Dog Lake Fen, review available well permit data from the Cities of Burnsville and Eagan to determine whether the calcareous fen groundwater hydrology is still intact.
- At Savage Fen, review the fen in 5 years to determine whether new wells would be warranted, particularly if the Dakota Avenue extension project is pursued.
- Check data of the measuring point at the monitoring wells once every 5 years.

4. Geochemistry

- Establish geochemistry of the fens by sampling at least one representative well in the aquifer beneath each viable fen once per year for dissolved major ions and nutrients. Field measurements for water temperature, specific conductance, pH, and dissolved oxygen concentration should be made at the time of sample collection. A sample also should be collected and analyzed to determine the stable-isotopic ratios of oxygen and hydrogen in the groundwater.
- Include collecting the geochemistry data discussed above in the LMRWD Monitoring Plan.

5. Recharge Analysis

- Identify recharge areas for each fen complex to better protect the fens from long-term adverse influences and changing land use in upland areas.

6. Management Plans

- Complete management plans, or sustainability reports, for all fens, starting with Seminary and Savage Fens to close or minimize gaps in information about the fens.

ACKNOWLEDGEMENTS

High-value resources, such as trout waters and calcareous fens, deserve attention from all the jurisdictions in which they are located if they are to remain viable. It is the hope of the Lower Minnesota River Watershed District (LMRWD) that the organizations who share aspects of fen management take actions, large and small, that accumulate over time as a net benefit for these valuable landscape features

It is in this spirit that we acknowledge the cities, counties, landowners, utilities, and agencies that have helped gather information over the years. We specifically call attention to the following for their direct assistance in assembling this summary report:

- The LMRWD provided funding and technical support.
- The Minnesota Board of Water and Soil Resources provided financial support.
- The Minnesota Department of Natural Resources provided access to their fen-related data and information and provided technical support; the details are provided in **Appendix A**.
- The Metropolitan Council Environmental Services provided access to their monitoring data and offered technical support.
- The Scott and Dakota County Soil and Water Conservation Districts and Carver Watershed Management Organization provided data and support for fen-related information.
- Young Environmental Consulting Group reviewed and analyzed available information and authored the summary report and recommendations.

1.0 INTRODUCTION

A fen is a wetland complex associated with groundwater seeps and springs that can be thought of as leaks in the confining materials. The groundwater supply at these leaks will fluctuate as the head on the underlying aquifer fluctuates. Enough head must be maintained on the aquifer so that groundwater can constantly leak out in quantities adequate to sustain the wetland complex. Calcareous fens, the type of fen discussed in this report, are characterized by a substrate of peat and depend on a constant supply of cold, oxygen-poor groundwater rich in calcium and magnesium bicarbonates. Calcareous fens are among the rarest types of wetlands in the United States. This ecosystem supports a unique plant community that sustains many rare and endangered plant species not found in other environments. Two of the calcareous fens included in this study, Gun Club Lake South and Savage, have been carbon-dated at about 10,000 years (Almendinger & Leete, 1998b).

Fewer than 500 calcareous fens are known to survive in the world (Olson, 2002); about 200 are known in Minnesota (MNDNR, 1998). In addition to the rarity of the resource itself, calcareous fens support a disproportionately large number of rare plant species in Minnesota (Carver County, MN 2016). Calcareous fens have special protection under Minnesota State Law (Minnesota Statutes 84.0895) and may not be drained, filled, or otherwise altered or degraded. The Minnesota Department of Natural Resources (MNDNR) is responsible for identifying, listing, and maintaining the quality and integrity of calcareous fens in Minnesota (Minnesota Statutes 8420.0935).

The calcareous fens studied for this report are located in the Lower Minnesota River Valley, in Carver, Dakota, and Scott Counties in Minnesota. They often are adjacent to other wetland areas. For many years, the ecological significance of the fens was poorly understood, and they may have been altered during attempts at wetland reclamation or drained for other uses. The fens are formed on peat aprons covering wide areas of Minnesota River valley terraces that receive diffuse discharges of calcareous groundwater (Almendinger & Leete, 1998a).

The official designation of a protected calcareous fen in Minnesota relies on vegetation surveys to determine whether the fen harbors specific indicator species. However, others, including Komor (1994) and Almendinger and Leete (1998a and b) have performed detailed hydrogeologic and geochemical analyses of selected fens to better describe their physical characteristics in addition to their indicator species. These studies identified the conditions necessary to support the vegetation unique to the calcareous fens. Komor (1994) studied the hydrogeochemistry of Savage Fen based on sampling conducted in 1992. Almendinger and Leete (1998a and b) studied Gun Club Lake South, Nicols Meadow,

and Savage Fens within the Lower Minnesota River Watershed District (LMRWD or District) and three other fens further upstream based on data collected during 1989–94, with most measurements started during 1992.

Because fens require protection, a concise, defensible definition of what constitutes a fen is necessary. To address this need, the State of Minnesota has developed a set of four specific technical criteria used to identify calcareous fens, based on hydrology, soils, chemistry, and vegetation (MNDNR, 2016).Those criteria include the following:

- **Hydrology:** Hydrology is characterized by stable, typically upwelling groundwater inflows sufficient to maintain saturation for the development of a histosol or histic epipedon soil (such as peat).
- **Soils:** Soils are characterized by the presence of either a histosol or a histic epipedon soil.
- **Water Chemistry:** Water chemistry of calcareous fens should be characterized by documentation of the following parameters:
  - pH of 6.7 or more [higher],
  - Calcium of 30 mg/l or more,
  - Alkalinity of 1.65 meq/l or more, and
  - Specific conductance of 500 μS/cm or more.
- **Vegetation:** Meets the calcareous fen vegetation technical criterion when, under normal circumstances, the area has a natural community index value of 50 or more by summing the appropriate regional index values of the vascular plants plus the bryophyte calcareous fen indicator species (MNDNR, 2016).

This report details the evaluation of data, focusing on six calcareous fens identified within LMRWD. These are Gun Club Lake North Fen, Gun Club Lake South Fen, Nicols Meadow Fen, Black Dog Lake Fen complex, Savage Fen complex, and Seminary Fen (**Exhibit 1**). The fens are located within the regulatory boundary of the LMRWD, an approximate 80-square-mile region located in the southwest portion of the Minneapolis-St. Paul (MSP) metropolitan area. The boundary of the District generally follows the floodplain of the Minnesota River and the bluff line extending from the City of Carver and Louisville Township in the west to the river's confluence with the Mississippi River.

Over the years of data collection and studies by a variety of organizations, fen nomenclature and locations have become convoluted, but each fen has an official name in the Minnesota State Register. For example:

- Gun Club Lake South is also known as Fort Snelling Fen.

- Gun Club Lake North is also known as Quarry Island Fen.
- Nicols Meadow Fen is sometimes spelled as Nichols but is listed as Nicols because that is the name of an original property owner, the adjacent roadway, and the bygone Nicols Station.

The names of the other fens appear to be uniformly accepted.

The District adopted its Amended Watershed Management Plan in October 2018. As a part of that amendment, the District embraced a management strategy of adopting overlay districts in areas draining to calcareous fens and trout waters called High Value Resource Areas (HVRAs). The goal of adopting these HVRA overlay districts is to understand, preserve, protect, and restore unique natural resources while evaluating projects that propose to alter them. The standards for development projects with an HVRA require more stringent erosion and sediment control and stormwater management standards with an emphasis on prevent erosion and infiltrating stormwater water. This project moves the District closer to its stated management goals and strategies. Importantly, the fens assessed for this effort have been studied individually or in small groups in the past, but they have not been collectively studied with an organized approach.

2.0 PURPOSE AND SCOPE

Effectively managing and protecting groundwater-dependent resources like calcareous fens requires reliable and accessible information. This report's purpose is to review the findings of previous studies, identify gaps in existing information, suggest needs for enhanced data collection and information, and outline a long-term, comprehensive plan for monitoring the fens.

2.1 Scope

The scope of this report is the identified calcareous fens in the District's jurisdiction, shown in **Exhibit 1**. Data and other information used in this report were obtained from a variety of sources. Much of the information was provided by the MNDNR and is summarized in **Appendix A**. Readily available data from public and private sources on Gun Club Lake North, Gun Club Lake South, Nicols Meadow, Black Dog Lake, Savage, and Seminary fens were also evaluated. The data were reviewed and assessed to determine their quality and applicability to manage these resources in the future.

3.0 PHYSICAL SETTING

Six calcareous fens have been identified within the District, spanning three counties. The fens in this report are protected by state or federal ownership, though adjacent and upland parcels remain in private ownership. The fens are downgradient of upland bluffs that are believed to provide recharge to the groundwater supplying the fens (Komor, 1994) and that historically have had agricultural land uses. Land use in much of the watershed has evolved from agricultural to urban, suburban, and industrial uses. A detailed analysis of the current and proposed land uses, as well as the ownership status of the LMRWD fens, appears in **Appendix C**; summary findings for each fen are included in **Section 4**.

3.1 Dakota County Fens

The Gun Club Lake North (Quarry Island) Fen, Gun Club Lake South (Fort Snelling) Fen, Nicols Meadow Fens, and Black Dog Lake Fen complex are in northwest Dakota County.

The fens are downgradient of the Cities of Mendota Heights, Eagan, and Burnsville. All four fens are located completely or partially within Fort Snelling State Park and/or the Minnesota River Valley National Wildlife Refuge. Many of them have experienced some disturbance from direct or indirect encroachment.

3.2 Scott County Fens

The Savage Fen complex is nearly surrounded by developed areas in the City of Savage in Scott County and shows some signs of disturbance and encroachment. Much of the Savage Fen complex is protected as a Scientific and Natural Area (SNA) managed by the MNDNR (1998).

3.3 Carver County Fens

Seminary Fen is on the north side of the Minnesota River, within the municipal boundaries of the Cities of Chaska and Chanhassen in Carver County, Minnesota. Housing development is north and upgradient of the fen with some agriculture and rights of way nearby. Part of Seminary Fen is also protected as an SNA managed by the MNDNR, while other areas remain under private ownership. Assumption Creek, a protected trout stream, originates adjacent to Seminary Fen.

3.4 Calcareous Fen Vegetation

Only a select group of plants are able to withstand the relatively hard growing conditions that are typical of calcareous fens. Plant species that are capable of tolerating the calcium-rich conditions are referred to as calciphiles. **Table 3-1** lists the vascular plants that are used to identify calcareous fens in Minnesota. Each plant is given a score based on its value for characterizing the fens being assessed. The higher the

value, the greater a plant's importance in characterizing a wetland as a calcareous fen. Plants that are listed by the state as threatened are indicated with THR, while plants that are listed as of special concern are indicated with SPC, following the scientific name.

Table 3-1 Regionalized List of Vascular Plant Indicators and Scores Used to Identify Calcareous Fens in Minnesota (MNDNR, 2018).

Scientific name	Common Name	Region			
		Northwest Minnesota	Minnesota River Valley	Southeast Minnesota	Southwest Minnesota
Berula erecta THR	Cut-leaf water parsnip	-	5	5	-
Betula pumila	Bog birch	1	5	5	-
Bidens coronata	Crowned beggar ticks	-	5	5	-
Bromus ciliatus	Fringed brome	1	5	5	-
Cardamine bulbosa	Spring cress	5	5	5	5
Carex aquatilis	Water sedge	1	5	25	25
Carex hystericina	Porcupine sedge	1	5	5	25
Carex interior	Inland sedge	1	5	5	5
Carex prairea	Prairie sedge	25	25	25	25
Carex sterilis THR	Sterile sedge	25	25	25	25
Cladium mariscoides SPC	Twigrush	5	25	-	-
Dasiphora fruticosa	Shrubby cinquefoil	1	25	25	-
Eleocharis rostellata SPC	Beaked spikerush	25	25	-	-
Eriophorum angustifolium	Tall cottongrass	1	1	5	5
Gentianopsis procera	Smaller fringed gentian	1	5	25	25
Liparis loeselii	Yellow widelip orchid	1	5	5	5
Lobelia kalmii	Kalm's lobelia	1	25	25	25
Oxypolis rigidior	Cowbane	-	5	5	-
Parnassia glauca	Grass of Parnassus	5	25	25	25

Scientific name	Common Name	Region			
		Northwest Minnesota	Minnesota River Valley	Southeast Minnesota	Southwest Minnesota
Primula mistassinica	Mistassinica	25	-	-	-
Rhynchospora capillacea THR	Hair-like beakrush	25	25	25	25
Salix candida	Safeleaf willow	5	5	5	-
Scleria verticillata THR	Low nutrush	25	25	25	25
Symphyotrichum boreale	Northern bog aster	1	5	5	5
Triantha glutinosa	Sticky tofeldia	5	25	-	-
Trichophorum cespitosum	Tufted bulrush	5	25	25	-
Triglochin maritima	Seaside arrowgrass	1	25	25	25
Triglochin palustris	Marsh arrowgrass	25	25	25	25
Valeriana edulus THR	Edible valerian	-	5	5	-

Note: Where the table does not contain a value in a regional column, that plant is not expected to occur in that region.

When the unique hydrology and geochemistry conditions that sustain calcareous fens are disrupted, invasive species can take hold and displace native fen plants, creating extensive monotypic stands. The addition of these invasive species can drastically alter natural communities, leading to the decline of rare species in the fens. Problematic and invasive plants of concern include reed canary grass (*Phalaris arundinacea*), common buckthorn (*Rhamnus cathartica*), glossy buckthorn (*Ramnus frangula*), purple loosestrife (*Lythrum salicaria*), and giant reed grass (*Phragmites australis*) among others.

3.5 Hydrogeology of the Fens

Calcareous fens are unique wetlands in that they are dependent on a distinctive combination of groundwater, geology, geochemistry, and surface water hydrology to exist. The following generally outlines geology, groundwater, and surface water hydrology characteristics of calcareous fens.

3.6 Geology

The geologic atlases of Carver, Dakota, and Scott Counties, Minnesota, show the surficial and bedrock geology and other physical and hydrologic features of the area in and near the fens. **Exhibit 2** shows the

surficial geology. The unconsolidated sedimentary units present in the lower Minnesota River valley area where the fens are located consist of organic deposits, terrace deposits, and floodplain alluvium. Organic deposits consisting of peat and organic-rich silt and clay underlay the fens. Terrace deposits are located at the higher elevations bordering the floodplain, consisting of sand and gravel that are naturally permeable and allow for infiltration and recharge of the underlying aquifers. Floodplain alluvial deposits consisting of poorly bedded clayey silt are located at lower elevations near the Minnesota River and are more impervious to infiltration.

The depth to bedrock in the vicinity of the fens (**Exhibit 3**) ranges from less than 50 feet below the land surface (bls) in the vicinity of Gun Club Lake North Fen to approximately 250 feet bls in the vicinity of Seminary Fen. A buried bedrock valley exposing the Tunnel City group, which is the deepest open bedrock unit in the watershed, is present about 1.4 miles northeast of Nicols Meadow Fen and is located equidistant of both Nicols Meadow Fen and Gun Club Lake South Fen. This exposure extends to the west and widens beneath Seminary Fen on the north side of the Minnesota River. At its deepest point, the uppermost bedrock units are approximately 350 to 400 feet bls. The regional groundwater flow direction within the unconsolidated deposits in the vicinity of the fens is generally upward and toward the Minnesota River.

3.7 Groundwater

Upwelling groundwater not only sustains the fens but is often the source of baseflow for streams near the fens. Because the upwelling groundwater is uniformly cold year-round, many of the streams are able to sustain a population of stream trout. Some of the streams are protected by the MNDNR as designated trout waters, shown in **Exhibit 1** (MNDNR, 2015).

The groundwater is also high in calcium and magnesium carbonates, one of the unique characteristics of calcareous fens. Waters with those chemical requirements are thought to originate from shallow or deep bedrock aquifers, many of which are composed of dolomitic rock (Bauer, 2009; Ruhl, 1983). Almendinger and Leete (1998a) suggested that calcareous glacial deposits, rather than calcareous bedrock, are the probable source of the dissolved calcium carbonate transported by groundwater to the fens they studied. They describe the process by which water quickly becomes saturated with respect to carbonates as it percolates through the glacial drift.

3.8 Surface Water Hydrology

As discussed above, the fens depend on upwelling groundwater to sustain their unique ecosystem. The groundwater discharged to the fens is replenished by infiltration of precipitation upstream in the

landscape. The terrace deposits at higher elevations are porous and allow rain and snowmelt to infiltrate down to the underlying aquifers. Unless the ground is paved or otherwise covered with impervious surfaces, falling precipitation will find its way to the subsurface and recharge the groundwater. Agriculture and urban development disrupt this natural cycle with drain tiles and storm drains that divert stormwater runoff to nearby streams and prevent the runoff from infiltrating.

The fens lay within the Minnesota River Valley and may be subject to inundation from floodwaters. It is uncertain what effect the flooding would have on fen health. Descriptions of cores that were obtained for the studies by Almendinger & Leete (1998b) and Komor (1994) did not mention evidence of layers indicative of floodwater deposition. However, floodplain maps developed by the Federal Emergency Management Agency for Dakota, Scott, and Carver Counties (FEMA, 2020) confirm that all the fens except Savage Fen lie within the area of the 100-year flood.

3.9 Climate Summary

A discussion of the climate in the lower Minnesota River watershed occurs in **Appendix D**. It shows that the average annual temperature in the watershed is about 45 degrees Fahrenheit (F) ranging from an average of 14°F in January to about 72°F in July. The average precipitation is about 32 inches per year, with most occurring from May through August. Assessment of trends suggests that winters are getting warmer, with cold temperatures warming the fastest; annual precipitation is increasing; and extreme rainfall events becoming more common.

Appendix D also presents in detail the results of climate model projections in the lower Minnesota River watershed; the following summarizes the conclusions of the impacts of climate projections for the LMRWD:

- The average low temperatures in the District have been increasing since 1895; both the daily low and January daily temperatures suggest that the watershed may be warming faster at the low end of the spectrum and the District will probably experience fewer extreme cold values in the future.
- The average high temperatures have remained relatively steady, although there is evidence to suggest that summer average daily high temperatures are decreasing, long-term climate predictions point to hotter summers.
- There is evidence of a long-term increase in the growing season since 1970, and climate models suggest that the LMRWD is highly likely to experience increasing lengths of the summer growing season under all climate scenarios.

- Intense and heavy precipitation events are occurring more frequently in the LMRWD and are expected to increase in the future based on climate projections. The more intense and heavy precipitation not only causes localized flooding but also increases the erosion of streambanks and increased sediment and pollutant loading downstream.

These climate trends affect the hydrogeology and vegetation of fens and must be considered when looking to actively manage fen health in the future. At this time, it is not known if the loss of extreme winter temperatures will affect the health of the fens but should be considered in future evaluations. The increased length of the growing season is a problem for several reasons. First, the longer growing season could allow invasive species to outcompete native species more rapidly. Second, an earlier start to the growing season can allow pests to emerge earlier in the season and disrupt the natural fen ecosystem. Finally, while the growing season may begin earlier, this early start would subject native plants to break dormancy early, subjecting them to the danger of early frosts and spring snowstorms.

Another concern to the District with these climate trends is the intense and heavy storms occurring now and in the future. These storms, coupled with the land use composition of the watershed, have the increased potential to release sediment and pollutants upstream, depositing them downstream, potentially in the fens and the lower Minnesota River.

4.0 CHARACTERIZATION OF THE FENS

Many organizations have sampled and monitored the fens in the LMRWD for a variety of reasons. The resulting data sets are often not comparable because of different techniques and methods used in the data collection. The following is the result of an effort to summarize and interpret those data to describe individual fen characteristics and resources within the District.

4.1 Gun Club Lake North Fen

Gun Club Lake North is in Dakota County, within Fort Snelling State Park and the City of Mendota Heights. Gun Club Lake North Fen (also known as Quarry Island Fen) and Gun Club Lake South Fen were part of the same system until they were divided by the construction of I-494 in 1985 (Dakota County SWCD, 2018).

4.1.1 Topography and Land Use

Gun Club Lake North Fen and its associated HVRA are located adjacent to the Union Pacific (UP) Railroad right-of-way and at the base and west of a gentle slope covered with light industrial and office with some residential land use (**Exhibit 4**). The presumed recharge area for its groundwater supply is mostly encompassed by the cities of Eagan and Mendota Heights. These communities are well developed with a mix of residential and light industrial land uses and are transected by major roadways. The planned land use upgradient of the fen shown in **Exhibit 5** indicates the area will be entirely industrial land uses. **Appendix C** discusses the existing (as of 2016) and future (2030 and beyond) land uses as well as fen ownership in detail; however there is little change expected in land use because Gun Club Lake North Fen is located entirely within the boundaries of Fort Snelling State Park, which is under the purview of the MNDNR. The only nearby encroachment could be from the UP Railroad right-of-way that passes to the east of the fen and within the park boundary. Because the land uses surrounding the fen are not expected to change from current (2016) conditions, conservation measures are not recommended at this time. Close coordination with municipal partners and continued enforcement of the District rules will help ensure adequate stormwater management is implemented to protect the health of the fen from future development.

4.1.2 Vegetation

A calcareous fen data sheet from a July 20, 1994, occurrence visit of Gun Club Lake North Fen by H. Dunevitz showed the presence of at least two fen-indicator species. Information about any other vegetation assessments of Gun Club Lake North Fen was not found.

4.1.3 Geology

The geology of Gun Club Lake North Fen consists of unconsolidated materials generally composed of a layer of peat overlying sandy alluvial deposits. The depth to bedrock near Gun Club Lake North Fen is less than 100 feet and possibly less than 50 feet according to the Dakota County geologic atlas (**Exhibit 3**). The bedrock formations directly beneath the fen are the St. Peter sandstone and the Platteville and Glenwood formations. The Platteville and Glenwood formations have dolomitic, calcareous characteristics.

4.1.4 Hydrogeology

Dakota County Soil and Water Conservation District (SWCD) routinely measures water levels from one deep (277777) and one shallow well (277776) at the locations shown by **Figure 4-1**. Dakota County SWCD compiles and supplies these data to the LMRWD which funds the monitoring program. The MNDNR routinely measures water levels in these wells and stores those data in the Cooperative Groundwater Monitoring (CGM) online database (MNDNR, 2019). Data provided by the Dakota County SWCD were used for Gun Club Lake North Fen hydrographs. **Graphs 4-1** and **4-2** show hydrographs of the two wells installed in the Gun Club Lake North Fen. The hydrographs have not been adjusted to the September 2016 resurveyed measuring-point elevations; and the significance of the elevation change is evident as a step trend in the water level and is marked in a different color on the graphs. The hydrographs clearly show this sudden change which is an artifact of the changing measuring-point elevation. With that in mind, water levels display seasonal variability. Additional information about the monitoring wells is in **Appendix B**, including the MNDNR recommendation to install a new pair of shallow and deep wells along the UP railbed and further removed from the influence of the Minnesota River (shown on **Figure 4-1**).

4.1.5 Geochemistry

No geochemical data have been found for Gun Club Lake North Fen.

4.1.6 Minnesota River Influence

Review of the FEMA Flood Insurance Rate Maps for Dakota County, effective December 2, 2012, indicates that portions of Gun Club Lake North Fen would be inundated by a 100-year flood on the Minnesota River. The water-surface elevation of the 100-year flood is 714 feet mean sea level (MSL) (LMRWD, 2004), ground elevation at the fen averages about 715 feet, and the groundwater elevations range from about 702 to 704 feet MSL. It is unknown whether hydrostatic pressures equalize between the groundwater and floodwaters, preventing the flow of river water into the fen substrate.

4.1.7 Information Gaps and Needs

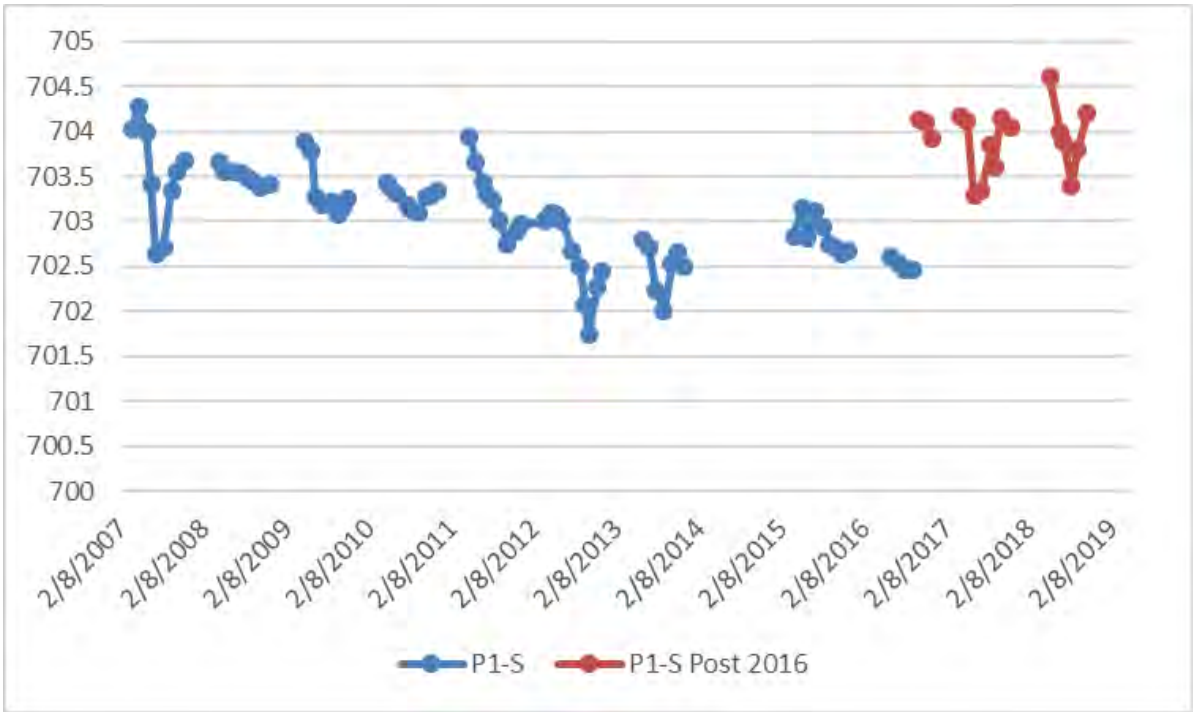
The Gun Club Lake North Fen ecosystem has been directly damaged by the construction of I-494 and indirectly influenced by development and land use changes. To adequately characterize this fen, the following considerations are provided:

- A vegetation survey of Gun Club Lake North Fen would help determine the need for additional protection for the fen. Other than an occurrence visit on July 20, 1994, there is no baseline vegetation data from which to judge whether there is a viable population of calciphytes that should be protected.
- At Gun Club Lake North Fen, it is recommended to maintain the existing wells and continue hand monitoring activities. Recommend installation of a new shallow and new deep well with instrumentation near the UP railbed, further removed from the influence of the Minnesota River and within healthy fen habitat.
- Geochemistry data has not been collected at Gun Club Lake North Fen. Major-ion and nutrient water chemistry should be sampled from the deeper of the two existing wells to verify that the groundwater chemistry is consistent with requirements of calcareous fens and to establish a baseline from which to assess changes in chemistry over time. This sampling should be conducted at least once each year.
- It is likely that flooding from the Minnesota River will periodically affect Gun Club Lake North fen, but it is unknown whether floodwaters are detrimental to the health of the fen or affect the upwelling of groundwater. Further study should be conducted to determine these impacts.

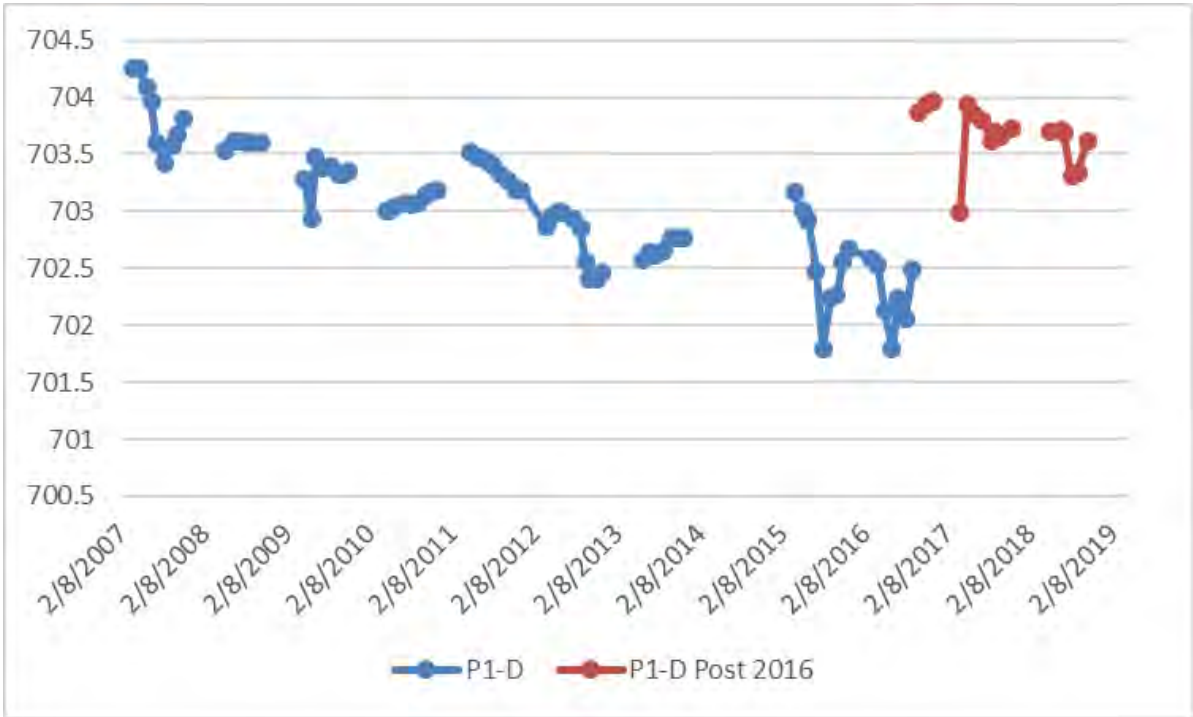
Fens Sustainability Gaps Analysis
Carver, Dakota, and Scott Counties Minnesota
Figure 4-1: Gun Club Lake North Location Map

Source - MN Geospatial Commons (MNDNR and MNDOT)

Graph 4-1. Gun Club Lake North Fen Well P1-S (277776) Groundwater Levels



Graph 4-2: Gun Club Lake North Fen Well P1-D (277777) Groundwater Levels



Note that the apparent downward trend in **Graphs 4-1** and **4-2**, may actually be the wells sinking over time. The water levels recover when the elevations are resurveyed in 2016.

4.2 Gun Club Lake South Fen

Gun Club Lake South Fen is located in Dakota County, within Fort Snelling State Park and the City of Eagan. Also known as Fort Snelling Fen, Gun Club Lake South Fen is south of I-494 between Highway 13 and Gun Club Lake (**Figure 4-2**). This fen was part of a larger fen complex that included Gun Club Lake North Fen but was divided by the construction of I-494, which was completed in 1985.

4.2.1 Topography and Land Use

The land near Gun Club Lake South Fen slopes upward to the east from the Minnesota River valley floor and includes light industrial land use, residential, and some open space (**Exhibit 4**). **Exhibit 5** shows planned land use for the area upgradient of Gun Club Lake South Fen. Although the naming convention for the planned land use is different, there do not appear to be any substantive changes in the overall land use.

Gun Club Lake South Fen is located entirely within the boundaries of Fort Snelling State Park, which is under the purview of the MNDNR. The only nearby encroachment could be from the UP Railroad right-of-way that passes to the east of the fen and within the park boundary; however significant changes in land use are not expected in the future. **Appendix C** provides greater detail about current and proposed land use and property ownership, but with no anticipated private land use changes directly impacting the fen itself, there are no recommendations at this time for conservation opportunities and continued close coordination with municipal partners, and continued enforcement of the District rules will help ensure adequate stormwater management is implemented to protect the health of the fen from future development. Aerial photographs show a few ponds and other areas that might enhance recharge, but due to urbanization, much rainwater will run off from impervious surfaces.

4.2.2 Vegetation

Vegetation in Gun Club Lake South Fen was assessed in 1982, 1993, 1994, 2003, and 2004 and is summarized as follows:

- **1982:** Notes from the first recorded vegetation on Gun Club Lake South Fen in September 1982. Various calcareous fen indicator species were present, suggesting a healthy ecosystem.
- **1993 and 1994:** A calcareous fen data sheet dated October 1999 appears to summarize the results of vegetation surveys conducted during 1993 and 1994. It describes the Gun Club Lake South Fen as several areas of calcareous groundwater discharge, dominated by several calcareous-fen indicator species, indicative of a strong and healthy calcareous fen ecosystem.

- **2003:** A site visit on March 12, 2003, recorded by an unidentified observer in their logbook described "a ditch excavated across the fen with a spring found." The logbook also described "a pronounced ice dome that is not from the spring; it is from the stormwater problem," indicating disturbance of the fen from data received from the MNDNR, the author is unknown. Undated photographs indicate severe erosion through the peat from excess stormwater discharge through the fen.
- **2004:** A formal vegetation survey, or relevé, report dated August 2004 was completed and describes a "small high diversity spot surr. by disturbed areas of *salix, cornus, phragmites*, and *phalaris*," indicating that Gun Club Lake South Fen was threatened by invasive species.
- **2019:** Barr Engineering completed the first phase of a relevé for this fen in 2019 and is expected to complete the second and final phase in summer 2020.

4.2.3 Geology

The geology at the Gun Club Lake South Fen consists of a peat layer overlying sandy alluvial deposits. A vertical cross section showing the hydrogeology of Gun Club Lake South Fen is depicted in **Figure 4-2**. Boring logs for nine of the 13 identified monitoring wells are available from the Minnesota Well Index (Minnesota Department of Health, 2019).

Peat deposit thicknesses range from approximately 20 to 25 feet bls. The peat is underlain by sand and gravel with some lenses of clay and silt to a depth of approximately 48 feet bls. Those deposits are underlain by sand to at least 85 feet bls. The bedrock surface is present at approximately 100 to 150 feet bls at Gun Club Lake South Fen, but none of the monitoring wells was drilled deep enough to verify bedrock depth.

4.2.4 Hydrogeology

Thirteen monitoring wells are located at Gun Club Lake South Fen (**Figure 4-2**), ranging in depth from 5 to 85 feet. **Appendix B** provides additional information about these monitoring wells and recommendations to enhance monitoring activities, summarized below. Like Gun Club Lake North Fen, the LMRWD funds monitoring activities by Dakota County SWCD, which routinely measures water levels in the wells, compiles the data, and supplies them to the LMRWD. The MNDNR also measures water levels in these wells and uploads their data into the CGM network; depths of the wells range from 5 to 80 feet bls. Water levels in the Gun Club Lake South Fen wells were measured annually from 2008 to 2019, except for in 2014. Dakota County SWCD monitoring results are shown in **Graphs 4-3** through **4-5**, grouped by the well identifiers N (Unique Numbers 484653, 482156, and 482155), S (591981, 277779, 591983, 277778) and W (482157, 482154, 591979, 591980) to reduce clutter from overlapping

measurements. The groundwater levels were relatively stable during the monitoring period with seasonable variability being the greatest change. Declines in water level during the summer months, with recovery during the fall, suggest a variety of influences. With more than 10 years of data, water levels at all the wells except S1 (591981) were stable or showed a possible trend toward rising water levels. Rising water levels may be consistent with increased annual precipitation in recent years (Magner, 2019) as shown in **Graphs 4-3** through **4-5**. The downward trend at S1 (591981) appears to be caused by the well's sinking because the trend reversed itself after the elevation was resurveyed in September 2016.

Groundwater head elevations for November 7, 2013, appear in the cross section in **Figure 4-3**, which is an illustration from Burns and McDonnell (2015). Groundwater contours for that date illustrate a consistent upward vertical gradient from deep groundwater toward the surface. In fact, many of the wells at Gun Club Lake South Fen flow, particularly the deeper wells; this means the water level rises above the top of casing and flows out of the well. These wells should be retrofitted to prevent flowing, either by attaching a riser or using a mechanical packer valve. The horizontal groundwater flow direction within the unconsolidated materials is generally to the northwest toward Gun Club Lake.

Almendinger and Leete (1998b) determined the hydraulic conductivity (*K*) of the peat and underlying sand deposits using slug tests. This is the only known test of aquifer characteristics for fens in the LMRWD. The authors recommended caution in the use of these *K* values because of the assumptions about the variables used during the slug tests. Layering within the peat typically causes the horizontal hydraulic conductivity (*KH*) to be much higher than the vertical hydraulic conductivity (*KV*). At the Gun Club Lake South Fen, the values for *KH* in the peat layers ranged from 2.1E–05 meters per second (m/s) to 6.0E–06 m/s. The values for *KV* in the peat layers ranged from 1.7E-06 m/s to 7.9E–06 m/s. The values of *K* in the sandy substratum at Gun Club Lake South Fen ranged from 3.1E–5 m/s to 4.8E–05 m/s.

As discussed in **Appendix B**, there are many wells in the vicinity of Gun Club Lake South Fen so no additional monitoring wells are suggested, but it is possible that some of these wells (482155, 482156, and 484653) could be sealed due to low variability or redundant hydrographs. In addition, it is recommended that the flowing wells at Gun Club Lake South Fen be retrofitted with either a riser or a mechanical packer valve. The deeper wells flow more frequently than the shallow wells and should be prioritized.

4.2.5 Geochemistry

Almendinger and Leete performed the most comprehensive study of the geochemistry of Gun Club Lake South Fen in 1998. The Fen shows the expected high values for calcium and magnesium cations, typical

of fens, but also suggests a transitional chemistry that would be expected in a confined aquifer with anoxic waters exposed to atmospheric pressures (Almendinger & Leete, 1998a and 1998b). It should be noted that the groundwater discharging into the Gun Club Lake South Fen may not have contact the bedrock aquifer. This may confirm that carbonates in the surficial glacial aquifers are more than adequate to provide the calcium and magnesium carbonates needed to achieve saturation and sustain calcareous fens.

No other comparable geochemical study has occurred since 1998.

4.2.6 Minnesota River Influence

Review of the FEMA Flood Insurance Rate Maps for Dakota County, effective December 2, 2012, indicates that portions of Gun Club Lake South Fen may be inundated by a 100-year flood on the Minnesota River. The water-surface elevation of the 100-year flood is 714 feet MSL (LMRWD, 2004), ground elevation at the fen averages about 715 feet, and the groundwater elevations range from about 702 to 704 feet MSL. It is unknown whether hydrostatic pressures equalize between the groundwater and floodwaters, which would prevent the flow of river water into the fen substrate.

4.2.7 Information Gaps and Needs

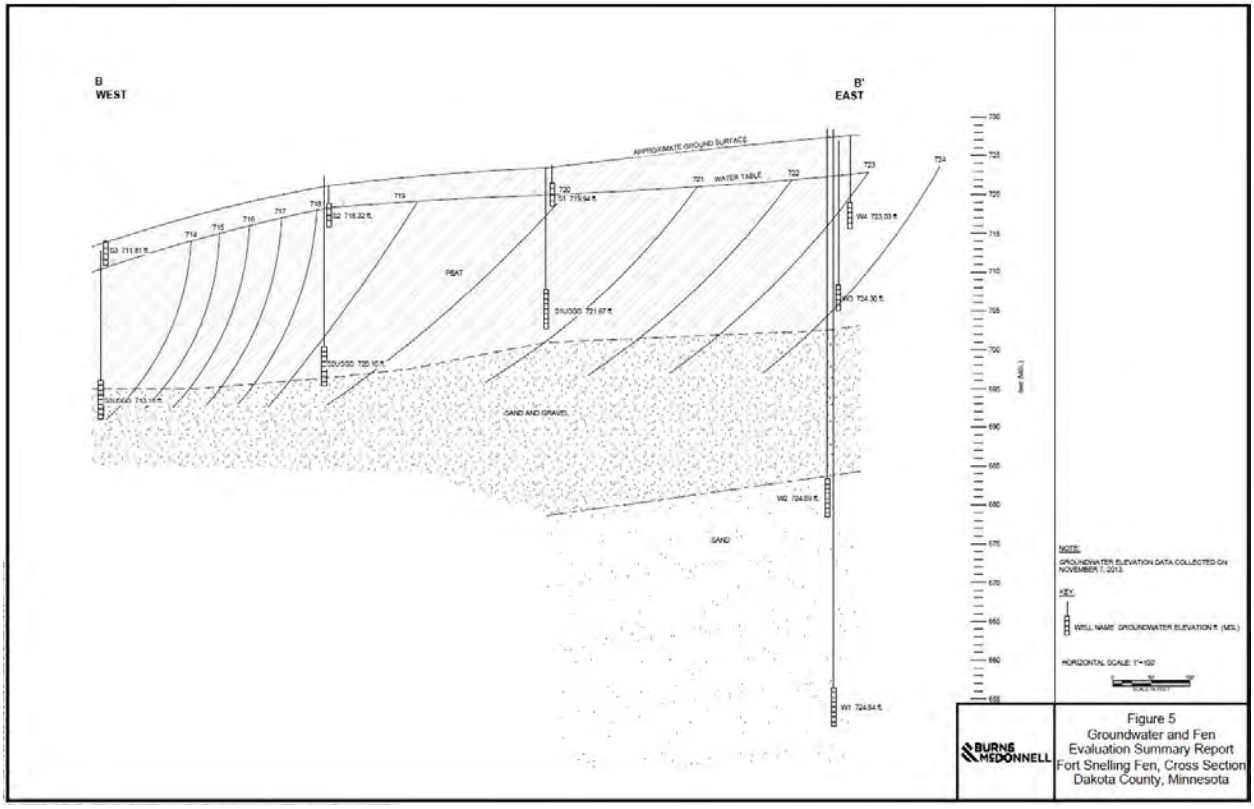
Gun Club Lake South Fen is susceptible to outside influences. It is downslope of nearby developed lands that could affect the fen's viability by altering the groundwater that sustains it. This section identifies some of the factors to consider when evaluating the fen's health and sustainability.

- Vegetation survey notes provided by the MNDNR show that populations of calcareous fen indicator species may be decreasing and that invasive species may be gaining a foothold in Gun Club Lake South Fen. Completion of the second and final phase of the relevés started in summer 2019.
- Continue monitoring water levels in the wells around Gun Club Lake South Fen but consider sealing those that may be redundant or have low variability.
- Install risers or mechanical packer valves on flowing wells.
- Continuing water level data collection from wells in Gun Club Lake South Fen shows that the fen has adequate water supply. Major-ion and nutrient chemistry data from one and preferably two wells may help to determine if the chemistry is comparable to historical data. Repeated annual sampling will establish the existence of trends over time.

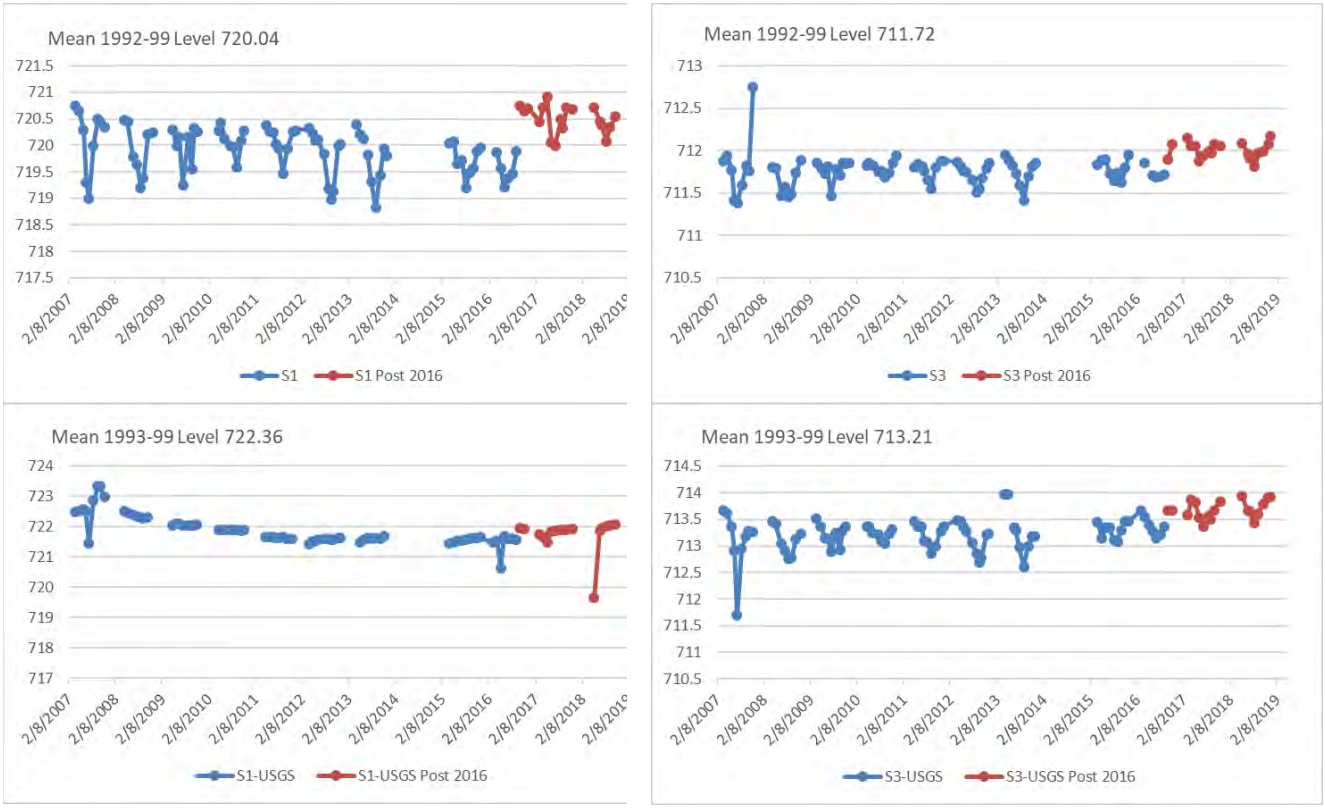
- Measuring water levels in the wells early in the year was often complicated by groundwater levels that exceeded the height of the well casing. It would help to install permanent or temporary extensions on the wells to determine the actual potentiometric surface of the groundwater.

Source - MN Geospatial Commons (MNDNR and MNDOT)

Figure 4-3. Vertical Cross Section Showing Hydrogeology of Gun Club Lake South Fen (Burns and McDonnell, 2015)

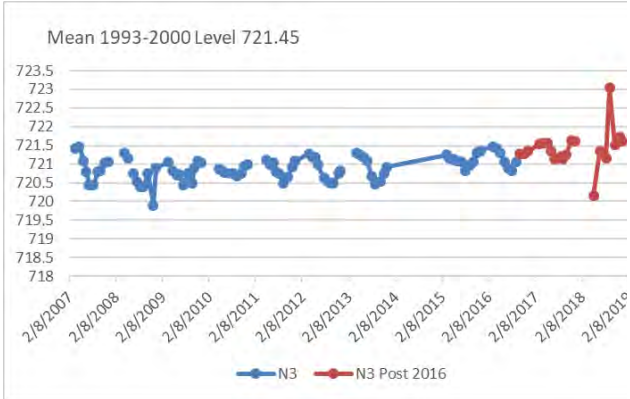


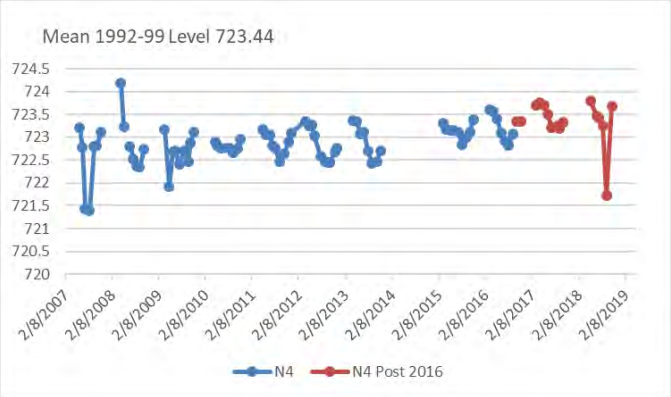
Graph 4-3. Groundwater Levels in Gun Club Lake South Wells Designated "S" (From left to right, top to bottom: 591981, 277779, 591983, 277778)

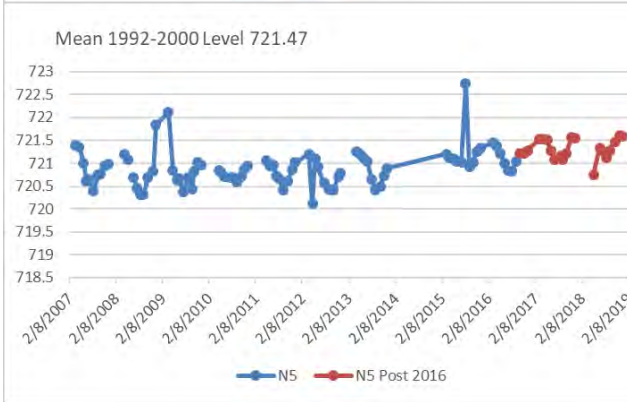


Note that the wells were resurveyed in 2016, which is shown in red.

Graph 4-4. Groundwater Levels in Gun Club Lake South Wells Designated "N" (From left to right, top to bottom: 484653, 482156, and 482155)

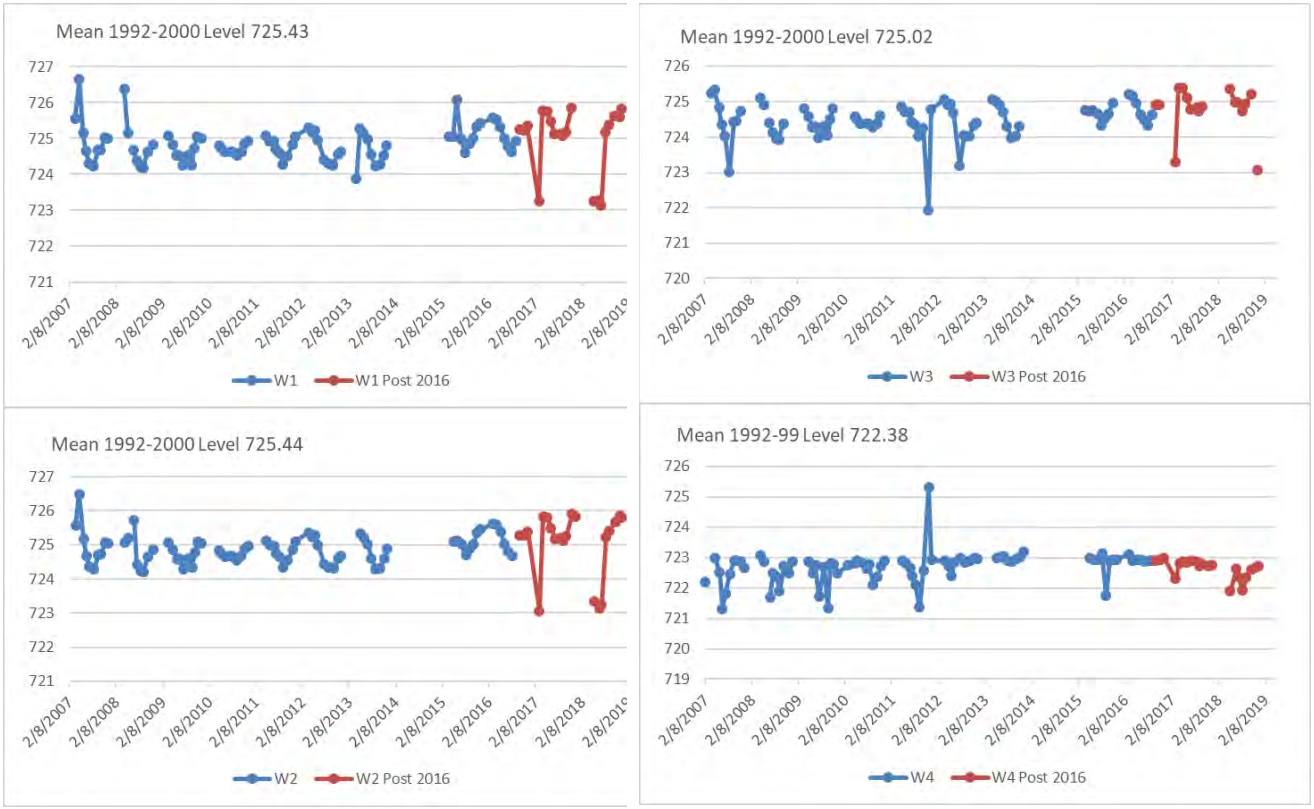






Note that the wells were resurveyed in 2016, which shown in red.

Graph 4-5. Groundwater Levels in Gun Club Lake South Wells Designated "W" (From left to right, top to bottom: 482157, 482154, 591979, 591980)



Note that the wells were resurveyed in 2016, which is shown in red.

4.3 Nicols Meadow Fen

Nicols Meadow Fen is located in Dakota County, partially in the Fort Snelling State Park and the City of Eagan, northeast of Cedar Avenue (TH 77) and northwest of TH 13 (**Figure 4-4**). Nicols Meadow Fen and Black Dog Lake North Fen may have been part of the same complex before TH77 divided them. The fen is adjacent to a UP Railroad line (formerly the Chicago and Northwestern Rail). Nicols Road appears to run through the fen and may be the origin of its name. Nicols Meadow Fen is associated with two historical trout streams, Kennealy and Harnack Creeks. The area around Nicols Meadow Fen has been disturbed by historical activities, including the nearby construction of a railroad flag station, construction of trout ponds on Kennealy Creek, municipal stormwater and wastewater construction projects, and agricultural activities.

4.3.1 Topography and Land Use

The fen lies in the Minnesota River Valley with land that slopes upward to the southeast. The land use in areas upgradient of Nicols Meadow Fen is shown in **Exhibit 4**. It is a mosaic of residential areas interspersed with industrial, retail, commercial, and transportation routes. The planned land use shown in

Exhibit 5 shows projected uses including commercial, industrial, and institutional activities. These types of land uses typically include a significant amount of impervious area, reducing the infiltration and the recharge of the underlying aquifer. There are few lakes and ponds that might contribute to groundwater recharge upgradient of the fen, but it is likely that storm sewers convey much of the precipitation away before it can infiltrate.

Appendix C details current and future land uses at Nicols Meadow Fen as well as land ownership of the fen. Over half of the direct drainage area to the fen is under public ownership, while the remainder is split between transportation right-of-way and private ownership. Conclusions from this report state that, like many of the fens in LMWRD's jurisdiction, Nicols Meadow Fen HVRA is expected to be fully developed by 2030 and experience a complete loss of undeveloped land. These undeveloped areas are anticipated to be converted primarily to highly impervious, high-risk land uses, including commercial and industrial. It is recommended that the land immediately within Nicols Meadow Fen be purchased for conservation, at an estimated cost of $296,000, based on the 2019 full market value.

4.3.2 Vegetation

Numerous vegetation surveys have been conducted several times at Nicols Meadow Fen since the 1980s. They are summarized as follows:

- **1980s:** Information from one site visit during 1980 and five visits in 1982 shows the presence of several calcareous fen indicator species. However, those species did not appear to dominate the plant community. Many other wetland plants were present in the vegetation surveys. Pumping during a construction project in 1989 near Nicols Meadow Fen caused head-gradient reversals, peat dewatering, and subsidence.
- **1990s:** Species identified during a 1992 site visit were not indicative of a calcareous fen community. Two seasonal vegetation surveys of Nicols Meadow Fen conducted in June and September 1993 were summarized in a baseline assessment report that described the presence of only two calciphilic species out of six species along with the predominance of plants that are not uniquely associated with calcareous fens. However, a site visit dated August 18, 1994, lists an abundance of calcareous fen indicator species, suggesting a very healthy community with the presence of some less-desirable plants, including reed grass. The differing results may reflect the differences between casual observations while on-site compared with a formal vegetation survey, or relevé. Almendinger and Leete (1998a) described Nicols Meadow Fen as being dominated by sedges in some parts but being overrun by common reed grass (*Phragmites australis*) in other parts, particularly along the UP Railroad tracks that cut the upgradient margin of the fen.

- **2000s:** Site visits during 2000 and 2001 described an overabundance of *phragmites*, the generic name for reed grass, as well as the "bad" appearance of the fen. *Phragmites* are typically an invasive plant known to dominate plant communities and to subordinate native plants. A site visit on August 20, 2003, describes "no water in hole, soil crumbly, only a bit moist in spite of rain last night." None of the plants identified in the 2003 site visit were consistent with calcareous fens, although some were identified as wetland species. Notes from a later visit (MNDNR, 2018) state that "the upper peat now appears relatively dry, decomposed, and friable, and may be irreversibly altered because of the de-watering."
- **2019:** Barr Engineering completed the first phase of a relevé for this fen in 2019 and is expected to complete the second and final phase in summer 2020.

Nicols Meadow Fen has been subject to a number of human-caused disturbances since at least the 1890s, and while as recently as 30 years ago it still maintained a healthy fen community, the trend captured by the vegetation surveys shows a loss of the unique calcareous fen species and an increase in less-desirable plants, such as reed grass.

4.3.3 Geology

The geology at Nicols Meadow Fen generally consists of a substrate of peat overlying alluvial sand deposits. The deposits are primarily part of the St. Croix glacial moraine. The bedrock surface is about 100 to 150 feet below ground surface. The bedrock is primarily the Prairie du Chien formation. A buried bedrock valley to the northeast exposes Jordan sandstone and is deep enough to expose the underlying St. Lawrence and Franconia dolomitic shale and siltstone. Because the bedrock near the fen is deep, it should not affect the fen. Almendinger and Leete (1998a and b) noted that the alluvial aquifer has sufficient carbonate minerals to enrich recharge waters before discharging to the fen without having to contact the carbonate bedrock.

4.3.4 Hydrogeology

The groundwater flow direction near Nicols Meadow Fen within the unconsolidated material is generally to the northwest toward the Minnesota River. **Appendix B** shows the location and construction information for the wells in Nicols Meadow Fen. Two pairs of nested monitoring wells are screened to assess the vertical gradients within the fen. Monitoring wells F1 (452922) and F2 (452923) are located in the northeast portion of the fen, and monitoring wells F3 (452924) and F4 (452925) are located in the southwest portion of the fen (**Figure 4-4**). Monitoring wells F1 and F3 are deep wells, completed at approximately 75 feet bls in the alluvial sands, while monitoring wells F2 and F4 are shallow wells and are completed just below the organic clay unit at approximately 15 feet bls and 21 feet bls, respectively;

both are monitored by the MCES and the Dakota County SWCD. The MCES has records from 1993 to present, while the Dakota County SWCD records are from 2007 to the present, with gaps that did not occur in the MCES data. The data were examined and found to be comparable, although an elevation change that affected the Dakota County data was not present in the MCES data. The more-complete, longer-term MCES data are presented here. As discussed in **Appendix B**, the MCES also has several monitoring wells nearby that may provide additional information about the groundwater hydrology near Nicols Meadow Fen.

The hydrographs showing groundwater elevations from 1993 to 2018 for Nicols Meadow Fen wells are shown in **Graphs 4-6** and **4-7**. Since about late 2008, the two deep wells, F1 and F3, have had water levels that were higher than the shallower wells, F2 and F4, indicating positive upward pressure that typically supports a heathy fen community. The water levels in the deeper wells appeared to be increasing over time and exceeded the height of the casing. They often were flowing when measured, as shown by the plateaus on the hydrographs. Later in the data collection program, the MCES employed techniques that allowed measurement of water levels that exceeded the height of the well casing. Before late 2008, the water level in well F1 was consistently about 3 feet lower, suggesting that a substantial change in the hydrology occurred. This change also was evident the data collected by the Dakota County SWCD. Water levels in the shallow wells F2 and F4 appear relatively stable over time.

A series of wells were installed near the water table of Nicols Meadow Fen, named WT-1 through WT-5 (540952, 277773, 277771, 277772, and 277770), and have been monitored since 2008. Water level records from three of these wells show similar patterns of variability over time. Water levels in well WT-4 (277772) are lower and much less variable than the other wells, suggesting that they are influenced by different hydrologic conditions.

Nicols Meadow Fen groundwater hydrology was examined again in 2014 as part of an effort to understand the effects of installation and operation of a new lift station for the Seneca wastewater treatment plant operated by the Metropolitan Waste Control Commission. Dewatering for the construction was permitted starting December 3, 2015, and ending on or before April 1, 2016. This period was chosen to ensure that the peat was protected from desiccation and degradation during dewatering by keeping it frozen during the winter months. The hydrographs shown in **Graph 4-6** did not show effects from that drawdown.

It is unclear why water levels in some of the wells appear to be highly variable while they are much less variable at other wells. It might be expected that wells F1 and F3 would have similar hydrographs because

they are situated in the same material, but that is not the case. Historical disturbances may have had a negative impact on the hydrogeology of Nicols Meadow Fen. The nearby Seneca Wastewater Treatment Plant, constructed in 1972 and expanded in 1992, actively dewaters 380 million gallons of water each year from aquifers adjacent to the fen. Dewatering for construction for the Seneca Wastewater Treatment Plant expansion in 1992 in the vicinity of Nicols Meadow Fen may have lowered the water table in the peat (WSB & Associates, Inc., 2008). In addition, the City of Eagan's municipal well fields withdraw groundwater from the Jordan, Mt. Simon, Prairie du Chien–Jordan (PDC–J), and Franconia–Mt. Simon bedrock aquifers and are located within 3 miles of Nicol Meadows Fen.

A 1996 letter describes a passive underdrain system at the Seneca Wastewater Treatment Plant that appears to be lowering water levels beneath the fen. Measurements taken in the late 1990s showed that the groundwater elevation of the water table was generally below the surface of the peat. Almendinger and Leete (1998b) stated, "When the water table drops some critical distance below the surface, aerobic decay of peat in the unsaturated zone can increase [the partial pressure of carbon dioxide] levels and carbonate solubility, thereby causing loss of carbonates from this zone by dissolution." It is not known how this might affect plants that have adapted to specific water chemistry found in calcareous fens.

The City of Eagan constructed a stormwater outfall into the fen in the 1950s. Although they subsequently abandoned the pipe, the July 2000 Super Storm caused severe erosion at this location. The Findings of Fact dated Sept. 27, 2004, from a Technical Evaluation Panel to the City of Eagan, stated that "several decades of stormwater outflow from the City has eroded an open cavity that is approximately 20 feet deep and 30 feet in diameter. The cavity is a significant hazard to human safety. It also is a site of groundwater seepage from the adjacent fen area." To address the problem, the MNDNR, LMRWD, and City coordinated a restoration design and transfer of stewardship to the MNDNR.

The hydrogeology of Nicols Meadow Fen is complicated by the layer of organic clay that appears to lie between the sand aquifer below the ground and the peat layer near the surface. The dimensions of the clay layer are not known, and it has variable hydraulic conductivity. This complicates the discharge of deeper groundwater to the surface of the fen. The clay layer may serve to prevent upward groundwater flow but could also retard drainage from the fen, temporarily protecting it from desiccation by holding a supply of water if groundwater is drawn down too far.

Recent data, including the results of updated well measuring point elevations, were not available when Burns and McDonnell (2015) prepared their summary of Dakota County fens. However, their observations and conclusions were discussed with the MNDNR, and the MNDNR recommended

maintaining a number of the existing active wells and outfitting more with data loggers, particularly near a down-cutting spring-fed swale that has the potential for a future restoration project. In addition, the MNDNR also recommends that the MNDNR, Dakota County, and MCES discuss monitoring wells and data collection at Nicols Meadow Fen to reduce redundancies in data collection efforts.

4.3.5 Geochemistry

Almendinger and Leete (1998a and b) noted that samples from Nicols Meadow Fen had substantially altered carbonate content that apparently resulted from chemical reactions associated with dewatering and peat decomposition and were not representative of natural fens. They added that selected data from Nicols Meadow Fen were used in their study to contrast with those from other studied fens because the Nicols Meadow Fen "had been so degraded."

No additional geochemistry data were found for Nicols Meadow Fen.

4.3.6 Minnesota River Influence

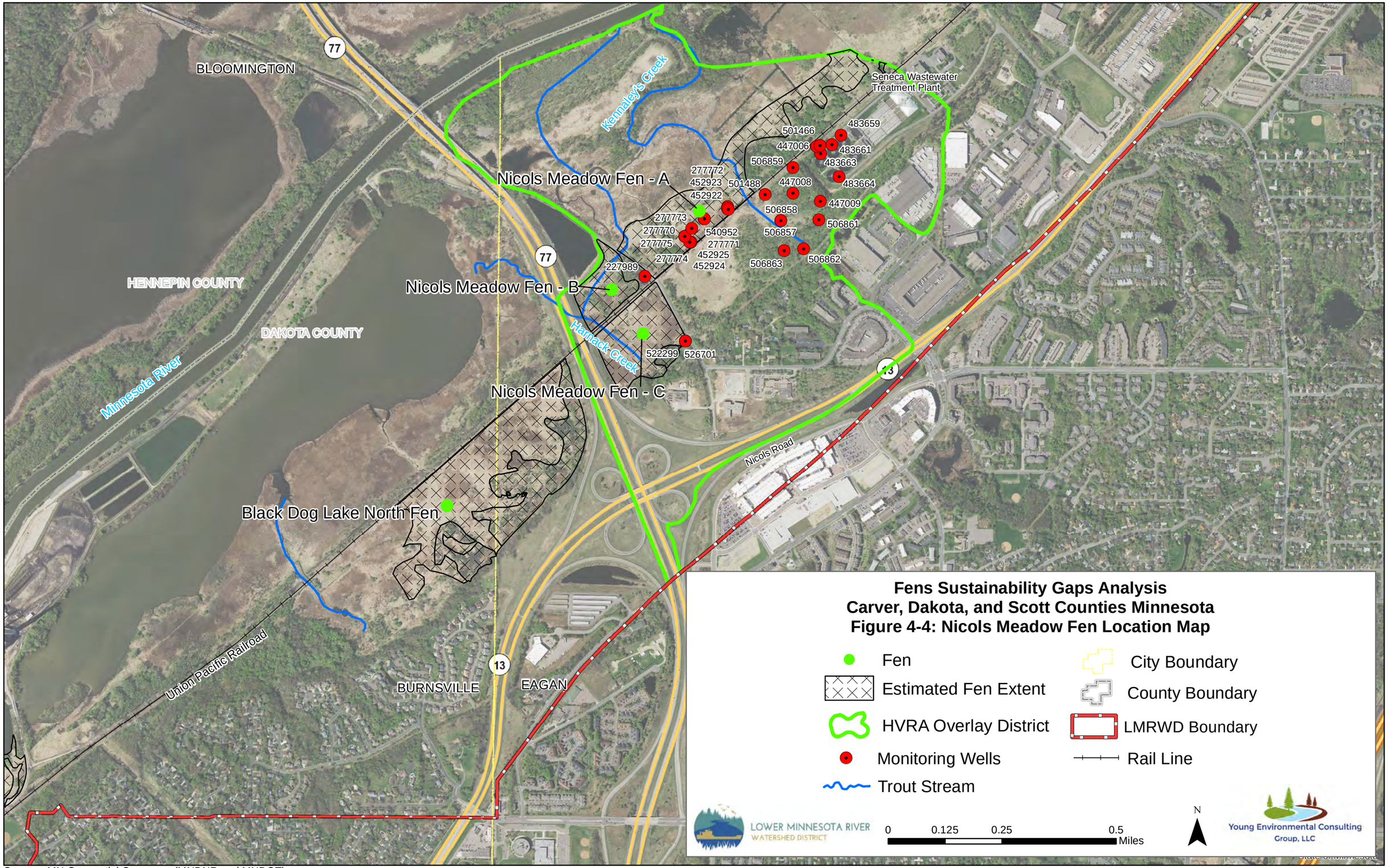
Nicols Meadow Fen is not likely to be affected by Minnesota River flooding. The 100-year flood water surface elevation at Nicols Meadow Fen is approximately 714.6 feet MSL and the average ground surface elevation is 720 feet. Because the fen is located at a higher elevation than the 100-year floodplain elevation, the groundwater upwelling is unlikely to be adversely impacted by periodic floods from the Minnesota River.

4.3.7 Information Gaps and Needs

Nicols Meadow Fen has been adversely affected by a variety of disturbances over many years and continues to show the adverse effects of those disturbances, evident in changes in the flora. Before the value of calcareous fens was recognized and regulatory protections were established, the fen was home to residents of the abandoned community of Nicols, MN (Dakota County Historical Society, 1989). Parts may have been altered, drained, and filled for the construction of the UP Railway, the TH 77 roadway, and other facilities. Below are some information gaps and needs for better management of the fen in the future:

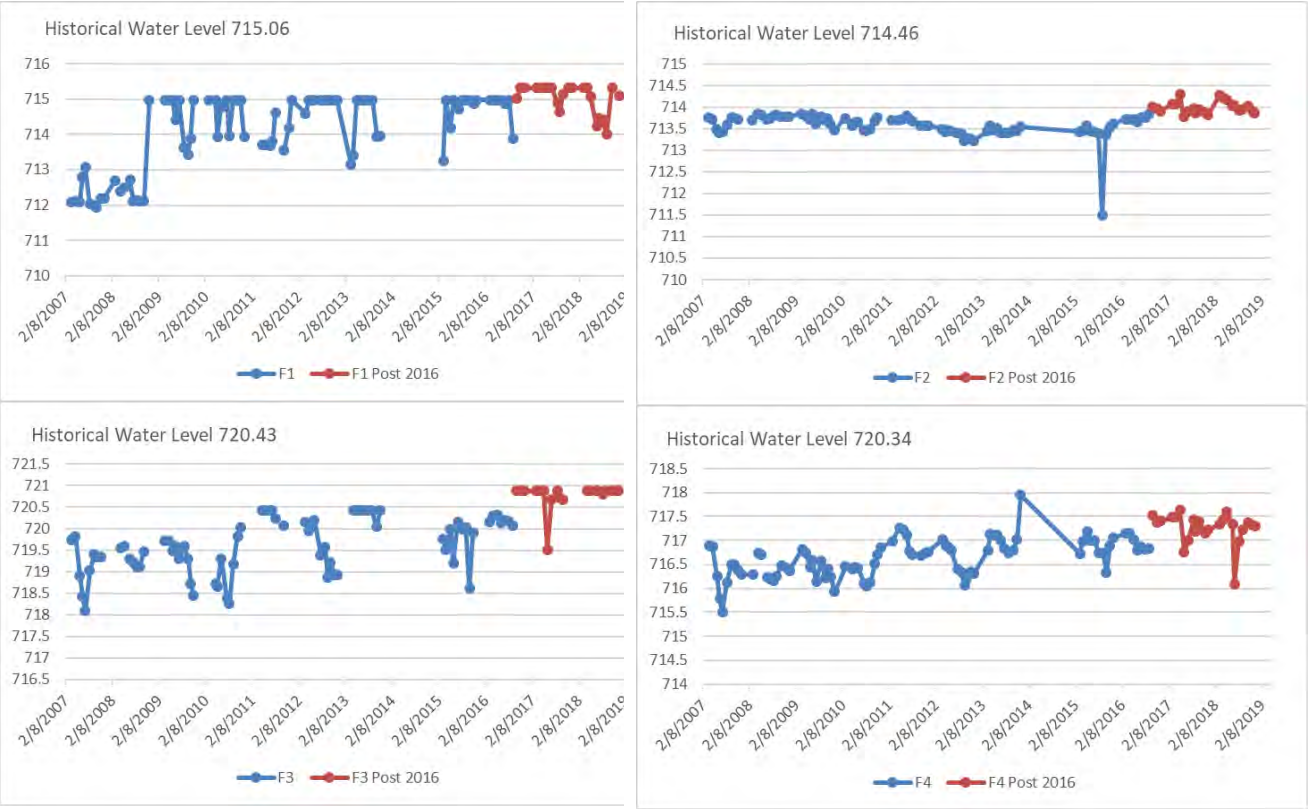
- Given the potential for development of private lands within the Nicols Meadow Fen, as detailed in **Appendix D**, it is recommended that portions of these parcels be purchased for conservation. Based on this preliminary assessment, the cost to purchase and conserve this area is estimated at $296,000, based on the 2019 full market value.

- Vegetation surveys at Nicols Meadow Fen show a trend, going back to the 1980s, of a gradual decline in calciphyte species and an increase in less desirable and invasive plants, such as reed grass. Invasive species have been identified as problematic in Nicols Meadow Fen during several vegetation surveys. Once established, invasive species can drastically alter the fen community by displacing native fen plants, creating extensive monotypic stands, and leading to the overall decline of rare species in the fens. Complete the second and final phase of the relevés started in summer 2019.
- Municipal and commercial groundwater withdrawals from the City of Eagan and the Seneca Wastewater Treatment Plan should be evaluated to determine if these permitted appropriations are affecting the Nicols Meadow Fen water supply.
- As detailed in **Appendix B**, the MNDNR has recommended maintaining a number of the existing active wells and outfitting more with data loggers, particularly near a down-cutting spring-fed swale that could be the site of a future restoration project.
- Coordinate monitoring activities and data collection between the MNDNR, Dakota County, and MCES at Nicols Meadow Fen to improve efficiency in data collection efforts.
- Coordination with the MNDNR and City of Eagan is recommended to confirm the restoration of the failed municipal stormwater outfall.



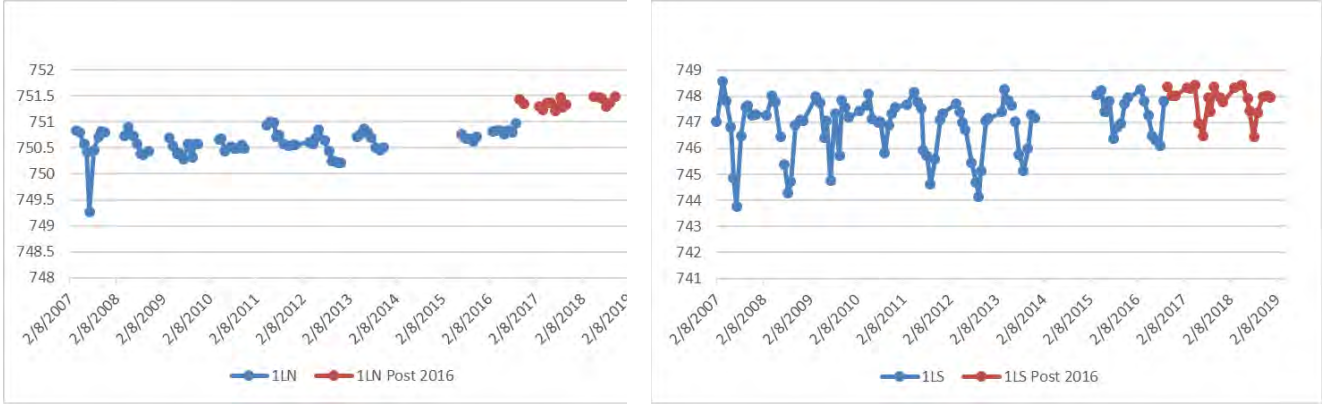
Source - MN Geospatial Commons (MNDNR and MNDOT)

Graph 4-6. Groundwater Levels in Nicols Meadow Fen Wells F1–F4 (Left to right, top to bottom: 452922, 452924, 452923, and 452925)



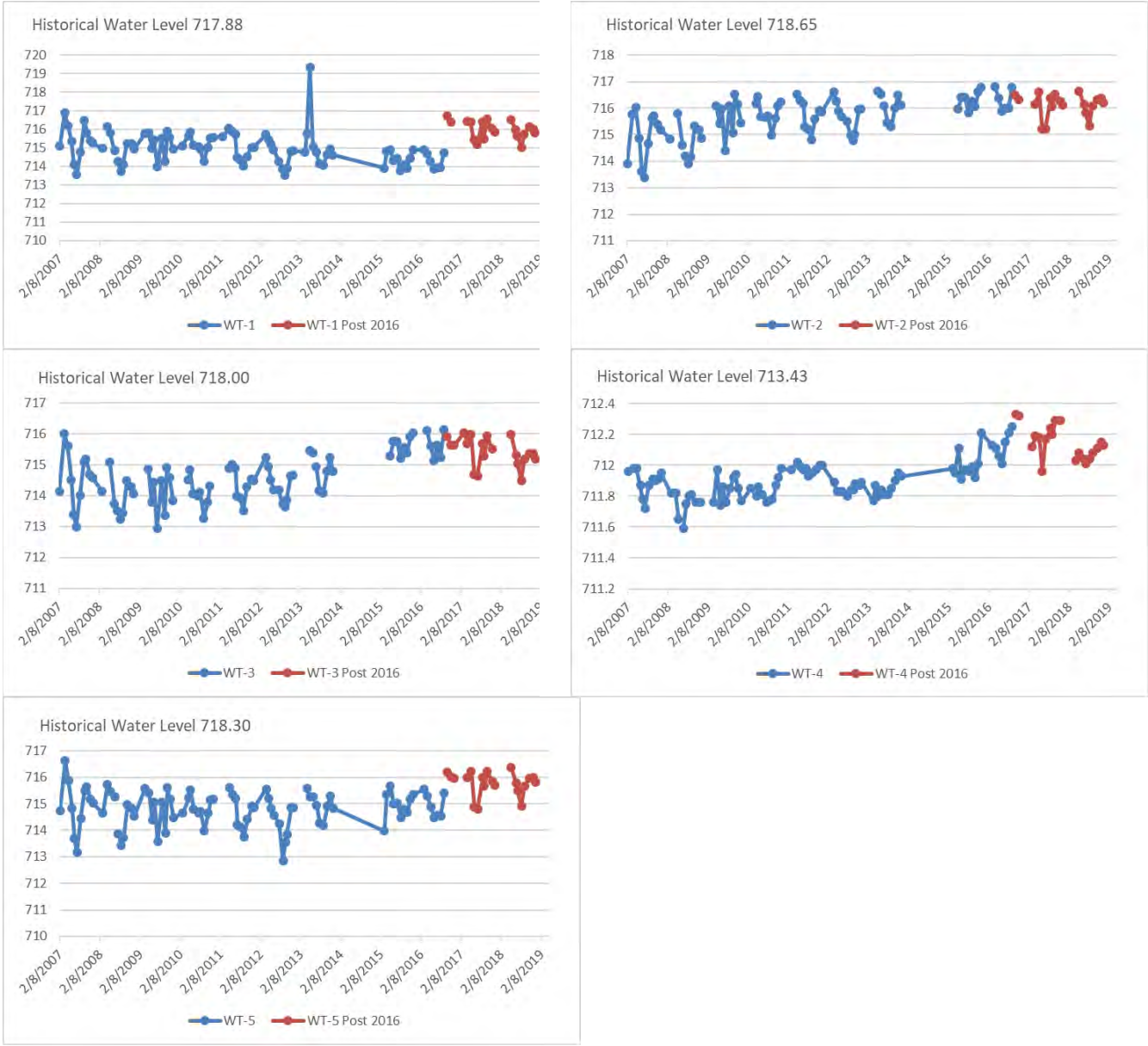
Note that the wells were resurveyed in 2016, which is shown in red.

Graph 4-7. Groundwater Levels in Nicols Meadow Fen Wells 1LN and 1LS (526701 and 522299)



Note that the wells were resurveyed in 2016, which is shown in red.

Graph 4-8. Groundwater Levels in Nicols Meadow Fen Wells WT1–WT4 (Left to right, top to bottom: 540952, 277773, 277771, 277772, and 277770)



Note that the wells were resurveyed in 2016, which is shown in red.

4.4 Black Dog Lake Fen Complex

Black Dog Lake Fen complex is located in Dakota County, within the City of Burnsville. Black Dog Lake Fen complex, shown in **Figure 4-5**, consists of four physically isolated surface features described as Black Dog Lake Fens *a*, *b*, and *c*, in addition to Black Dog Lake North Fen. The primary group (*a*, *b*, and *c*) is located east of Interstate 35W and south of Black Dog Lake. Each fen in the primary group is probably part of the same hydrogeologic system, although the plant communities show distinct

separation. Whether this separation is the result of human activity in the area or natural variability is unknown. Black Dog Lake North Fen is located about 3 miles northeast of the primary Black Dog Lake Fen and to the southwest of Cedar Avenue (TH 77); it is hydrologically more associated with Nicols Meadow Fen, based on their proximity. It is possible that Nicols Meadow Fen and Black Dog Lake North Fen were part of the same complex before Cedar Avenue divided them in 1890 (WSB & Associates, 2008).

There has been speculation by MNDNR staff that other parts of the fen are evident nearby but have been divided by railroad tracks or other manmade features, making it difficult to determine the size of the fen or if the fen community still exists.

4.4.1 Topography and Land Use

The land upgradient of Black Dog Lake Fen complex slopes upward toward the southeast with subtle terraces. **Exhibit 4** shows that the area upgradient of the Black Dog Lake Fen complex is primarily park, recreational, or preserve, with industrial and utility developments nearby, and residential land use further away. Based on the information documented in **Appendix C**, a significant portion of the park and preserve lands surrounding Black Dog Lake Fen may develop into low-density residential in the future. Planned land use shown in **Exhibit 5** encompasses most of the area upgradient of the fen complex as multi-optional development. According to the Metropolitan Council (MetCo, n.d.) multi-optional development suggests residential, industrial, commercial, and/or office uses.

Appendix C provides a detailed breakdown of land ownership at Black Dog Lake Fen, but roughly 60 percent of the direct drainage area is public, while 32 percent is privately held, and the remainder is transportation and utility right-of-way. The U.S. Fish and Wildlife Service owns the property immediately surrounding and east of Black Dog Fen complex. Urbanization of the undeveloped lands and larger properties, like Kraemer Quarry and Burnsville landfill, may adversely impact the health of the fens by reducing infiltration and recharge of the aquifer and allowing pollutants to enter the fen through stormwater runoff. While there are proposed changes in the current (2016) land uses, many of these changes appear to be minor and of low risk to the fen. Conservation purchases are not recommended until the MNDNR determines if enough of the native fen community exists to be viable.

4.4.2 Vegetation

Several vegetation surveys of the Black Dog Lake fens were reviewed for this report. Most were conducted in the 1990s and were not always specific about the locations surveyed. There is insufficient location information to attribute the survey as belonging to Black Dog Lake Fen *a*, *b*, or *c*. Year the

survey was conducted was estimated in some cases because the dates were not always documented. The early vegetation surveys described groupings of species that are characteristic of fens.

- **1985:** Management Plan Black Dog Preserve Scientific and Natural Area (SNA) (MNDNR, 1985) describes the location, access, features, and management considerations of the Black Dog SNA. It identifies eight rare plants associated with calcareous fen communities and other species that could be invasive. Threats to the resources and action plans are presented.
- **1987:** A vegetation survey, possibly conducted during 1987, of a "fen located between a landfill and the Chicago and Northwestern Railroad" notes "a degraded fen area from construction and a drainage ditch." It also notes "undisturbed parts are excellent example of rare fen community."
- **1994:** The MNDNR completed detailed vegetation survey in July and September titled "Dakota Co Site #7 Black Dog Lake Original form." It contains hand-colored maps showing summaries of vegetation in the entire wetland area south of Black Dog Lake between highways I-35W and TH-77. Unfortunately, the information is difficult to interpret because no map key is provided to understand the meaning of the abbreviations and the map color-coding. It describes three calcareous fen indicator species as being present. The publication also references the Black Dog SNA Resource Inventory Management Plan, 1984, which presumably is the 1985 document described above (MNDNR, 1985).
- **2008:** A Field Review by MNDNR biologists Norris, Texler, Miersch, and Booth on June 12 made an initial conclusion that a calcareous fen no longer existed here because hydrology had been disrupted sufficiently to eliminate fen conditions.
- **2018:** Two MNDNR botanists and a hydrologist visited Black Dog Lake Fen *a*, *b*, and *c* (Andrews, Hydrologist, MNDNR, 2019). They found no evidence of an intact fen community. They did, however, find and confirm a rare plant species.
- **2019:** The MNDNR provided an update Black Dog Lake Fens on June 17, 2019 (Andrews, email, 2019). Staff had evaluated Black Dog Lake Fens *a* and *b* for 30 minutes with the following results reported: "no fen plants, highly disturbed, soil is dry, storm water outlet has down cut 12 feet through the peat from the railroad to the river. . . . At Black Dog Lake Fen *c*, the north site was absent of fen plants, while the southern site had a wet meadow community. Whether the Black Dog Lake Fen complex can recover from this disturbance is unknown."
- **Date unknown:** A vegetation survey of Black Dog Lake Fens *a*, *b*, and *c*, in addition to an expansion of *c*, named *d*, was conducted, but the date is uncertain. It identifies the species present in fens *a*, *b*, and *c*. When compared with the list of species indicative of fens, we were unable to verify that any of the species identified, with one uncertain identification, were indicative of

calcareous fen plant communities. The most abundant species identified were invasive such as "RCG" (presumably reed canary grass, *Phalaris arundinacea*) and purple loosestrife (*Lythrum salicaria*).

The presence of calciphyte species at Black Dog Lake Fen complex has been spotty, at best. While pockets of rare plant species may exist, it is not clear that the fen community is intact, and the calcareous fen at Black Dog Lake may be extinct.

4.4.3 Geology

Soil borings deep into the Black Dog Lake Fens were not found, so information to describe the geology of the Black Dog Lake Fens specifically is unavailable. The geology generally will conform to that of other nearby fens. The unconsolidated sedimentary units present in the lower Minnesota River valley area where the Black Dog Lake Fen complex is located consist of organic deposits, terrace deposits, and floodplain alluvium. Organic deposits consisting of peat and organic-rich silt and clay underlie the fens. Terrace deposits are located at the higher elevations bordering the floodplain consisting of sand and gravel. Floodplain alluvial deposits consisting of poorly bedded clayey silt are located at lower elevations near the Minnesota River (**Exhibit 2**).

The depth to bedrock in the vicinity of the Black Dog Lake Fens ranges from less than 50 feet below the land surface to more than 50 feet (**Exhibit 3**). The fens are located near a transition on the depth to bedrock maps, so the depth to bedrock could be as much as 100 feet.

4.4.4 Hydrogeology

The Black Dog Lake Fen complex is in an area where the bedrock aquifer has a steep gradient toward the Minnesota River valley. The groundwater potentiometric surface elevations rapidly drop from nearly 800 feet mean sea level (MSL) beneath the upland bluffs to less than 700 MSL at the Minnesota River during median flows (Palen, 1990). Those deposits overlay a confined bedrock aquifer where hydrostatic pressure forces water to the surface, creating discharge areas where the fens can form.

The Black Dog Lake Fen complex is located east of Kraemer Quarry, a large, active dolomite-extraction quarry separated only by I-35W (**Figure 4-5**). The quarry dewaters 10 million gallons per day that are pumped to the Minnesota River (Minnesota Department of Health 2008). This can deplete the bedrock aquifer near the fen, which also draws down the surficial aquifer above the bedrock, and results in desiccation of the underlying peat substrate. These processes will continue to have negative effects on the Black Dog Fen complex until the groundwater appropriations are reduced or ended.

The land near the fen is mostly encompassed by the City of Burnsville, which gets most of its drinking water from wells in the Jordan, Mt. Simon, PDC–J, and Franconia-Mt. Simon bedrock aquifers. Burnsville also supplements its water supply with water pumped from a nearby quarry that dewaters the PDC–J. There appear to be holding ponds and other water features associated with their water supplies that may add to the recharge of groundwater near the fen.

In 2009, the nearby communities of Burnsville and Savage started reclaiming about 3 million gallons per day of that water for domestic water supply (Feyder, 2014), with the excess water being pumped to the Minnesota River.

As discussed in **Appendix B**, no monitoring wells were found in the Black Dog Lake Fen complex and there does not appear to be any monitoring of groundwater levels. Without this information, it cannot be determined whether permitted groundwater withdrawals are depleting the water that would sustain the fens; however, reviewing the permitted groundwater withdrawals from the cities of Burnsville, Eagan, and Savage may provide insight into whether the calcareous fen groundwater hydrology is still intact before installing new wells.

4.4.5 Geochemistry

No specific water-chemistry data for the Black Dog Fens were found.

4.4.6 Minnesota River Influence

Black Dog Lake Fen is within the 100-year floodplain of the Minnesota River, but due to the lack of groundwater level data in the fen, it is not known if this is a concern. Ground surface elevations show that Black Dog Lake North Fen is nearly 5 feet lower than the 100-year floodplain elevation of 714.6 (FEMA, 2020) and would likely be inundated during periodic flood events on the Minnesota River. The remainder of Black Dog Lake Fen complex has an average elevation of 724 feet, nearly 10 feet above the Minnesota River floodplain, and is unlikely to experience adverse effects from floodwaters.

4.4.7 Information Gaps and Needs

The Black Dog Lake Fen complex has been degraded by various outside pressures, including the construction of I-35W as well as land development and climate variability. Nearby permitted water withdrawals continue to affect the fen complex, despite reclamation projects by the cities of Burnsville and Savage. Below are some information gaps and recommendations to better manage the fen in the future:

- The Black Dog Lake Fen complex area may be subject to future development including the close of the Kraemer Quarry operation and conversion of the quarry to a deep water-supply reservoir for Burnsville and Savage. This could affect water levels in the aquifer supplying water to the Black Dog Lake Fen complex. More information on these projects is necessary to determine the effects on the fen.
- A nearby closed landfill leaking contaminants may result in excavation of the landfill and removal of its contents elsewhere (USEPA, n.d.). The owners of Kraemer Quarry also are interested in expanding their excavation to the area under the closed landfill. Each of these efforts would require additional dewatering for an indefinite time, further drawing down the underlying aquifer and drying out the fen.
- The head cut identified at Black Dog Lake Fens *a* and *b* may cause water from the fen and its underlying peat to drain further, resulting in desiccation and compaction of the substrate. Further review into the cause of the head cut may be warranted to determine if the fen hydrology has been irreversibly altered.
- A change in groundwater withdrawals may restore groundwater flow to the fen, but whether the fen vegetation can recover is uncertain. While pockets of rare plant species may exist, it is not clear that the fen community is intact, and the calcareous fen at Black Dog Lake may be extinct due to the altered hydrology.
- Monitoring of water levels in the Black Dog Lake Fen complex may not be justified because the fen itself may be too degraded to support calcareous fen vegetation any longer. Rather than invest in new monitoring wells, the MNDNR recommended reviewing available well permit data from the cities of Burnsville and Eagan, which could be valuable in determining whether the calcareous fen groundwater hydrology is still intact.
- In 2020–2021, the MNDNR plans to assess if the native calcareous fen vegetative community still exists within Black Dog Lake Fen. The outcome of this assessment will determine whether wells are placed in the fen or not.

HENNEPIN COUNTY

DAKOTA COUNTY

BLOOMINGTON

Nicols Meadow Fen - A

Nicols Meadow Fen - B

Nicols Meadow Fen - C

Black Dog Lake North Fen

Minnesota River

Union Pacific Railroad

35W

77

Black Dog Lake

13

BURNSVILLE

EAGAN

Burnsville Landfill

Black Dog Lake Fen - A

Black Dog Lake Fens - C

Black Dog Lake Fen - B

Kraemer Quarry

Fens Sustainability Gaps Analysis
Carver, Dakota, and Scott Counties Minnesota
Figure 4-5: Black Dog Lake Fen Complex Location Map

Fen
Estimated Fen Extent
HVRA Overlay District
City Boundary
County Boundary
LMRWD Boundary
Rail Line

LOWER MINNESOTA RIVER WATERSHED DISTRICT

0 0.25 0.5 1 Miles

N

Young Environmental Consulting Group, LLC

Source - MN Geospatial Commons (MNDNR and MNDOT)

4.5 Savage Fens

The Savage Fen complex is located in Scott County, in the City of Savage. It is roughly bounded by McColl Drive to the South, State Highway 13 on the north and west, and Savage Fen SNA to the east. The Savage Fen complex consists of eight distinct areas that make up the larger fen complex identified on at least one map image from 1998 that was provided by the MNDNR (**Figure 4-6**).

4.5.1 Topography and Land Use

Savage Fen is surrounded by residential and industrial land use, with some agricultural areas remaining today (**Exhibit 4**). The fen complex is separated from the Minnesota River valley by State Highway 13 and some light industry to its north; it lies at the base of bluffs that are about 100 feet high to its south. The plateau above the bluffs, which constitutes much of the shallow-groundwater recharge area, is mostly agricultural, residential, and undeveloped.

Because of its proximity to the urban areas, the Savage Fen complex has experienced many disturbances, including attempts at road building, dumping, and off-road vehicle use. Several attempts have been made to complete Dakota Avenue (County State Aid Highway 27) through the fen complex, but that could alter fen hydrology and connectivity. The planned land use shown in **Exhibit 5** suggests that much of the land adjacent to and upgradient of the fen complex could be converted from agricultural and undeveloped land and made available for residential development and multi-optional development. According to the Metropolitan Council (MetCo, n.d.), multi-optional development suggests residential, industrial, commercial, and/or office uses. This type of development poses a high risk to the fen in terms of altered hydrology and reduced groundwater recharge from the addition of new impervious surface, discussed in detail in **Appendix C**.

As mentioned previously, there is ongoing pressure for commercial, industrial, and residential development around the fen complex, with a complete loss of the current (2016) undeveloped lands, shown on the planned land use map (**Exhibit 5**). Ownership of the lands surrounding the Savage Fen complex is discussed in detail in **Appendix C**, with private ownership constituting 59 percent of the HVRA. Given the potential for private lands to develop into higher-risk categories, **Appendix C** recommends pursuing the purchase of private land for conservation for approximately $2.2M, based on the 2019 taxable value of the land. Grant funding sources are available for the purchase of conservation lands, including the Legislative-Citizen Commission on Minnesota Resources and the Trust for Public Lands among other entities. A review of potential funding sources should be evaluated and applied for to secure this area in the future.

Much of the private property south and upgradient of the fen complex is owned by Karl Bohn and his namesake partnership. As a major landowner, Mr. Bohn has shown great interest in the Savage Fen complex because he has attended many of the meetings of record concerning the future of the resource. Many other entities own small parcels upgradient of the fen complex.

4.5.2 Vegetation

Savage Fen has been the subject of several vegetation surveys, detailed below.

- **1980–82:** The MNDNR conducted a series of relevés and identified an abundance of calciferous plant species.
- **1987:** A series of relevés seem to confirm the presence of calciphiles, but the results were not as supportive of a strong calcareous fen community. Records of subsequent formal vegetation assessments were not found, but field notes suggest several informal assessments of fen health, including reports that rare calcipherous plants were observed. Also noted were several instances of invasive species, especially reed grasses, including *Phragmites*.
- The MNDNR provided records showing vegetation management of Savage Fen from 1987 to 2019 (Bernardo, 2020). Manual removal and spot spraying were employed at focused locations to control a variety of invasive species several times during 1987–2019. A prescribed burn was conducted in April 1993.
- **1994:** Komor (1994) offered two possible explanations for the encroachment of reed grass in Savage Fen. The first is the result of more soil erosion and runoff of sediment-laden water into Savage Fen because of development. The second observed that wetland drainage in the recharge area removed sites of focused recharge and diminished the supply of upwelling groundwater at the fens.
- **2008:** The U.S. Army Corps of Engineers conducted relevés at five sites in Savage Fen in 2008 (Eggers, 2020). Two of the sites had at least five calcareous fen indicator species present and only one site had none.
- **2019:** A return visit, not a relevé, in 2019 (Eggers, 2020) stated that two of the sites looked radically different in 2019 compared with 2008. The site having the highest condition calcareous fen community in the entire Savage Fen complex in 2008 was described as having become a thicket of young glossy buckthorn shoots by 2019. The other three relevé locations were still recognizable in 2019 as the plots that were completed in 2008, but *Phragmites* and buckthorn were encroaching on the site.

The vegetation surveys conducted at Savage Fen complex demonstrate the continued encroachment of invasive species into the calcareous fen, particularly reed grass and buckthorn, since the mid-1980s. Those with concerns about restoring calcareous fens may find some relief in the results of restoring part of Savage Fen. A portion of the fen was excavated and filled to establish a roadway through the fen circa 1984. The replaced peat was planted with native fen vegetation in May 1987. By 1995, the plant community appeared to have returned to its native population; however, a summary of *Restoration Attempt of Highly Disturbed Fen Area by Eggers* (2016), completed in 2016 showed that the following actions were most successful in restoring that part of Savage Fen:

- Replaced fill material with fen peat
- Restored wetland hydrology
- 80 percent relative cover by native species, 115 species overall
- Six calciphiles colonized site, including a state-threatened species and an orchid species
- Prescribed burns
- Hybrid cattail and *Phragmites* dominated one third of site
- Control effort (herbicide) for *Phragmites* good for seven growing seasons, then needed to be retreated
- Sterile sedge: appeared after nine growing seasons and three prescribed burns. According to the MNDNR, sterile sedge (*Carex sterilis*) is one of the strongest indicators of a healthy calcareous fen.

4.5.3 Geology

The shallowest bedrock beneath the fen is the Shakopee formation, which is the uppermost member of the Ordovician Prairie du Chien group. The Shakopee formation consists of fractured sandy dolomite (**Exhibit 5**). Overlying the bedrock are 3–30 feet of sedimentary glacial deposits (**Exhibit 4**). The peat beneath the fen is between 2 and 15 feet thick.

Two west-to-east geophysical surveys of part of the Savage Fen, using seismic reflection to determine the depth of geologic features, were conducted in 1997 (Skancke, 2019). The results suggest bedrock about 20–25 feet beneath the fen surface, which rapidly drop to 40 or more feet bls near the edge of the fen. Another seismic model suggests that the bedrock surface might be only 15 feet bls but declines steadily from west to east, with some irregularities, to about 40 feet bls.

Samples of groundwater discharging to the Savage Fen complex were determined to be less than 40 years old in 1994 (Komor, 1994), indicating that recharge water may be susceptible to contamination because it is recent, shallow water.

4.5.4 Hydrogeology

Groundwater recharges on the terraces and uplands to the south. The terraces and uplands hydrologically upgradient of Savage Fen are covered by cultivated and fallow fields, suburban and rural homes, and numerous small lakes, ponds, and wetlands. Groundwater in the upland areas flows northward through the dolomitic bedrock and overlying glacial till and discharges in the Minnesota River Valley.

Groundwater coming into the Savage Fen wetland complex is provided by the drift (glacial sand and gravel) aquifer, although the deeper PDC–J bedrock aquifers also could provide discharge. The precise boundaries of the recharge areas for both the drift and PDC–J aquifers are not known but are believed to extend as much as 10 miles to the south (Komor, 1994).

Jeanette Leete of the MNDNR led an effort to develop a multilayer analytical element model (MLAEM) to better understand the hydrogeology of Savage Fen. The project was not pursued to completion because of lack of support.

Water levels for selected Savage Fen wells with long-term records starting in the late 1980s to early 1990s are shown in **Graphs 4-7** through **4-10**. Information about the locations and construction of the groundwater monitoring wells in Savage Fen Complex is provided in **Appendix B**. It shows that wells are located mostly near the western edge of the complex and may not be representative of the overall hydrology. Except for Well 6 (#244113), with water levels that increased about 2 feet during the 1990s and remained at the increased levels, most of the well water levels were seasonally variable but showed no long-term trends. However, water levels in Wells 8 (#244111), 9 (#491702), and especially 10 (#431194) started to exceed the height of the measuring point (MP) and became flowing wells after about 2010. This is evident through readings, often appearing as spikes on the graph, that are equal to the MP. Some of the graphical software ignores readings greater than or equal to the MP and might not indicate that water levels have increased in recent years. Nearby deep and shallow observation wells (#517640 and # 517639) located on the bluff above the Savage Fens (**Graphs 4-11** and **4-12**) show a substantial and sustained increase of about 3 feet in water levels, starting in 2013. This nearby increase in water levels may also be affecting water levels in the fen and the wells located there. These increased water levels could be the result of increased precipitation or decreased groundwater withdrawals as surrounding communities switched their supplies to water reclaimed from nearby Kraemer Quarry (Feyder, 2014).

As detailed in **Appendix B**, there are a number of wells in the vicinity of Savage Fen, primarily clustered in the western and central fen areas. While some of these wells are outside the LMRWD's boundary, after discussion with the MNDNR, these wells were determined to be valuable for monitoring the health of the Savage Fen. Thus, the MNDNR recommends maintaining these wells and has also suggested that some of the existing wells be considered for sealing while others may benefit from additional instrumentation. Although the existing wells are clustered to the west, these wells provide the information needed to evaluate the health of the fens; no new wells to the east are warranted at this time. However, the MNDNR does recommend reviewing the fen in 5 years to determine whether new wells would be warranted.

4.5.5 Geochemistry

Komor (1994) collected and summarized a large amount of geochemical data for Savage Fens. This publication characterizes the chemistry of the groundwater and surface water at various locations in the fen. The report describes how water chemistry changes from its suggested source of recharge to where upwelling groundwater interacts with the peat, the vegetation, and the atmosphere. Komor (1994) surmised that much of the water discharging to Savage Fens passes through bedrock aquifers. However, chemical and isotopic signatures further suggest that water discharging to the fens is a mixture from near and distant recharge areas, following shallow and deep flow paths (Komor, 1994).

Consistent with other fens evaluated for this study, the groundwater discharging to Savage Fens is rich in calcium and magnesium carbonates. This groundwater discharge provides the basis for the hydrology that sustains the calcareous fens.

During 1989, Tom Gullett of the MNDNR used silver rods to assess the oxidation and reduction potential of the peat substrate beneath the fens. The silver rod turns black where the rod is exposed to free sulfide, which is where bacteria are reducing sulfate ions to free sulfide. The rod remains silver where no sulfide is present. It was not determined why this sampling was conducted. Although the exposure time was not evident, the results show strong stratification within the peat. The silver rods showed alternating layers, tens of centimeters thick, where the peat was either oxidized or reducing. This helps explain conflicting water chemistry results in which some samples have detectable concentrations of sulfate, whereas other samples contain no sulfate because has reduced to sulfide. It also helps explain why people sampling the wells sometimes note the smell of rotten eggs, which is an indicator of hydrogen sulfide gas where sulfate has been reduced to sulfide.

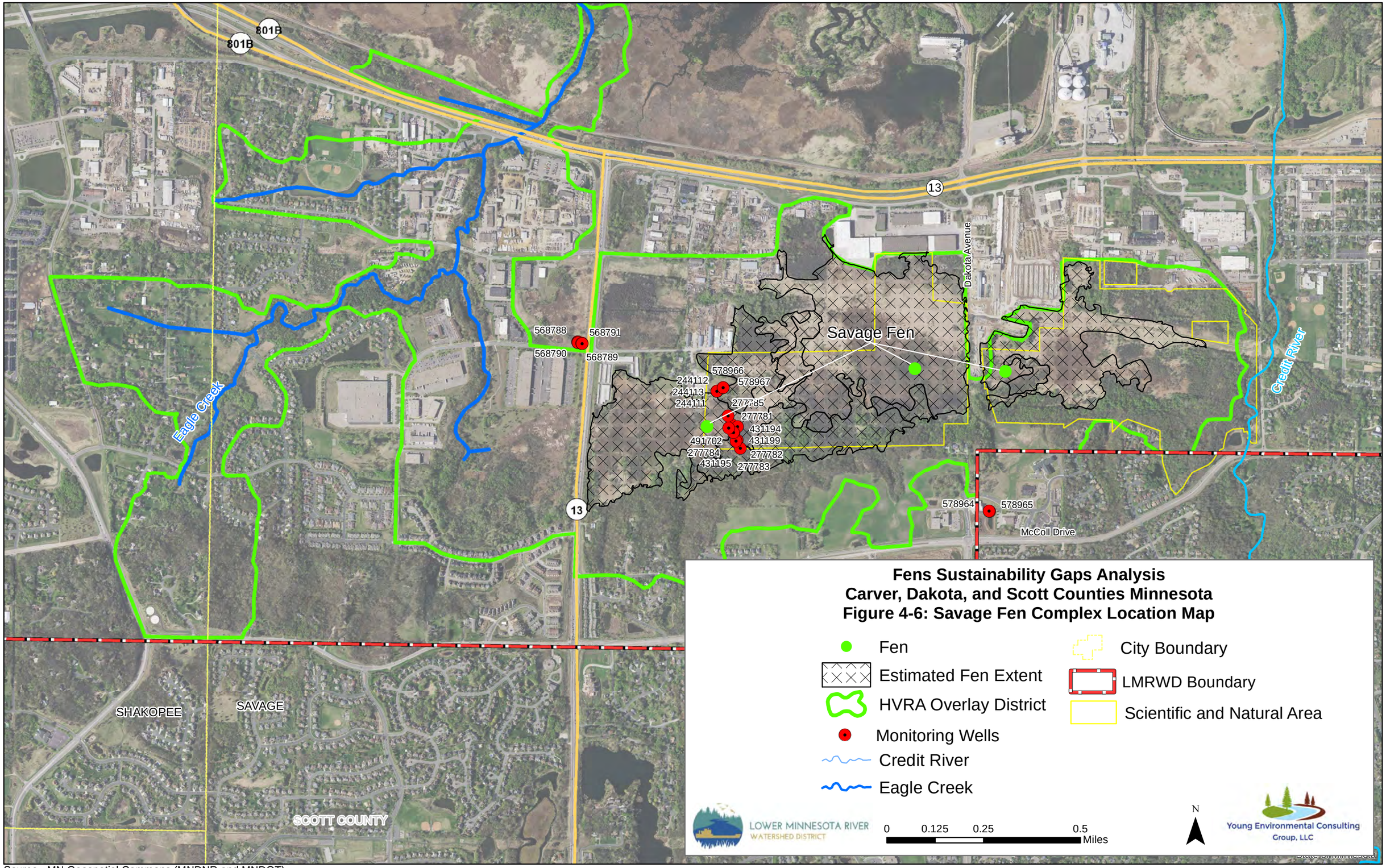
4.5.6 Minnesota River Influence

As discussed in **Section 3.3.2**, Savage Fen is not located in the 100-year floodplain, and most of the fen complex is above the 500-year floodplain elevation of the Minnesota River (FEMA, 1980, 1994). This is not to say that the fen does not experience flooding, only that the Minnesota River is not expected to affect the groundwater hydrology at Savage Fen.

4.5.7 Information Gaps and Needs

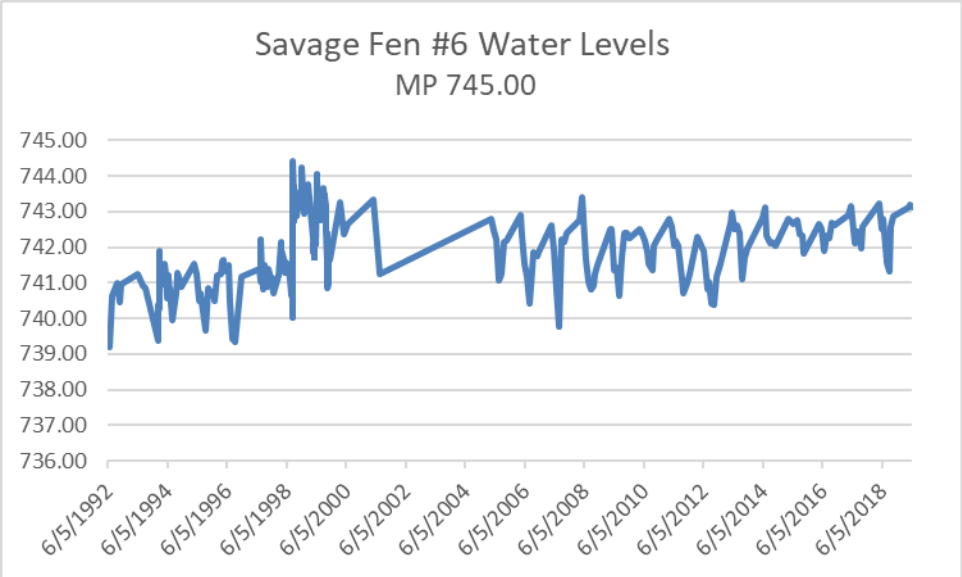
The Savage Fen has been heavily studied over the years, unlike any of the other fens evaluated for this report. The following findings may be unique to Savage Fen but could help our understanding of fen hydrology in general.

- Savage Fen is expected to experience increased land development losing most of the current (2016) open spaces for future industrial and commercial developments. Given the potential for impacts to the fen, it is recommended that consideration be given to the purchase of private fen land for conservation. The preliminary acquisition costs are estimated at $2.2M for Savage Fen and detailed in **Appendix C**. Grant funding sources are available for the purchase of conservation lands, including from the Legislative-Citizen Commission on Minnesota Resources and the Trust for Public Lands among others, to secure this area in the future. The vegetation surveys conducted at Savage Fen complex demonstrate the continued encroachment of invasive species into the calcareous fen, particularly reed grass and buckthorn, since the mid-1980s.
- Although the existing wells at Savage Fen are clustered to the west, these wells provide the information needed to evaluate the health of the fens; no new wells to the east are warranted at this time. However, the MNDNR does recommend reviewing the fen in 5 years to determine whether new wells would be warranted, particularly if the Dakota Avenue extension project is pursued.
- Recharge water is susceptible to contamination because it is recent, shallow water. Further studies of the impacts this may have on the Savage Fen are needed to determine if this is a potential risk to fen health.

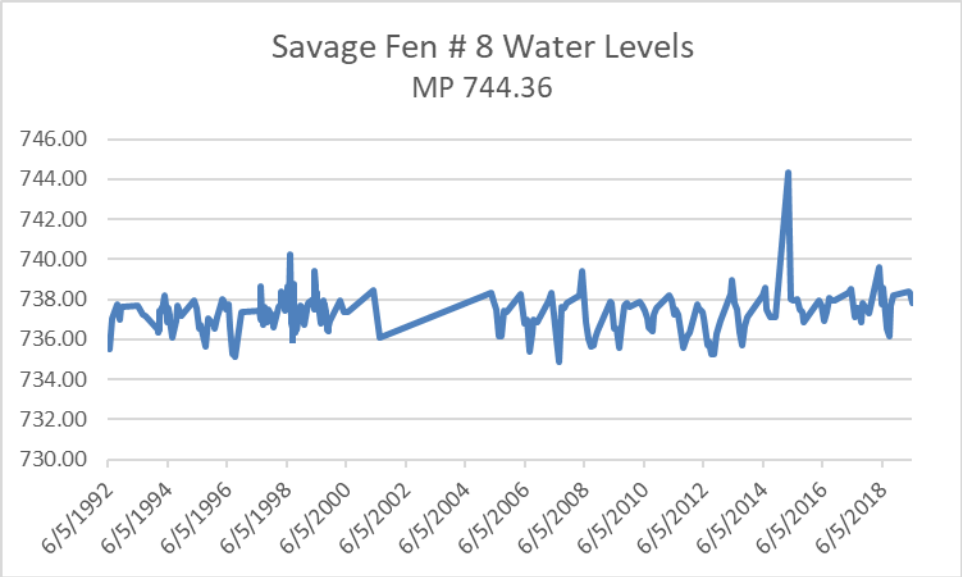


Source - MN Geospatial Commons (MNDNR and MNDOT)

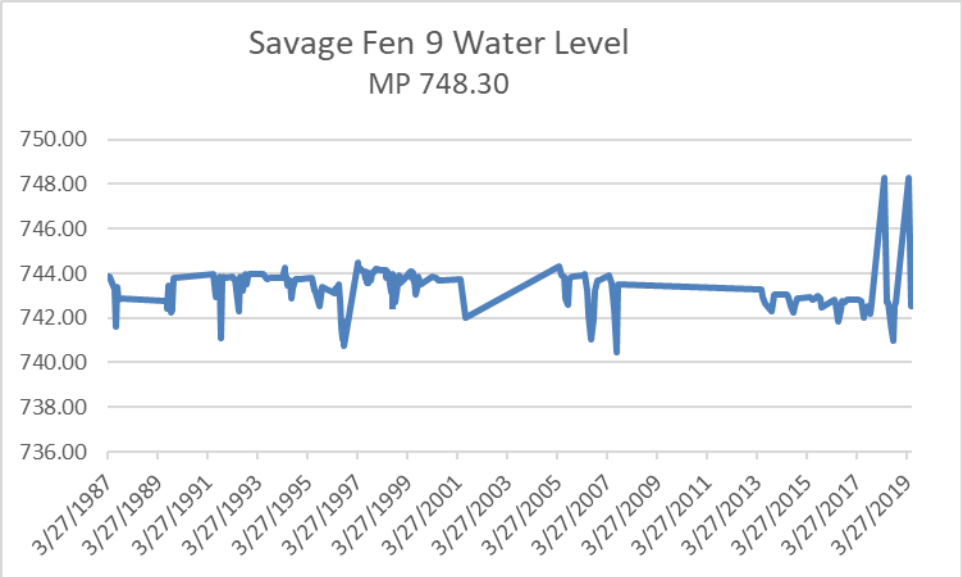
Graph 4-9. Groundwater Levels in Savage Fen Well 6 (#244113)



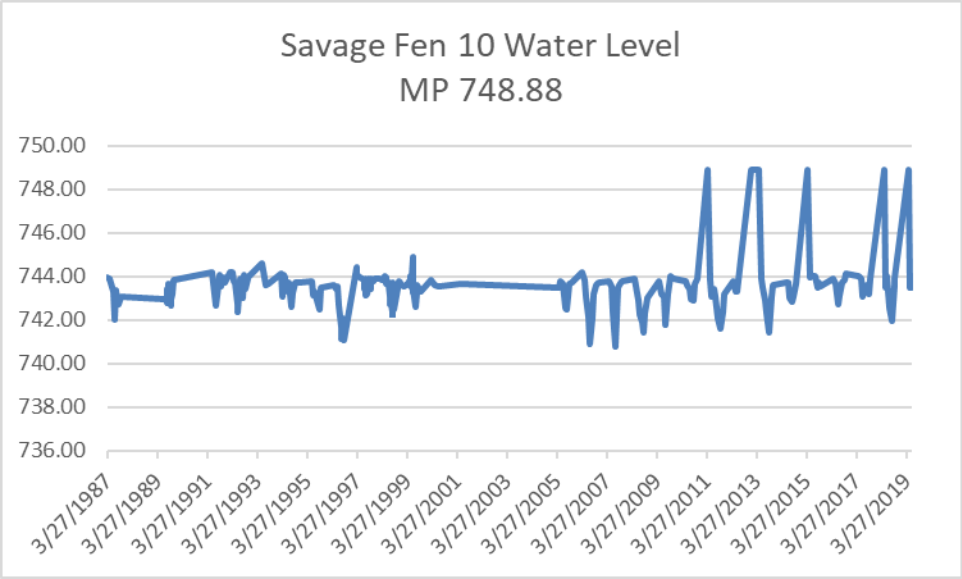
Graph 4-10. Groundwater Levels in Savage Fen Well 8 (#244111)



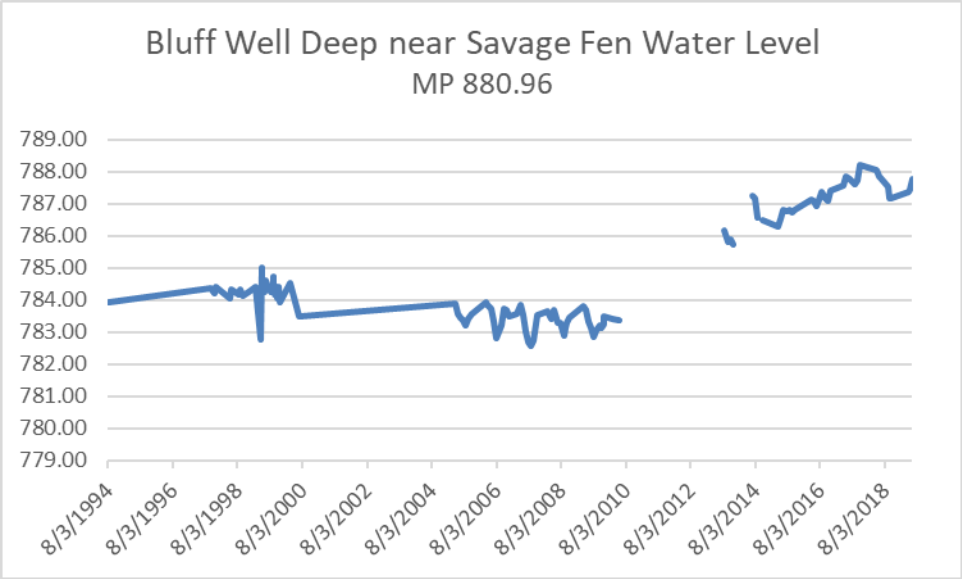
Graph 4-11. Groundwater Levels in Savage Fen Well 9 (#491702)



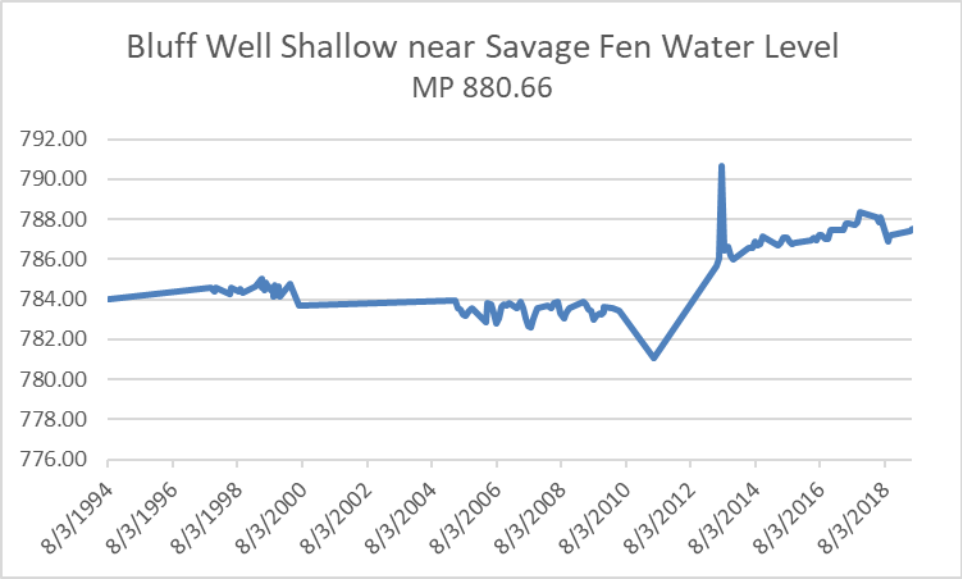
Graph 4-12. Groundwater Levels in Savage Fen Well 10 (#431194)



Graph 4-13. Groundwater Levels in Savage Fen Bluff Shallow Well (#517639)



Graph 4-14. Groundwater Levels in Savage Fen Bluff Deep Well (#517640)



4.6 Seminary Fen

Seminary Fen is the only fen in this study that lies on the north side of the Minnesota River, in Carver County (**Figure 4-6**). Seminary Fen lies mostly within the City of Chanhassen, with portions of the western edge of the fen complex overlapping into the City of Chaska. The fen is located along old Highway 212, west of Highway 101 and east of the City of Chaska. Seminary Fen is about 69 acres in size, but like most fens, the borders tend to be indeterminate. Seminary Fen is closely associated with

Assumption Creek, which may also receive most of its baseflow from groundwater upwelling, like the fen.

4.6.1 Topography and Land Use

Seminary Fen is situated on a hillside about 40 feet above the river valley. Much of the probable recharge area for the groundwater discharging to Seminary Fen is on top of the nearly 200-foot-high bluffs to the north that are roughly half residential and half parks and undeveloped areas. As a suburb of the Twin Cities Metropolitan Area, this area is experiencing rapid development that is expected to continue. However, some of the bluff terrain is cut by ravines and is too steep and unstable for development.

Seminary Fen was substantially altered when water was diverted from the fen to support the Mudcura Sanitarium spa (Olson, 2002). The surface disturbance of the fen and redirection of its water was considerable (Wetterlin, written communication, 2013). Mudcura opened in 1909 and was a rapidly growing business for several decades until its popularity waned in the 1940s. It was deeded to a group of Franciscans in 1951 who operated the Assumption Seminary and College. The buildings were abandoned in about 1970 and the MNDNR ultimately acquired the property to establish the Seminary Fen Scientific and Natural Area. Most of the historical disturbance of Seminary Fen and the adjacent Assumption Creek has been mitigated, but out-of-sight drainage tiles may still affect the hydrology, and keen observers will find remnants of the historic structures that altered the landscape.

Seminary Fen is thought to have some of the finest vegetative features in the area, including a prominent peat dome and an excellent community of native fen plant species. Portions of the fen were affected earlier in the 20th century when drainage tiles were installed and areas of the peat layer were mined. What remains of the fen complex, however, is still thought to be in excellent condition. The discovery of areas of fen south of Highway 212 has increased the value of this resource because portions of this area are less disturbed than other parts of the fen complex.

Current land use near Seminary Fen is shown in shown in **Exhibit 4**. Most of the land is park and open space with some agricultural land within the HVRA and in the SNA. The planned land use displayed in **Exhibit 5** shows the elimination of undeveloped land and the expansion of agricultural and multifamily residential land use within the HVRA and adjacent to the Seminary Fen SNA. As discussed in detail in **Appendix C**, while these types of land uses may not be as detrimental to fen health as a large-scale industrial complex might be, they can still affect infiltration and groundwater recharge, also causing increased stormwater runoff and pollutant loading.

The MNDNR owns much of the property within Seminary Fen, including the SNA. Several government entities, including Carver County, the City of Chaska, and the Hennepin County Railroad Authority, own adjacent properties. A detailed discussion of land ownership appears in **Appendix C**; while Seminary Fen is expected to experience development in the surrounding HVRA, most of these developments are anticipated to be low risk for the fen itself, and conservation purchases are not recommended at this time.

4.6.2 Vegetation

Many vegetation surveys of Seminary Fen have been conducted over the years. The main portions of the fen that have been more extensively surveyed lie north of Highway 212. More recent surveys indicate that good areas of fen remain in the area south of Highway 212. What follows is a brief summary of the highlights of those surveys.

- **1990:** Vegetation surveys of Seminary Fen conducted in 1990 by the MNDNR showed a strong presence of calcareous fen indicator species.
- **1995:** A relevé by the Minnesota Biological Survey (MBS), conducted in 1995, suggested that the presence of indicator species was not as strong. A second relevé, not attributed to any entity and interpreted in subsequent years, suggested that calcareous fen indicator species predominate in Seminary Fen.
- **2002:** Joannes Janssens performed a bryophyte (mosses) survey of Seminary Fen using the techniques described in the *Field Guide to Mosses & Liverworts of Minnesota's Calcareous Fens* (Janssens, 2014). Most vegetation surveys for calcareous fens, and those evaluated for this report, relied on vascular plants to characterize the plant communities, so this survey is not readily comparable to others. The survey suggested that the fens had a strong presence of calcareous fen indicator species.
- **2003:** Notes from a site visit dated August 20 listed many species that were identified in the fen, but only a few of them were considered indicator species, and they did not appear to predominate in the plant community.
- **2008:** A review of ecological assessments to evaluate the effects of rerouting Trunk Highway 41 close to Seminary Fen dated August 13 concurred that fen indicator species are present. However, a subsequent undated survey of a series of transects attributed to the MnDOT did not indicate a strong presence of calcareous fen indicator species.
- MNDNR provided records showing vegetation management of Seminary Fen from 2011 to 2016 (Bernardo, 2020). Manual removal and spot spraying were employed at focused locations to control a variety of invasive species several times between 2011 and 2016. Prescribed burns were

conducted in May 2011 and in 2015. Plant community reconstruction and reseeding was performed on about four acres in June 2016.

4.6.3 Geology

The bedrock exposure beneath Seminary Fen (**Exhibit 3**) is entirely of the Tunnel City Group, a complex formation from the upper Cambrian age that includes thin layers of fossiliferous sandstones, calcium carbonates, and conglomerates, many of which are cross-bedded and reworked by flood events (Eoff, 2014). The bedrock is about 250 feet below the land surface. The intervening material is predominantly glaciofluvial material, which is described as material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. This material would contain enough carbonates to enrich groundwaters flowing through it before discharging to Seminary Fen. Closer to the surface, the material is organic (biogenic), a result of the accumulation of peat beneath Seminary Fen.

Figure 4-8 shows a theoretical south-to-north cross-section looking west of the hydrogeology of Seminary Fen. Although it is not entirely consistent with the geology of Seminary Fen, it displays how the surface of the fen is an expression of the water table fed by groundwater from the north having a positive head, causing upwelling of groundwater beneath Seminary Fen.

4.6.4 Hydrogeology

Nearly 20 water-level observation wells have been installed in and around Seminary Fen that are classified as “actively read” with the data housed in the MNDNR’s CGM application. Information about many of those wells and a map showing their locations appears in **Appendix B**.

Two wells adjacent to Seminary Fen with recent data and another nearby well with the longest available water-level record were chosen to represent the hydrology near the fen. The long-term record at MW-7WT is shown in **Graph 4-15**. It is a water table well only 15 feet deep and shows seasonal fluctuations that would be expected as groundwater levels respond to snowmelt runoff followed by reduced declining water levels as evapotranspiration and possibly groundwater withdrawals reduce water levels. These annual fluctuations can be more than 6 feet some years. It is not known why those annual fluctuations became muted after 2014, but it appears that the extreme low water levels did not occur. Reduced pumping from nearby water supply wells could cause this change, but that was not investigated. The long-term record from this well does not appear to show any other trends.

Water levels for two other wells are shown in **Graphs 4-16** and **4-17**. The wells are adjacent to each other and are much deeper than other fen wells. QWTA (817607) is 79 feet deep, while CTCG (817606) is 300 feet deep. QWTA water levels show considerable variability but the range was always less than 2 feet. A

slight, sustained increase in the recent water levels is likely related to above-normal precipitation during 2019; rainfall at MSP during the first half of 2019 was more than 6 inches higher than normal (MNDNR, n.d.) The deeper well, CTCG, shown in **Graph 4-17** had annual water-level fluctuations of about 6 feet that do not seem related to recharge and evapotranspiration and may be the result of seasonal pumping. There are no peaks in springtime water levels, but there are substantial declines later in the summer months when withdrawals may be needed for irrigation.

As discussed in **Appendix B**, Seminary Fen has a good distribution of wells in its vicinity, including a number of wells that are outside the LMRWD boundary. After discussion with the MNDNR, these wells were determined to contribute to the overall understanding of the Seminary Fen hydrology, and thus they should be maintained.

Several wells (277864–277686) are to be kept until a future restoration project related to the erosion of a nearby spring-fed ditch is completed and then sealed. The MNDNR hopes to collect at least 2 consecutive years of monitoring data to aid in the development of restoration designs.

4.6.5 Geochemistry

Little chemistry data was found for Seminary Fen. Mention of chemical data was described in the environmental impact studies performed in conjunction with the realignment of TH 41, but the actual data were not found. The Phase I study (MNDOT, 2014) mentions that “all samples are calcium-magnesium-bicarbonate dominated waters with neutral to alkaline pH values that are uniformly above pH 6.7. Total dissolved solids content is high ranging from 200 to 1200 mg/L, with the majority of the samples ranging from 500 to 1000 mg/L.”

The Phase II study (MNDOT, 2007) discusses water samples collected June 22, 2006, using polyvinyl chloride (PVC) pipe driven into the peat substrate to collect water samples: “The pH of the groundwater samples ranges from 7.1 to 7.5, calcium ranges from 88 to 100 mg/l, EC ranges from 695 to 840 uS/cm, and alkalinity ranges from 4.6 to 7.8 meq/l. The pH of the surface water sample was 7.7, calcium was 100 mg/l, EC was 742 uS/cm, the alkalinity was 3.0 meq/l. All ground and surface water samples exceeded the minimum values of a calcareous fen.” These results show that the waters of Seminary Fen are consistent with those needed to support a viable community of calciferous plants.

4.6.6 Minnesota River Influence

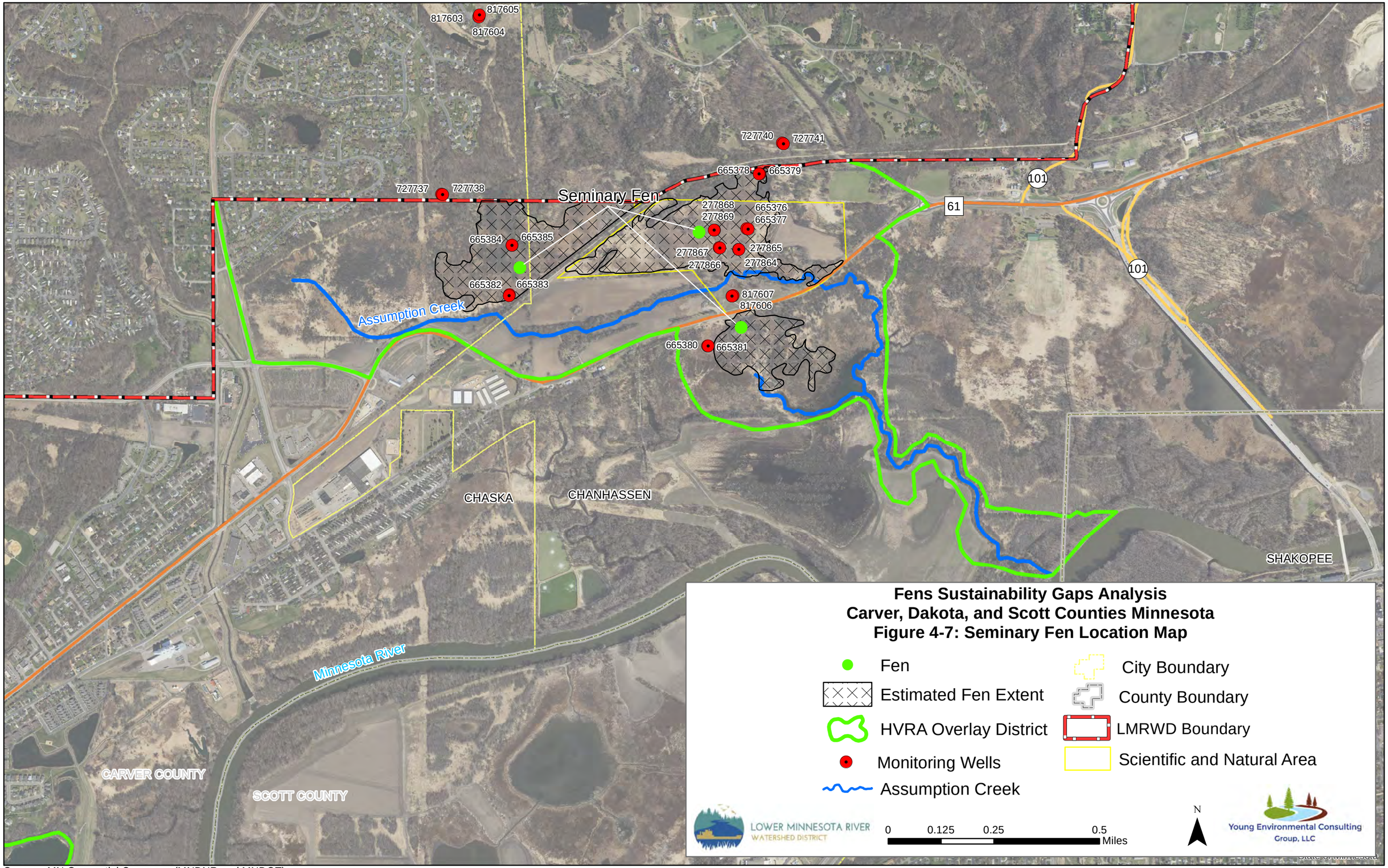
The majority of Seminary Fen is located significantly above the mapped floodplain elevations of 721 feet (FEMA, 2020). More precise estimations of flooding susceptibility may be made by comparing measured

fen water level elevations to projected flood-stage elevations at the cross-sections nearest the fens in the future.

4.6.7 Information Gaps and Needs

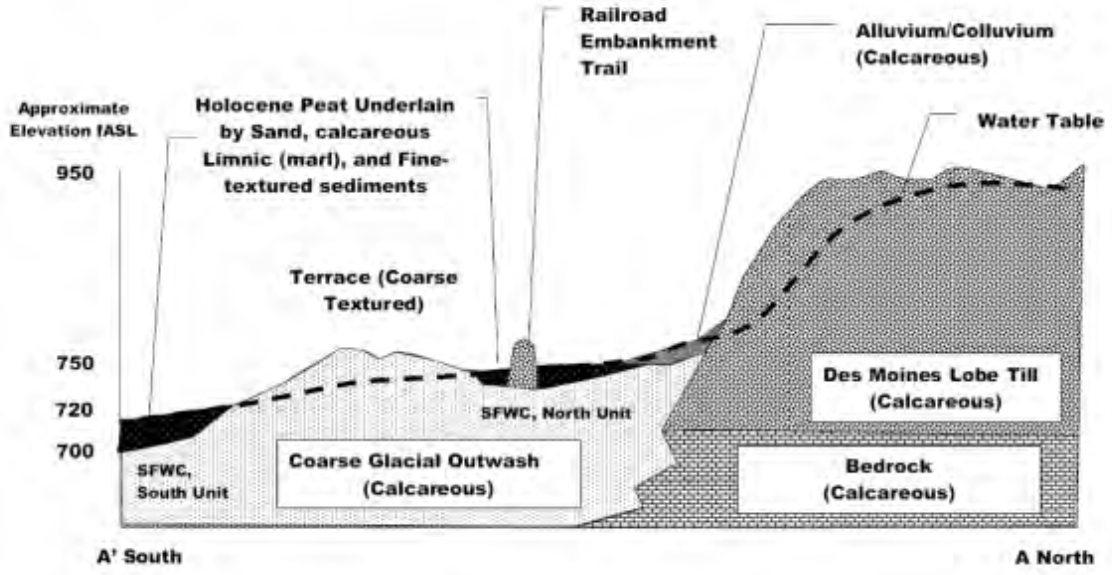
Seminary Fen is recognized as a high-value resource that is afforded considerable protection. Realignment and enhancement of highways and other roadways near Seminary Fen seem to be the most immediate threat to Seminary Fen. The planning documents reviewed for this study clearly identify threats to the fen resource and suggest alternatives that will protect the fen or avoid it entirely.

- Seminary Fen shows many signs of historic encroachment from agriculture, redirection of water to a spa, and roadways. Although the fen appears resilient, these scars may adversely affect it and should be examined to understand whether they must be corrected.
- Development in the recharge area in the upgradient bluffs should be designed to encourage recharge rather than directing stormwater to streams. Close coordination with municipal partners and continued enforcement of the District rules will help ensure adequate stormwater management is implemented to protect the health of the fen from the potential effects of future development.
- The MNDNR manages much of the fen as an SNA; however, some areas of the fen remain under private ownership. Planned land use discussed in **Appendix C** proposes expansion of agriculture and multifamily residential land use within the HVRA and adjacent to the Seminary Fen SNA. This could be a concern because the HVRA is considered a buffer area intended to provide resource protection.
- The uninterrupted supply of groundwater discharging to the fens must be maintained so the vegetation and underlying peat do not become desiccated. Several studies conducted in connection to the fen, including major highway alignments, asserted the importance of avoiding desiccation of the fens during dewatering or damming of water, often done as part of roadway construction.
- Reliable, long-term monitoring will provide the best information from this unusually dense network of monitoring wells. Reducing redundancy will improve the efficiency and reduce the costs of maintaining the monitoring network.
- Because Seminary Fen is relatively healthy despite a history of disturbances, routine water chemistry data should be collected to establish a record of groundwater chemistry and variability that will help establish the range of chemistries that could sustain calcareous fens.

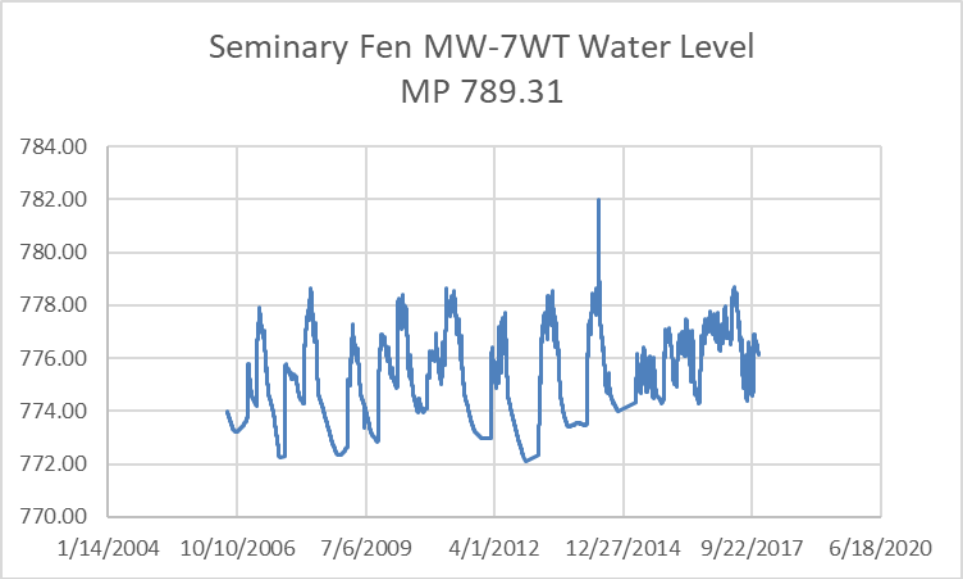


Source - MN Geospatial Commons (MNDNR and MNDOT)

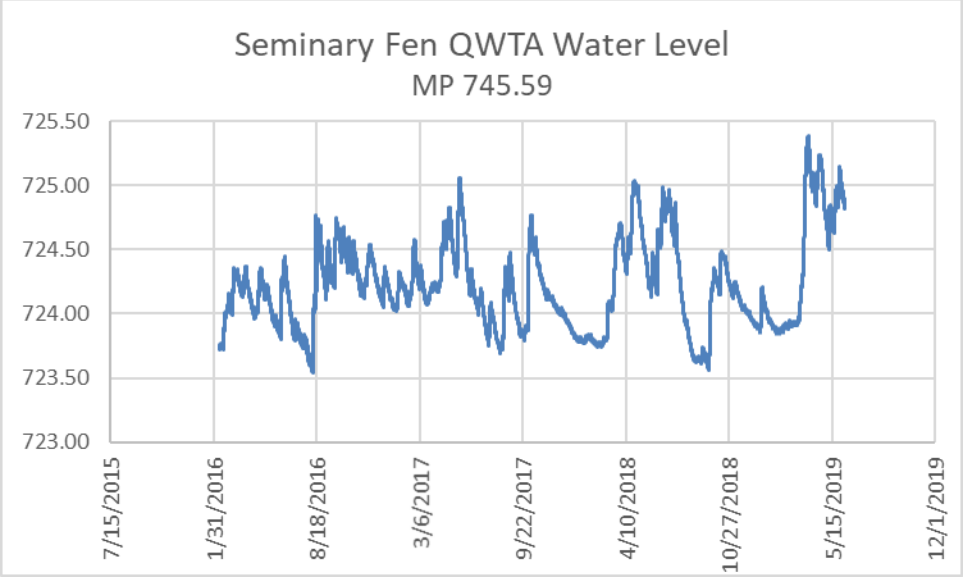
Figure 4-8. Theoretical Vertical Cross Section Showing Hydrogeology of Seminary Fen: Adapted from Peterson Environmental Consulting, Inc. (2006)



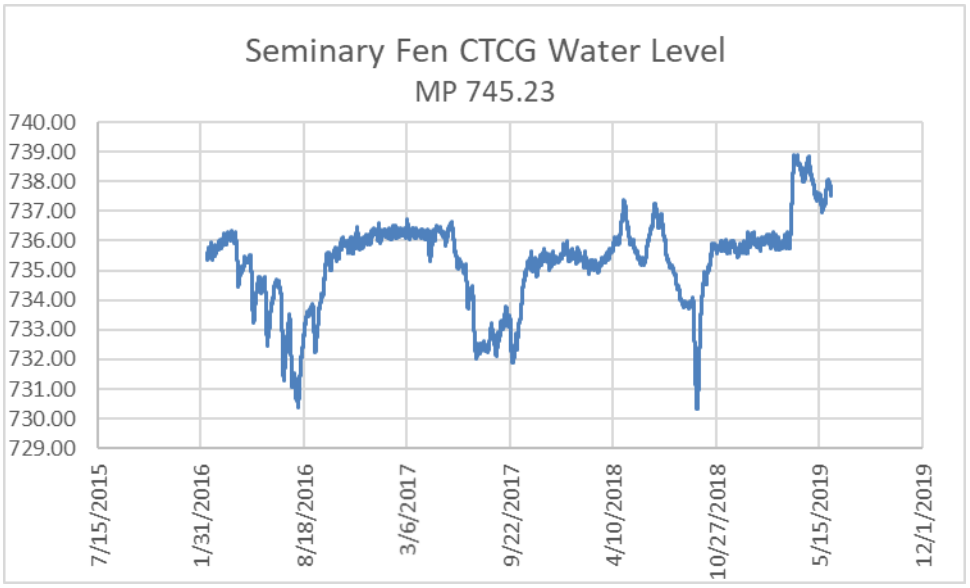
Graph 4-15. Groundwater Levels at Seminary Fen Well MW-7WT (727737)



Graph 4-16. Groundwater Levels at Seminary Fen Well QWTA (817607)



Graph 4-17. Groundwater Levels at Seminary Fen Well CTCG (817606)



5.0 SUMMARY AND RECOMMENDATIONS

The LMRWD fens have been subject to numerous studies and projects documented in this report. Many studies have tried to document the occurrence and distribution of indicator vegetation species in selected fens of interest to resource managers and researchers. Some have collected semiquantitative measurements of water chemistry, while others have conducted detailed studies of the interaction between the upwelling groundwater and water chemistry in selected fens. The reports and information resulting from these organized studies have provided great insight into the floristic and geochemical characteristics of calcareous fens.

Review and assessment of fen characteristics and data available revealed gaps in our understanding of the fens that must be addressed for future management of the LMRWD fens. **Table 5-1** summarizes important elements of fen characteristics ordered approximately by relative importance. The years included in the table are the most recently collected data, though some data collection is ongoing. Empty cells indicate that information is needed because existing data are dated or have uncertainties.

Table 5-1: Availability of Data and Gaps in our Knowledge of Fen Sustainability

Data Available	Gun Club Lake North Fen	Gun Club Lake South Fen	Nicols Meadow Fen	Black Dog Lake Fen	Savage Fen	Seminary Fen
Groundwater Levels	Ongoing	Ongoing	Ongoing	-	Ongoing	Ongoing
Vegetation Survey:						
Qualitative	2019	2019	2019	2019	2019	2019
Quantitative (Relevé)	2019–20	2019–20	2019–20	2019–20	2019–20	2019–20
Groundwater Chemistry	-	-	-	-	-	-
Resurvey Well Datum	2016	2016	2016	-	-	-
Bryophyte Survey	-	-	-	-	-	2002
Recharge Assessment	-	-	-	-	-	-

Carver and Dakota County SWCDs, Carver County Watershed Management Organization (WMO), the MCES, and other organizations have been collaborating with the MNDNR and the LMRWD for several

years to measure groundwater levels in each of the fens. These data are valuable to understand fen hydrology and to provide a baseline from which to assess whether water levels have changed over time. That collaboration and coordination is important and should continue. The following recommendations are based on the fen characteristics described in **Section 3**; these characteristics should also serve as a guide to maintain the health and longevity of the fens.

5.1 Land Conservation

The land surrounding calcareous fens in the Lower Minnesota River valley are integral to the health of the fens. To protect the fens in their jurisdiction, the LMWRD established High Value Resource Areas (HVRAs) that encompass the upstream areas that directly drain to the fens. Considering current and future development of the HVRAs and the risk of impact to the health of the fens, the detailed analysis presented in **Appendix C** recommends the following for consideration:

- Continue to enforce the District Rules and complete project reviews on all proposed developments within the fens' HVRA overlay districts.
- Savage Fen and Nicols Meadow Fen are both expected to experience increased land development from open space or park, recreation, or reserve areas to industrial and commercial developments. Given the potential for impacts to these fens, it is recommended that consideration be given to the purchase of private fen land for conservation. The preliminary acquisition costs are estimated at $2.2M for Savage Fen and $296,000 for Nicols Meadow Fen. Grant funding sources are available for the purchase of conservation lands, including from the Legislative-Citizen Commission on Minnesota Resources and the Trust for Public Lands among others. A review of potential funding sources should be evaluated and application and/or proposal draft to secure this area in the future.
- Black Dog Lake Fen, according to the MNDNR, is degraded due to a number of factors. Before any conservation practices can be recommended, it should first be determined if this fen is viable.

5.2 Vegetation Surveys

Conduct qualitative vegetation surveys to document the presence or absence of fen indicator species at the fen once every 2 to 3 years and a quantitative relevé every 5 to 7 years to verify whether fens are thriving or degrading. This would provide an indication of the variability in the fen community structure and would alert managers that invasive species have gained a foothold and need corrective actions.

A comprehensive vegetation survey, or relevé, of each fen in the LMRWD was scheduled to begin in August 2019 and will be completed in the summer of 2020. The data collected from this survey will be

evaluated to provide a uniform assessment of the health of each fen. More complete understanding of the health of each fen will help managers better direct resources to manage the fens.

It is recommended that bryophytes (mosses and liverworts) be included in subsequent vegetation surveys of the all fens (Janssens, 2014). Nearly all the vegetation surveys and relevés reviewed for this study focused on vascular plants. Some researchers recommend the use of bryophytes as another indicator of viable calcareous fens; they are identified as one of the characteristics to be used when delineating calcareous fens.

Manage invasive species in the fens using techniques such as manual removal or other environmentally sound practices that will not damage the fens. Controlled burns have been suggested, but no evidence was found to suggest that they are warranted for improving fen ecosystem health. It is not known whether fens periodically experienced wildfires, much as the native prairies historically did when they dominated the nearby landscape; in fact, the Wisconsin Wetland Association (2018) has cautioned that prescribed burns should not be used in peat bogs, presumably because peat fires can easily get out of control and consume all the peat that supports the wetland. A thick layer of peat sustains the fens and could be consumed during a controlled burn, destroying the fen.

5.3 Groundwater Monitoring

Establish routine, uniform groundwater monitoring for all the fens determined to be viable. A review of the existing fen monitoring well network is provided in **Appendix B**; wells at Gun Club Lake South Fen, Nicols Meadow Fen, and Seminary Fen are being monitored by the MNDNR and Dakota and Carver County SWCDs. These wells should be monitored either by the MNDNR or SWCD, not both. As conveyed in **Appendix B**, some fens have a great number of wells, while more wells are needed in other fens. Groundwater monitoring recommendations are summarized below:

- At Gun Club Lake North Fen, maintain the existing wells and continue hand-monitoring activities. Recommend installation of a new shallow and new deep well with instrumentation near the Union Pacific railbed, further removed from the influence of the Minnesota River and within healthy fen habitat.
- Analyze well records at Gun Club Lake South Fen for wells 482155, 482156, and 484653 to determine whether these wells should be maintained with the others identified in **Appendix B**.
- At Nicols Meadow Fen, maintain existing wells and consider outfitting them with instrumentation.

- At Black Dog Lake Fen, due to the degradation of the fen habitat, the MNDNR has recommended assessing the fen health before any wells are installed. The MNDNR has recommended reviewing available well permit data from the Cities of Burnsville and Eagan that could be valuable in determining whether the calcareous fen groundwater hydrology is still intact.
- Although the existing wells at Savage Fen are clustered to the west, these wells provide the information needed to evaluate the health of the fens, and no new wells to the east are warranted at this time. However, the MNDNR does recommend reviewing the fen in 5 years to determine whether new wells would be warranted, particularly if the Dakota Avenue extension project is pursued.

Water levels should be referenced to a measuring point at a known elevation and measured in at least two selected wells on a monthly basis, especially during April through October. These measurements would be at representative wells that already have long-term records of water levels.

The datum of the measuring point at the monitoring wells must be checked more frequently than they have been. Once every 5 years is recommended, but more frequent checks may be needed for wells located in soft substrate that are not anchored. A uniform process should be employed to correct well-datum differences that are apparent in many well hydrographs after monitoring-well datum were redetermined in September 2016.

5.4 Geochemistry

The geochemistry of the fens should be established by sampling at least one representative well in the aquifer beneath each viable fen once per year for dissolved major ions and nutrients. This will establish a water-chemistry baseline and will provide a basis for determining whether changes in a fen are related to the water chemistry. Field measurements for water temperature, specific conductance, pH, and dissolved oxygen concentration should be made at the time of sample collection. A sample also should be collected and analyzed to determine the stable-isotopic ratios of oxygen and hydrogen in the groundwater. This relatively inexpensive analysis can provide information that can be interpreted to determine the source of the waters recharging the groundwater. A subsequent synoptic, nonrecurring sampling of stable-isotopic ratios from upland surface waters in the perceived recharge areas should be conducted to further describe the flow of recharge waters to groundwater discharging into the fens.

It is also recommended that the LMRWD Monitoring Plan be updated to include this collection of geochemistry data, as described above.

5.5 Recharge Analysis

Identify recharge areas for each fen complex to better protect the fens from long-term adverse influences and changing land use in upland areas. Each fen has unique flow characteristics that cannot be generalized other than understanding that recharge occurs upgradient and that the water dissolves calcium carbonates and other minerals from the glacial or bedrock aquifers as it flows toward the discharge zones at the fens. Several approaches to assess recharge to the fens could be used, with each having different accuracy and expense. One of the most basic and cheapest approaches would be to use the techniques employed for wellhead protection evaluation (Minnesota Department of Health, 2019). The wellhead assessment is often an empirical approach that requires little additional data.

Existing groundwater flow models such as Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0 (Metropolitan Council, 2014) can be run in reverse to approximate an area of recharge for each of the fens.

Recharge can be defined using geochemical assessments to group waters based on their chemical signatures. Water-chemistry sampling can be combined with graphical geochemical techniques including Piper, trilinear, and Stiff diagrams to show the ionic activities of major ions in the water samples. These could show how water chemistry evolves as the water moves from recharge areas to the fen. It also might reveal whether the chemistry of source waters is changing and help scientists infer how that might affect the sustainability of the fens. These geochemical tools will complement the analysis of stable isotopes in water. Stable isotopes rely on the partitioning of waters into heavy versus lighter isotopes depending on evaporative effects of precipitation, lakes, and streams.

Recharge of groundwater supplying the fens could be assessed using computer modeling, but this is often expensive and may require collecting additional data to quantify aquifer characteristics. Time would be needed to calibrate, run, and validate models for each of the fens. However, even coarse models can provide some useful information. The Metropolitan Council of the Twin Cities (2015) developed a long-term water supply plan that modeled water level elevation in various Twin Cities-area aquifers based on projected water use. Although it is difficult to apply the results to features as small as the fens in this study, the model showed a notable trend near Nicols Fen. The groundwater levels adjacent to the Kraemer Quarry rebounded substantially when operations at the quarry ended and pumping of groundwater was stopped.

5.6 Management Plans

Management plans, or sustainability reports, should be completed for all fens, starting with Seminary Fen and Savage Fen. These fens have a good foundation of information, although some of these data should be validated as recommended in this report.

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