

Prepared for



LOWER MINNESOTA RIVER
WATERSHED DISTRICT



Photo: Barr Engineering

February 2024

Gun Club Lake Fens Stewardship Plan

GUN CLUB LAKE FENS STEWARDSHIP PLAN

Prepared for

**Lower Minnesota River Watershed District
Chaska, Minnesota**

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
SWCD	Soil and Water Conservation District
HVRA	High Value Resource Area
LMRWD	Lower Minnesota River Watershed District
MSL	Mean sea level
MNDNR	Minnesota Department of Natural Resources
MnDOT	Minnesota Department of Transportation
MHAPO	Minnesota Historical Aerial Photographs Online
NHIS	National Heritage Information System
TH	Trunk highway

Introduction

The Gun Club Lake Fens are a collection of unique wetlands, classified as calcareous fens, within Fort Snelling State Park in the cities of Eagan and Mendota Heights. The fens are approximately 69 acres in size and located south and east of the Minnesota River and adjacent to Gun Club Lake. The Fens are divided by I-494 into Gun Club Lake North Fen or Quarry Island Fen (North Fen), and Gun Club Lake South Fen or Fort Snelling Fen (South Fen) (Figure 1). Calcareous fens are among the rarest types of wetlands in the United States, dependent on a constant supply of cold, oxygen-poor groundwater that is nearly saturated with calcium and magnesium bicarbonates. This groundwater upwells to the ground surface through a peat substrate, providing the conditions to support the fen ecosystem that sustains unique plant communities that can contain many rare and endangered plant species not found in other environments.

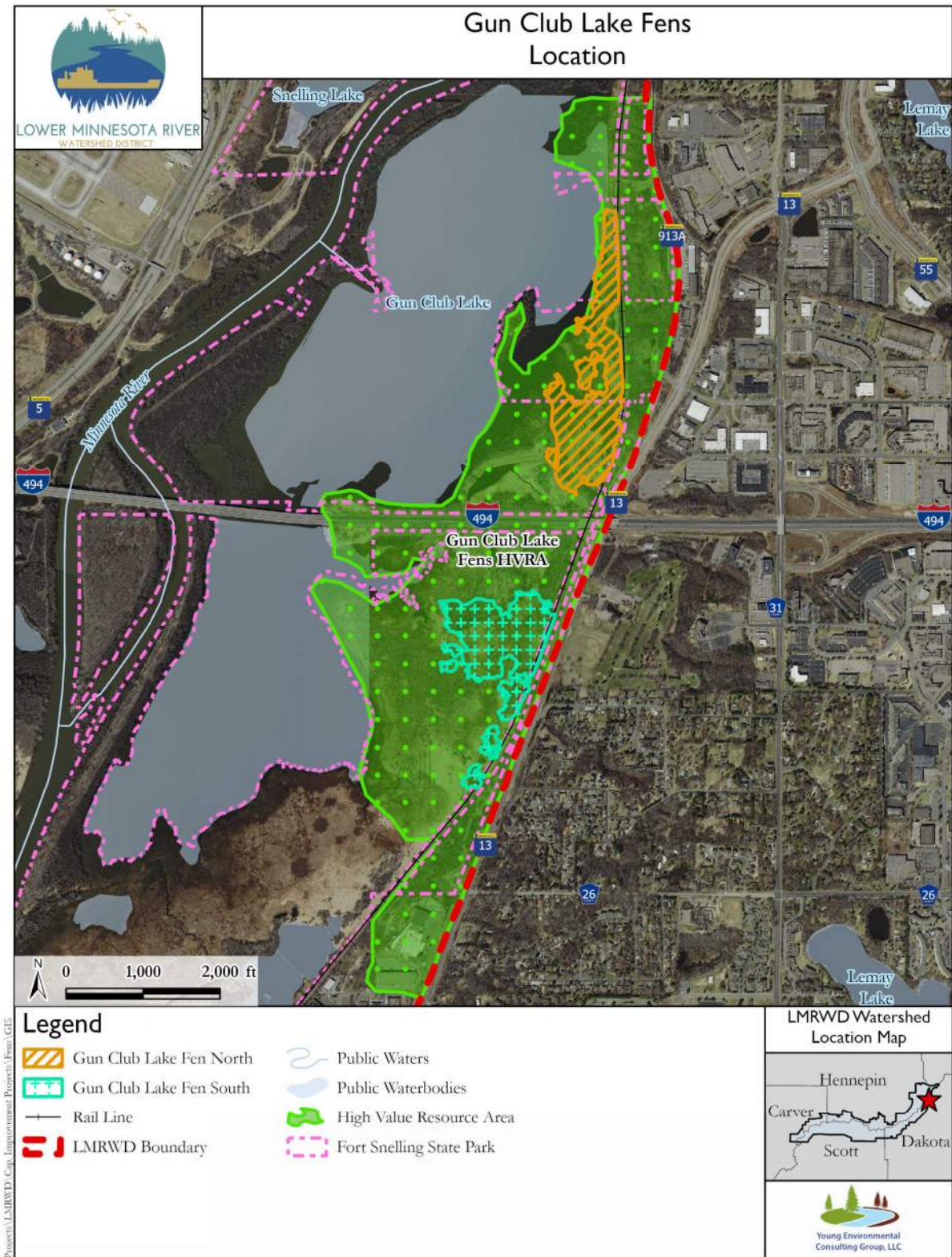
Agriculture, railroad construction, road construction, and development have altered the landscape in the vicinity of the Gun Club Lake Fens since the late 1800s. Increased imperviousness in the watershed and associated changes to drainage patterns and hydrology have impacted drainage, groundwater levels, and native vegetation communities in the Fens. These changes have stressed the Fens' ecosystem and threaten their long-term viability, bringing about the need to identify and validate existing data and develop management and stewardship opportunities to protect and restore the Fens.

In 2021, Young Environmental prepared a Fens Sustainability Gaps Analysis for Carver, Dakota, and Scott Counties, Minnesota (Gaps Analysis) (Young Environmental, 2021) for the Lower Minnesota River Watershed District (LMRWD), which recommended the development of management plans for fens in the LMRWD. The fen management plans would identify stewardship actions that would help protect and sustain these valuable resources into the future. In response to the recommendation of the Gaps Analysis, this Gun Club Lake Fens Stewardship Plan (Stewardship Plan) has been prepared and identifies stewardship and management actions, areas of additional study, and education and outreach opportunities for the Gun Club Lake Fens (Fens). This Stewardship Plan represents continued commitment to the LMRWD's goal to protect, enhance, and sustain valuable resources, such as the Gun Club Lake Fens, that lie within its boundaries.

The Gun Club Lake Fens are within one of the High Value Resource Areas (HVRAs) identified in the LMRWD's 2018 Comprehensive Watershed Management Plan (2018 Plan) and Rules. The HVRAs are a management strategy, adopted as part of the 2018 Plan, that consist of managing areas directly draining into calcareous fens and trout waters through the formation of HVRA overlay districts. These HVRAs require special consideration and adherence to protection standards. The goals of the plan, rules, and the corresponding HVRA overlay districts are to understand, preserve, protect, and restore unique natural resources while critically evaluating projects that propose to alter them.

The Stewardship Plan's focus is to outline stewardship and management needs and actions to protect, restore, and sustain the Gun Club Lake Fens. Those stewardship needs and actions are presented early in the plan to highlight their importance. Information and data on the fens and the surrounding area, including data gathered since completion of the Gaps Analysis, are presented later in the plan. The Gaps Analysis also includes additional detailed background information and data that informed the recommendations of this Stewardship Plan.

Figure 1 Gun Club Lake Fens Location



Based on analyses of past fen studies, vegetation assessments, and groundwater monitoring data described throughout this document, the Stewardship Plan proposes the following data collection, resource investigation, and stewardship actions needed to help protect and restore the Gun Club Lake Fens:

- Improve and restore native vegetation communities within the fens by conducting vegetation assessments; controlling invasive, nonnative vegetation species; and propagating and reintroducing native vegetation species;
- Build on the existing body of hydrology and groundwater monitoring data by continuing existing monitoring efforts in the fens, developing a more robust monitoring network in the North Fen by adding monitoring wells, and collecting water quality data in the fens to help better understand the quality and sustainability of the groundwater supply; and
- Encourage stakeholder engagement in protecting the fens by developing education and outreach materials and activities that inform stakeholders, encourage conservation, and provide stewardship and engagement opportunities for the public. Increased awareness and understanding of these threatened ecosystems will help encourage protection of the Gun Club Lake Fens into the future.

This Stewardship Plan is intended to create awareness of the value and uniqueness of the Gun Club Lake Fens and guide future stewardship, creating a collective commitment to protect them. This Stewardship Plan identifies stakeholders that can participate in the preservation and protection of the fens and recommends stewardship actions aimed at protecting and enhancing the fens' ecosystem and mitigating risks of degradation.

STAKEHOLDER ENGAGEMENT

The Minnesota Department of Natural Resources (MNDNR) and the LMRWD play the lead roles in planning and implementing ongoing studies, monitoring, stewardship actions, and education and outreach for the Gun Club Lakes Fens.

The MNDNR has management authority over Fort Snelling State Park and regulatory authority over calcareous fen resources. The MNDNR also conducts groundwater monitoring efforts and manages the monitoring network associated with the Gun Club Lake Fens, the Cooperative Groundwater Monitoring Network. The MNDNR is a key collaborator in the analysis and distribution of groundwater data, future vegetation surveys of the fens, and plans for the removal of invasive species such as buckthorn. Because of their extensive knowledge of calcareous fen resources, the MNDNR is also a key partner in education and outreach efforts.

The LMRWD is responsible for regulating development projects that occur within the Gun Club Lake Fens HVRA and surrounding areas within the district. In coordination with the MNDNR, the LMRWD will play a lead role in coordinating stakeholder education, outreach, and collaboration and facilitating the implementation of stewardship programs and actions.

Developing collaborative relationships with stakeholders and other groups interested in taking part in studying, managing, and enhancing the Gun Club Lake Fens is key to making informed management decisions and implementing actions that will protect and sustain the fens. In addition to the MNDNR and LMRWD, other stakeholders and partners are needed to collaborate on responsible development in areas surrounding the fen and groundwater recharge area, plan and

implement stewardship actions such as monitoring and vegetation propagation and control, and track stewardship progress. These stakeholders include the Minnesota Pollution Control Agency, Minnesota Department of Transportation, Minnesota Department of Health, Minnesota Geological Survey, US Army Corps of Engineers, Metropolitan Council of the Twin Cities, City of Eagan, City of Mendota Heights, Dakota County Soil and Water Conservation District, National Audubon Society, Minnesota Landscape Arboretum, Minnesota Native Plant Society, Science Museum of Minnesota, Great River Greening, private property owners in the vicinity of the Fens, and prospective developers of nearby properties.

Many organizations and individuals would likely support the protection and enhancement of the Gun Club Lake Fens and associated resources. However, many of those stakeholders may be unaware of the unique ecosystem that exists in the fens. Outreach efforts by the LMRWD can inspire interest and engender involvement and participation from unexpected persons and groups.

Engagement with stakeholders will provide the adjacent landowners, developers, and responsible public entities with information about the importance of protecting the fens. The LMRWD can facilitate this engagement by developing education and outreach materials with input from collaborators to encourage groundwater conservation and provide opportunities for the public to be involved with restoring and protecting the Gun Club Lake Fens. This may include coordinating volunteer efforts to help with the removal of invasive, nonnative vegetation species and working with the MNDNR and the Minnesota Landscape Arboretum on opportunities to conduct plant propagation programs and seed collections of threatened and endangered species. It is imperative that education and outreach efforts highlight the sensitivity of the fen and the need to minimize human activity within the fen that would impact fen vegetation and habitat. When planning for stewardship actions within the fen, such as invasive vegetation control or groundwater monitoring, only actions that would result in minimal impact to the fen should be considered. Education and outreach efforts should focus on preserving and protecting the fen's sensitive habitat and should discourage activities that could detrimentally impact the fen ecosystem.

STEWARDSHIP OPPORTUNITIES

Since the Gaps Analysis was presented, some of the recommendations have been addressed and new opportunities have been identified (Young Environmental, 2021). After a thorough review of the existing information and projections about the health of the fen, the MNDNR and the LMRWD will work with stakeholders to plan and implement continued monitoring, assessment, and other actions to mitigate threats to the health of the Gun Club Lake Fens and enhance the fens' ecosystem. Stewardship opportunities and actions are described below and in Table 1, which outlines proposed stewardship opportunities, actions, and timelines.

Vegetation Assessment

One of the recommended relevés of the Gaps Analysis has been conducted in the South Fen. This vegetation survey revealed several healthy fen-indicator species. A vegetation assessment was not conducted within the North Fen. Establishment of relevé plots is recommended in the North Fen to evaluate the health of the vegetation communities and inform mitigation activities associated with the eroded channel through the North Fen described later in this plan. Relevés should be conducted at multiple points within both fens on a regular basis to verify that they continue to support thriving

fen communities. Vegetation assessments conducted at five-year intervals may identify previously overlooked plants and help assess the Fens' response to stewardship actions.

Vegetation Management

The presence of invasive species in the Gun Club Lake Fens was confirmed during the most recent vegetative assessment (Tix, 2020). There are several methods to consider for managing invasive, nonnative species. These include hand pulling, digging, spot herbicide treatments, and controlled burns. Controlled burns add the risk that a peat fire could be started, which would be difficult to control and could destroy parts of the fen. New techniques and protocols for identifying and managing invasive species are being developed, such as the use of drones, which should be considered. Development of a vegetation management program is recommended for the Gun Club Lake Fens to address threats from invasive, nonnative species. This program would identify vegetation management needs, identify volunteer groups or experienced vegetation management personnel to implement management actions, and use and develop vegetation control techniques and methods that minimize disturbance and damage to native plant species and the fen ecosystem.

Fen Vegetation Indicators

The development of additional fen indicators would help expand the toolbox used by practitioners, making identification of fens more efficient and informing ongoing stewardship needs. Vascular plants are assessed using the relevé method, and plants unique to the fen environment are given point values that are added to achieve a score used to characterize the wetland as a calcareous fen. Other indicators may be equally or more effective at identifying a calcareous fen and may be identified cheaply and easily. Bryophytes, including mosses, liverworts, and hornworts, have been suggested as useful fen indicators (Janssens, 2014) because they may not require season-specific, paired site visits required when using vascular plants as fen indicators. House (2021) suggested that bryophytes are a good indicator of the health of a calcareous fen. However, there is a paucity of technical experts and resources to pursue investigating bryophytes as a tool for fen characterization. Identifying other indicators will require research into various fen floral and faunal characteristics. One or more research organizations could fund that work, and teaching staff and students at nearby scholastic institutions or state or federal agencies with a mandate and funding to pursue these studies could conduct it.

Groundwater Elevation Monitoring

The primary contributor to fen health appears to be the sustained flow of calcium-enriched groundwater from beneath. Gun Club Lake Fens' sustainability depends on this continuous supply of upwelling groundwater. Therefore, it is important to continue monitoring the groundwater elevations within the existing wells. Continued operation of automated recorders provides more detail and better resolution of changes in groundwater levels as they change over time. Additionally, the installation of more wells within the North Fen would provide more data to better understand its condition. Continued coordination by the MNDNR with existing and potential users of the

groundwater that sustains the fens is necessary to prevent overallocation to users and maintain groundwater levels and conditions to sustain a healthy fen ecosystem.

Groundwater Quality Monitoring

Young Environmental (2021) noted that little water chemistry data were available to describe the groundwater quality beneath the Gun Club Lake Fens. One study was conducted in the South Fen, which noted that water chemistry is consistent with the calcium- and magnesium-bicarbonate waters associated with calcareous fens (Almendinger & Leete, 1998a). Young Environmental (2021) recommended routine sampling of groundwater chemistry to better describe water quality and form the basis for identifying trends. The data will provide information about the current ionic strength and the proportions of ions that comprise the water supplying the fen, establish a baseline, and quantify the variability of the chemicals in the water. The information will also provide documentation of changes in water chemistry related to changing land use that could affect the Gun Club Lake Fens. Sampling a pair of shallow and deep wells is suggested, with the shallow well completed in the peat layer and the deeper well completed in the sand and gravel aquifer beneath the peat layer. The peat deposits provide a highly organic, minimally transmissive medium, whereas the sand and gravel provide a mineral-rich, more transmissive medium. Therefore, the water chemistry in each of these environments may have characteristically distinct differences.

The annual samples collected would be accompanied by field measurements of water temperature, specific conductance, pH, and dissolved oxygen that are also used to determine if the water sampled is representative of the aquifer chemistry by documenting three consistent readings before samples are collected. Because peat has low transmissivity, insufficient water may be withdrawn to achieve the three reading criteria before collecting the water chemistry samples. The samples collected should be field filtered, preserved, and laboratory analyzed for dissolved major-ion concentrations and concentrations of nutrients, including dissolved phosphorus and nitrogen species, alkalinity, and dissolved organic carbon.

Age-dating indicators should also be sampled annually from deeper wells until the age of the water supply to the Gun Club Lake Fens is clearly established. Recent groundwater is more likely than old groundwater to have contaminants from recent man-made sources, such as pesticides, nitrate nitrogen, and chloride salts, because those chemicals could have been applied to or released on the landscape when the groundwater recharged the aquifer. A variety of tools are available to age-date the water, and it will be necessary to evaluate which one is most appropriate for the Gun Club Lake Fens groundwater. Tritium analyses are indicative of water recharged in the 1950s and 1960s, chlorofluorocarbons indicate water recharged in the 1930s through the 1980s, and sulfur hexafluoride indicates water recharged since about 1965. Other tests can be used to refine those numbers or age-date the water that was recharged decades or centuries earlier. Because each test can be expensive and some are difficult to collect and analyze, selecting a different indicator to be sampled each year is prudent to provide results that confirm or refute previous findings. Stable isotope analysis can also document characteristics of water that provide recharge to the aquifers that supply the Gun Club Lake Fens.

Education and Outreach

Partnerships with interested stakeholders will help broaden support and increase understanding of the value of calcareous fens needed to support Gun Club Lake Fens' stewardship. A broadened base of support will also enhance opportunities to secure needed funding. Potential opportunities include securing grants while promoting volunteer opportunities to help manage invasive, nonnative species. Opportunities to work with the Minnesota Landscape Arboretum, local universities, state and federal agencies, and other entities to assess the vulnerabilities of the native fen flora to chemicals that may be in the area should be considered while implementing this stewardship plan. There are also engagement and educational opportunities to collaborate and develop partnerships with local, state, federal, and nonprofit agencies and the landowners adjacent to the Gun Club Lake Fens.

Stewardship Strategy Table

Table 1 provides recommendations for the various stewardship strategies to protect and restore the Gun Club Lake Fens. The lead agency in most of these efforts is the MNDNR. The MNDNR and LMRWD provide education and outreach opportunities.

Table 1. Gun Club Lake Fens Stewardship Strategies

Item	Stewardship Strategy	Category	Lead Agency	Additional Considerations	2024	2025	2026	2027
1	Develop and implement a nonnative, invasive species management program to identify and map invasive species and implement actions to control them in the Gun Club Lake Fens.	Vegetation	MNDNR and LMRWD	Identify stakeholders to implement control measures, including volunteer groups and vegetation professionals as needed. Consider using drones and field verification to map nonnative, invasive species. Short-term efforts need long-term follow-up. Disturbances within the fen may affect the occurrence of invasive plants.	Develop and Implement Plan			
2	Repeat plant surveys every five years using the vegetation plots established in the 2019–2020 relevé.	Vegetation	MNDNR and LMRWD	Relevé plots are established in Gun Club Lake South Fen. No plots are located within Gun Club North Fen. Surveys could be scaled up to include plots in several locations throughout the fen for improved assessment.		Repeat Survey		
3	Establish relevé plots in Gun Club Lake North Fen and conduct plant surveys at five-year intervals.	Vegetation	MNDNR and LMRWD	Plots should be established in Gun Club Lake North Fen. Surveys could be scaled up to include plots in several locations throughout the fen for improved assessment. Information obtained will help inform potential mitigation of the eroded channel in the North Fen.		Establish Plots and Survey		
4	Encourage Minnesota Landscape Arboretum and other stakeholders to pursue propagation programs, replanting, and seed collections of threatened and endangered fen species.	Vegetation	MNDNR	The goal is to develop tools to restore and enhance fen ecosystems that include the Gun Club Lake Fens. This small-scale effort would be conducted only on public lands. It could be scaled to a larger effort to include private lands.				
5	Continue research and validation of tools for fen identification, indicators of fen vigor, and the chemistry that sustains the fen.	Vegetation	MNDNR	Studies of bryophytes as fen indicators are on hold because too few experts are available. Identify and assess additional methods to expand the current fen assessment and identification toolbox.				
6	Install two paired shallow and deep groundwater monitoring wells further north in Gun Club Lake North Fen to assess fen health.	Groundwater Monitoring	MNDNR	A shallow well should be installed in the peat layer and a deeper well in the alluvial sands. A larger number of wells can be installed for greater characterization. Information obtained will inform potential channel mitigation.		Well Installation	Continued Monitoring	Continued Monitoring
7	Sample at least two groundwater wells for field measurements, major ions, and nutrients. Rotate sampling of age-dating indicators each year.	Groundwater Monitoring	MNDNR	This work could be scaled up by collecting extra water and requesting additional analyses by qualified laboratories.			Data Assessment	Data Assessment
8	Continue to evaluate and enhance the groundwater monitoring network every few years. Eliminate redundancies as needed.	Groundwater Monitoring	MNDNR	This is an ongoing effort that is addressed every few years.	Ongoing Sampling			
9	Assess historical and recent groundwater elevations in nearby wells to create maps of water levels surrounding the Gun Club Lake Fens.	Groundwater Monitoring	MNDNR and LMRWD	Groundwater beneath the fen is part of a larger resource that could be studied according to area and time to better understand the resource as it relates to the fens. Additionally, knowledge on area groundwater trends may provide insight into potential causes associated with water level declines in Gun Club Lake North Fen.	Ongoing Evaluation		Ongoing Evaluation	
10	Identify opportunities for stormwater infiltration in groundwater recharge areas upgradient of the fen.	Groundwater and Hydrology	LMRWD	Work with municipalities and developers to promote low-impact development techniques that increase infiltration of clean stormwater, which will enhance groundwater recharge.				
11	Assess the health of Gun Club Lake North Fen from vegetation surveys and groundwater monitoring to determine mitigation strategies for the eroded channel or gouge/scar.	Channel Mitigation	MNDNR and LMRWD	The current recommendation for mitigation is no action due to uncertainty of fen vitality. Once monitoring of groundwater levels and vegetation has occurred, fen vitality can be assessed.		Outreach and Development		Outreach and Development
12	Track weather, precipitation, and longer-term changes in climate to assess how fen health is impacted by climatological changes and to help inform future fen management decisions.	Climate	LMRWD and MNDNR	Include assessment of climatological data when evaluating groundwater monitoring and vegetation data. This will help identify and assess trends and inform fen management needs and stewardship opportunities.		Groundwater Elevation Assessment	Groundwater Elevation Assessment	
13	Develop education and outreach materials and support ongoing efforts to inform stakeholders about ongoing stewardship actions and the importance of protecting and enhancing Gun Club Lake Fens.	Education and Outreach	LMRWD and MNDNR	This requires guidance and support from the MNDNR managers. Participation is expected from many stakeholders.	Ongoing Support			
14	Support the education, outreach, and water conservation efforts promoted by the MNDNR regulatory unit.	Education and Outreach	MNDNR and LMRWD	This ongoing work is supported by many entities and could be modified, adapted, and disseminated with a relatively modest application of existing resources.				
15	Improve tracking and entry of data collected by various entities for permits, water use, pumping, and monitoring. The provided	Data Management	MNDNR	This should be initiated as a test effort but could become a large-scale program that would result in a high-quality, streamlined dataset useful	Ongoing Collaboration			

Item	Stewardship Strategy	Category	Lead Agency	Additional Considerations	2024	2025	2026	2027
	data need to be reviewed and entered into a centralized database. The system should include feedback to assure data quality and consistency.			to resource managers. Although it would focus on Gun Club Lake Fens resources, it could be scaled up to resources throughout the state.				
16	Identify funding opportunities to enable the long-term management of invasive, nonnative species; plant and animal surveys; groundwater monitoring; and land acquisition.	Collaboration	MNDNR	Ongoing.	Ongoing Collaboration			
17	Determine interest from stakeholders such as US Fish and Wildlife Service or the Minnesota River Valley Audubon Chapter in studying faunal populations to better understand their association with fens.	Wildlife	LMRWD	European research has suggested that some nonplant species, including insects and arachnids, are uniquely adapted to the fen ecosystem.		Ongoing Collaboration		Ongoing Collaboration

Environmental Setting

The Gun Club Lake Fens are a collection of unique wetlands, classified as calcareous fens, located south and east of the Minnesota River in the cities of Mendota Heights and Eagan. The fens are divided by I-494 into the North Fen and South Fen (Figure 1). Both portions of the fen are in Dakota County in Fort Snelling State Park. As a part of Fort Snelling State Park, the Fens are managed by the MNDNR. Together, the Fens are approximately 69 acres in size, but like most fens, the borders and fen-community locations tend to be indeterminate. The fens are bordered to the west by Gun Club Lake and to the east by the Union Pacific railway and Trunk Highway (TH) 13.

Fens in Minnesota have been protected since 1991 by the state's Wetland Conservation Act. They cannot be drained, filled, altered, or degraded. Calcareous fens are among the rarest types of wetlands in the United States, characterized by a peat substrate and dependent on a constant supply of cold, oxygen-poor groundwater that is nearly saturated with calcium and magnesium bicarbonates. These ecosystems support unique plant communities that can sustain many rare and endangered plant species not found in other environments. Calcareous fens in this portion of the Minnesota River Valley have been carbon dated as approximately 10,000 years old (Almendinger & Leete, 1998a).

The Minnesota River Valley was created when Glacial River Warren drained Glacial Lake Agassiz after the last period of glaciation (Young Environmental, 2022b). Almendinger and Leete estimated the age of the South Fen as just over 10,000 years old (1998b). Age dating was not conducted in the North Fen. The Gun Club Lake Fens are in the Minnesota River Valley at an average ground surface elevation of 716 and 715 feet mean sea level (MSL) for the North and South Fens, respectively. These elevations are just above the 100-year flood elevation of the Minnesota River, 714 MSL, indicating that inundation from the Minnesota River in portions of the fens occurs during 100-year flood events.

The fens' unique ecosystems are being threatened by invasive, nonnative species and changes to the hydrology that supports them. Fens are also known to be efficient carbon sinks (Cooper, 2009) and contain a diversity of wetland plants, many of which are threatened or endangered in Minnesota. Losing even one species may cause unforeseen effects throughout the rest of the ecosystem. The benefits of preserving threatened and endangered species are immeasurable (Carrington, 2020). Two federally listed species are known to occur near the fens, the rusty-patched bumblebee and the northern long-eared bat. Assessing existing data and promoting methods to ensure the fens are sustained and viable into the future are imperative.

Residential, commercial, and industrial developments are located east and upgradient of the Gun Club Lake Fens. Although the fens themselves are protected from development as a part of Fort Snelling State Park, nearby development has impacted the fens by changing the area hydrology. Figure 2 highlights these disturbances.

Known disturbances within the fens began in the 1860s with the construction of the railroad that borders the fens to the east (Schmidt, Pratt, Vermeer, & Bradley, 2007). Around the time of railroad construction, the land use in the area was largely agricultural (Young Environmental, 2022a). In the early 1900s, drainage alterations and ditching occurred throughout the watershed and near the current location of I-494, likely for agricultural purposes. In the mid-1900s a gravel pit was constructed east of the fens, and flow was diverted away from the northern portion of the fen to the southern portion. Construction of I-494 in 1982 completely divided Gun Club Lake Fens into the North Fen and South Fen.

Figure 2. Disturbances to the Gun Club Lake Fens



A channel that has eroded into the North Fen has been evident in aerial imagery dating back to the 1940s, although it likely formed following the construction of the railroad (Young Environmental, 2022a). Railroad construction channelized flow from the east under a railroad bridge, and subsequent watershed development has increased imperviousness and runoff volumes. The railroad bridge is located at the outlet of the Minnesota Department of Transportation's (MnDOT) Pond D that collects flow from nearby highways. Evaluation by Young Environmental indicates that the channel in the North Fen has not yet stabilized and will continue to erode if not addressed (Young Environmental, 2022a). The 2022 Gun Club Stormwater Intrusion Study (Young Environmental, 2022a) provides potential management strategies to reduce ongoing erosion of the channel, such as flow dispersion within the fen, providing upstream storage to reduce runoff rates and volumes and channel stabilization. Because the MNDNR is uncertain of the long-term viability of the North Fen, no action has yet been taken to address the channel, and stewardship actions are not proposed in this plan (Young Environmental, 2022a).

Geology

The bedrock geology beneath the North Fen is less than 100 feet to less than 50 feet below the ground surface and consists of St. Peter sandstone and Platteville and Glenwood formations (Young Environmental, 2021). The deeper St. Peter sandstone contains quartzose sandstone overtop siltstone, shale, and coarse sandstone (Balaban & Hobbs, 1990). Shallower Platteville and Glenwood contain fine-grained dolostone, limestone, and sandy shale. The South Fen bedrock is deeper, ranging from 100 to 150 feet below the ground surface and is predominately composed of the Prairie du Chien Group, which consists of Shakopee Formation overlaying Oneota Dolomite (Young Environmental, 2021; Balaban & Hobbs, 1990). Because of the depth to bedrock at the South Fen, carbonate-enriched waters probably originate from surficial aquifers (Almendinger & Leete, 1998b; Almendinger & Leete, 1998a).

Soils

Calcareous fens develop in unusual settings, where cool, mineral-rich upwelling groundwater keeps the soil surface continuously wet, allowing for the formation of peat. In these areas, saturated soils obstruct the flow of oxygen from the atmosphere, slowing the rate of decomposition and creating an accumulation of layers of partially decayed vegetation and saturated soils such as mucks or peats. The pH of the soil can range from neutral to strongly alkaline. The soil is typically rich in calcium bicarbonates, with tufa that looks like gritty chalk, sometimes identified as marls.

According to the USDA Soils Map (USDA, n.d.), the North Fen is primarily composed of Seelyeville muck with Rondeau series muck to the north, and the South Fens is primarily composed of Seelyeville muck with Boots series muck and minimal loam material to the south. The portions of Gun Club Lake Fens nearest I-494 contain variable soil materials that are part of the Udorthents series. Because the majority of both fens are composed of muck, the soil is very poorly drained. However, soil infiltration and drainage characteristics are inconsequential in the fen environment because the source of water comes from beneath.

Climate

Climate information helps understand what conditions gave rise to the vegetation in the fen and other characteristics presently observed. Predictions about the climate may help identify stressors that could threaten the Fens' sustainability. The following information on climate is summarized from Appendix D of Young Environmental (2021).

Climate records for the Minnesota River Valley began in 1895. The records indicate that average low temperatures have been increasing since, with fewer extreme cold temperature events. The report also shows that average high temperatures have remained consistent.

Research cited in Appendix D of Young Environmental (2021) suggests that, in the future, the growing season will be longer and winters will be warmer. Summer storms are expected to be more intense and provide more rainfall. Extreme runoff events might cut channels through the fens, which would drain water from below the surface that sustains the vegetation and ecosystem. It is not known how changes in direct precipitation might affect the fen complex, which is reliant on upwelling groundwater. However, changes in precipitation upgradient of the fens might alter the proportion of water that becomes runoff rather than recharging the aquifer supplying the fen.

Rising temperatures could favor warmer-climate plants, including invasives, impacting native fen plants that evolved in a cooler temperature regime. There is concern that a warmer climate could allow invasive species to outcompete native species and allow pests to emerge earlier in the season, which could disrupt the natural fen ecosystem.

Hydrology

The hydrology of the Gun Club Lake Fens is a complex association between upwelling calcium- and magnesium-rich groundwater, unique plant communities, and surface water. The Gun Club Lake Fens currently receive runoff from nearby roadways and direct discharge from the railroad to the channel through the North Fen (Young Environmental, 2022a). The fens' watershed and groundwater recharge areas have been altered by agricultural activity, roadways, railways, and development. These changes to the landscape have increased imperviousness, which can result in decreased groundwater recharge and increased runoff. Additionally, there is potential for degraded water quality due to runoff from roadways, impervious surfaces, and municipal maintenance activities, which may negatively impact the fens. Both fens contain small unnamed streams that discharge to the adjacent Gun Club Lake. The streams are likely fed by the same groundwater source as the fens.

Groundwater

Groundwater characteristics of the Gun Club Lake Fens include an estimate of groundwater flow directions in the underlying bedrock aquifer (Prairie du Chein) from upgradient areas that contribute flow to the fens. This area is called the groundwater-shed and is similar to a surface watershed. The basis of the groundwater-shed is the potentiometric surface of the uppermost bedrock aquifer.

The potentiometric surface map of the Prairie du Chien aquifer (Figure 3) shows the direction of groundwater flow. In confined aquifers, pressure causes the water level in a well to rise above the aquifer. These levels are measured, and the groundwater elevations are contoured to create a map of the potentiometric surface similar to how topographic maps show land-surface elevations. The potentiometric surface of an aquifer represents the potential energy available to move groundwater. Groundwater moves from higher to lower potentiometric elevations, flowing perpendicular to the contours. Important recharge areas could be indicated by high-elevation areas on the potentiometric surface when combined with other information. River valleys are typical examples of low-elevation discharge areas.

The Prairie du Chien potentiometric surface map (Figure 3) was created using static water-level data from the County Well Index (CWI) and river elevation points (500 meter spacing) along the Minnesota River and

smaller perennial streams. River elevation points are included where groundwater discharge is likely. The CWI records represent various climatic and seasonal conditions from 1960-2022 (MGS & MDH, 2023). This data variability creates some uncertainty in potentiometric surface elevations. Figure 3 shows a consistent pattern of flow away from the topographically highest parts of Dakota county (recharge areas) toward the discharge areas of the Minnesota River, Gun Club Lake Fens, and Nichols Meadow Fen. An approximate groundwater-shed for the Gun Club Lake Fens and Nichols Meadow Fen is shown with a dashed line to highlight a general recharge area of these groundwater discharge features.

The upper portions of the groundwater shed are areas where the aquifer receives recharge from precipitation. Stewardship of the fens should include evaluation of the quantity and quality of recharge in upland areas to assure a continued supply of high-quality groundwater to supply the fens.

The Dakota County Soil and Water Conservation District (SWCD) has been collaborating with the MNDNR and LMRWD for several years to monitor groundwater levels associated with the Gun Club Lake Fens. The Fen Gaps Analysis report (Young Environmental, 2021) provides detailed information about the wells located in the Gun Club Lake Fens.

Figure 4 shows the monitoring wells within and around the Gun Club Lake Fens. Two wells are located in the North Fen, and thirteen wells are located in the South Fen. Because most of the monitoring wells are located in the South Fen area, the majority of the groundwater analysis is focused on the South Fen.

Figure 3 Potentiometric Surface Map of the Prairie du Chien Aquifer

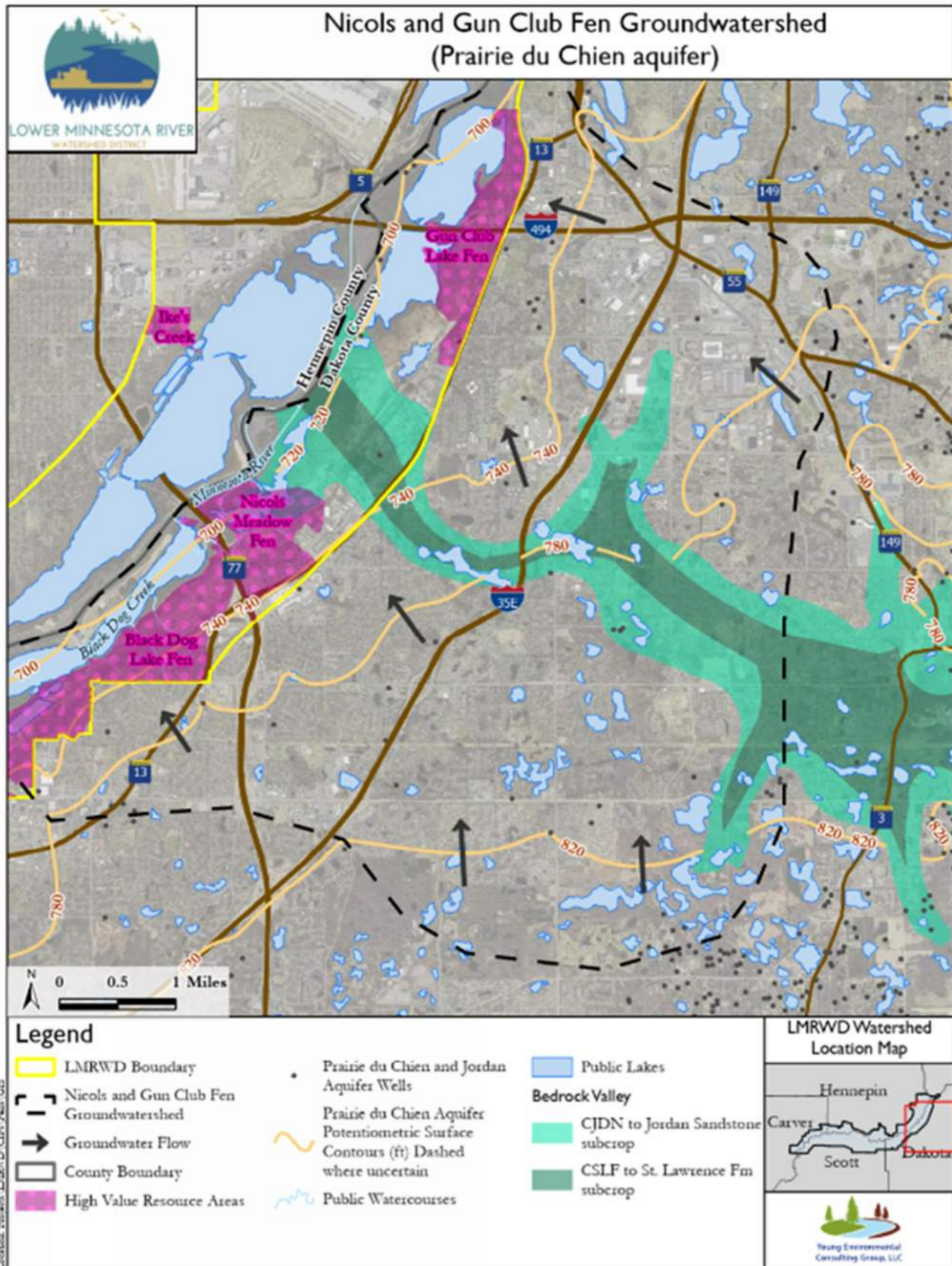


Figure 4. General Location of Monitoring Wells in and near the Gun Club Lake Fens



Historical Groundwater Data

Information reported by Young Environmental (2021) provides details about the groundwater data collected for the Gun Club Lake Fens. Historical records for groundwater within the fens are sparse because consistent monitoring was not conducted until the 2000s. The North Fen groundwater elevations show greater variability over time, whereas the South Fen groundwater elevations show less variability (Dakota County SWCD, 2021; Young Environmental, 2021). Stable, less variable groundwater elevations suggest a reliable supply of groundwater needed to sustain a viable fen ecosystem. Groundwater elevations in both fens show seasonal variability that may be related to seasonal pumping for domestic supply and irrigation.

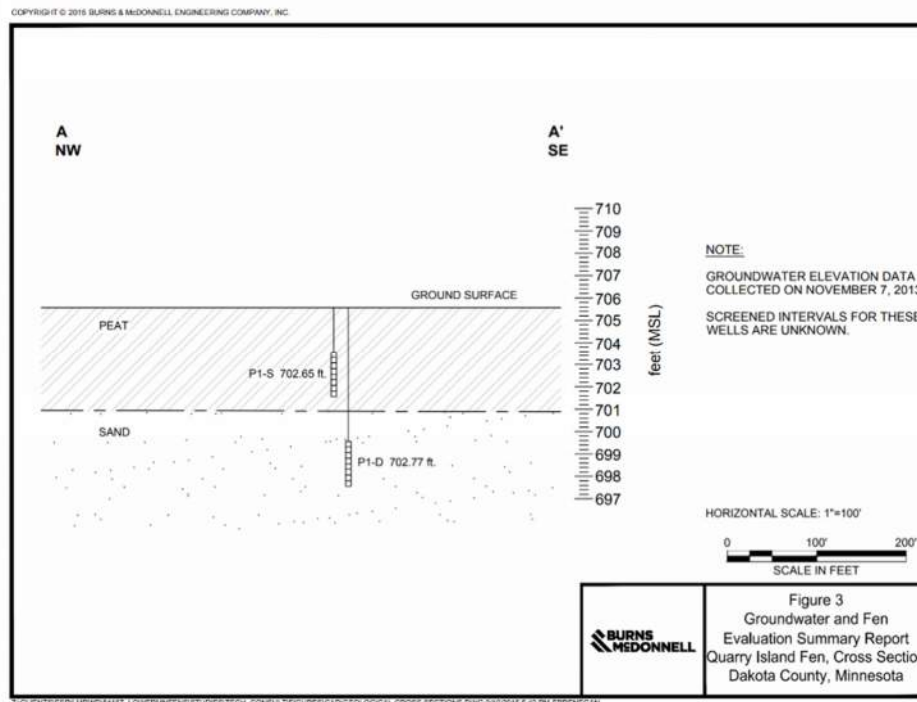
Hydrogeology

The Gun Club Lake Fens rely on a constant groundwater supply.

Figure 5 shows the cross section of paired shallow and deep wells in the North Fen from Burns and McDonnell (2015), which names it Quarry Island Fen. The wells are located on the southwestern edge of the fen and were installed in 2007 (Young Environmental, 2021). The deeper well, P1-D, was installed to a depth of 11.1 feet and the shallow well, P1-S, was installed to 7.1 feet. Soil borings taken near these wells provide further insight into the geology under the North Fen and informed

Figure 5. These wells have been routinely monitored by the Dakota County SWCD since their installation. Groundwater elevation records for the North Fen show that a consistent upward gradient typical of healthy fen systems is not present (Dakota County SWCD, 2021), suggesting that water flows elsewhere rather than toward the surface of the fen.

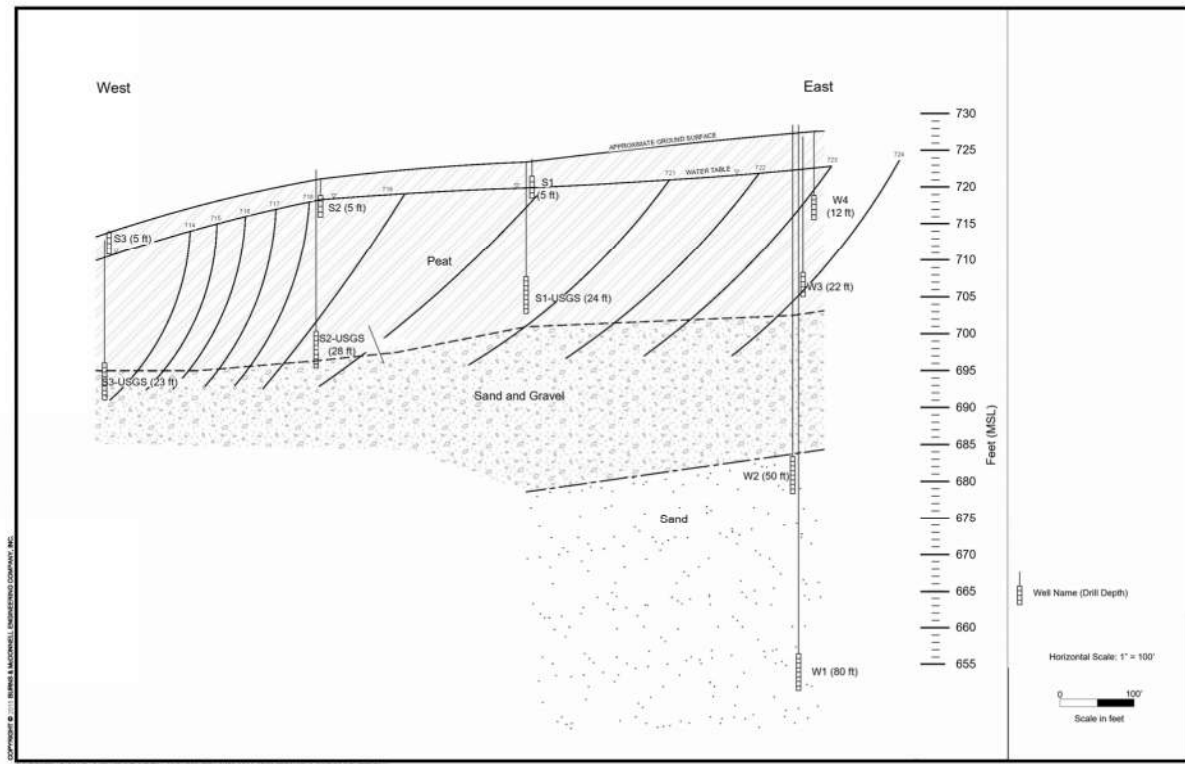
Figure 5. Gun Club Lake North Fen Cross Section from Burns and McDonnell (2015)



There are thirteen groundwater monitoring wells within and around the South Fen. Figure 6, adapted from Burns and McDonnell (2015), shows the cross section of four sets of paired shallow and deep wells in the

South Fen. Wells are located in and west of the South Fen. Soil borings taken near these wells provide further insight into the geology under the South Fen and informed Figure 6. Well records indicate an upward vertical gradient of groundwater, typical of healthy fen systems. Deeper water travels upward through alluvial sands and into peat before upwelling to the surface. Although all the wells were installed in 1992, routine monitoring of groundwater elevations did not occur until the late 2000s (Young Environmental, 2021).

Figure 6. Gun Club Lake South Fen Cross Section Adapted from Burns and McDonnell (2015)



Current Groundwater Hydrology

As shown in Figure 4, the South Fen has reasonably good groundwater monitoring well coverage. Groundwater levels are measured in and around the fen by both the MNDNR and the Dakota County SWCD (Young Environmental, 2021). Both datasets are uploaded to the Cooperative Groundwater Monitoring Network. The LMRWD supports the ongoing efforts by the Dakota County SWCD at the thirteen wells (Dakota County SWCD, 2021). Some of these wells are outfitted with data loggers. Groundwater elevations are manually measured monthly, and records are shared with the LMRWD annually.

Figure 7 is a graph provided by the Dakota County SWCD (2021) that shows the measured groundwater levels in the North Fen, identified as Quarry Island Fen. The red line indicates a resurvey of well measuring point elevations in 2016. The approximately two-foot decline in groundwater elevations from 2007 to 2017 appears to be the result of changing well measuring point elevations rather than a change in water levels. In the years following resurveying, the deeper well displays a downward trend, whereas the shallow well shows greater variability with no indication of lowering groundwater elevations. The specific cause of water

elevation decline is unknown. The most recent data measured in late 2022 show groundwater elevations of 704.14 feet in P1-S and 702.23 feet in P1-D (MNDNR, 2023). Both elevations are below the estimated ground surface elevation of 705 feet and suggest a lack of upward groundwater gradient (Burns & McDonnell, 2015). This indicates that the fen land surface near these wells may be dry, leading to desiccation of important fen vegetation.

Figure 7. Groundwater Elevations in Gun Club Lake North Fen from Dakota County SWCD (2021)

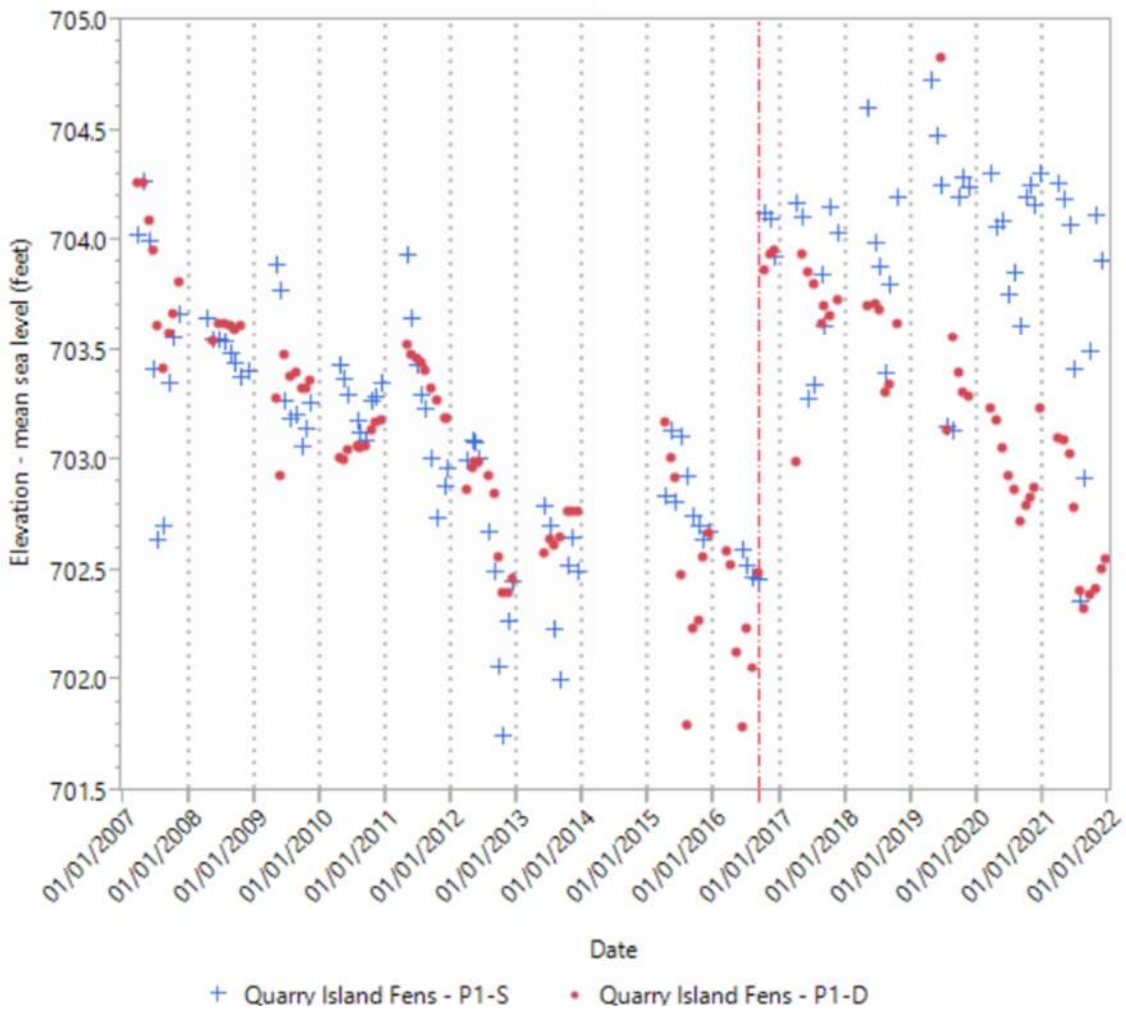


Figure 8 shows a hydrograph from the Dakota County SWCD (2021) for the thirteen wells they monitor in Gun Club Lake South Fen, identified as Fort Snelling Fens. The red line in 2016 indicates a resurveying of the wells (Dakota County SWCD, 2021) and does not suggest that measuring point elevations have changed substantially. Recent measurements suggest that the groundwater levels in the South Fen are rising. The upward trend may be a result of increased annual precipitation that replenished the aquifer (Young Environmental, 2021) or reduced pumpage of the groundwater for other uses.

Figure 8. Groundwater Elevations in Gun Club Lake South Fen Taken from Dakota County SWCD (2021)

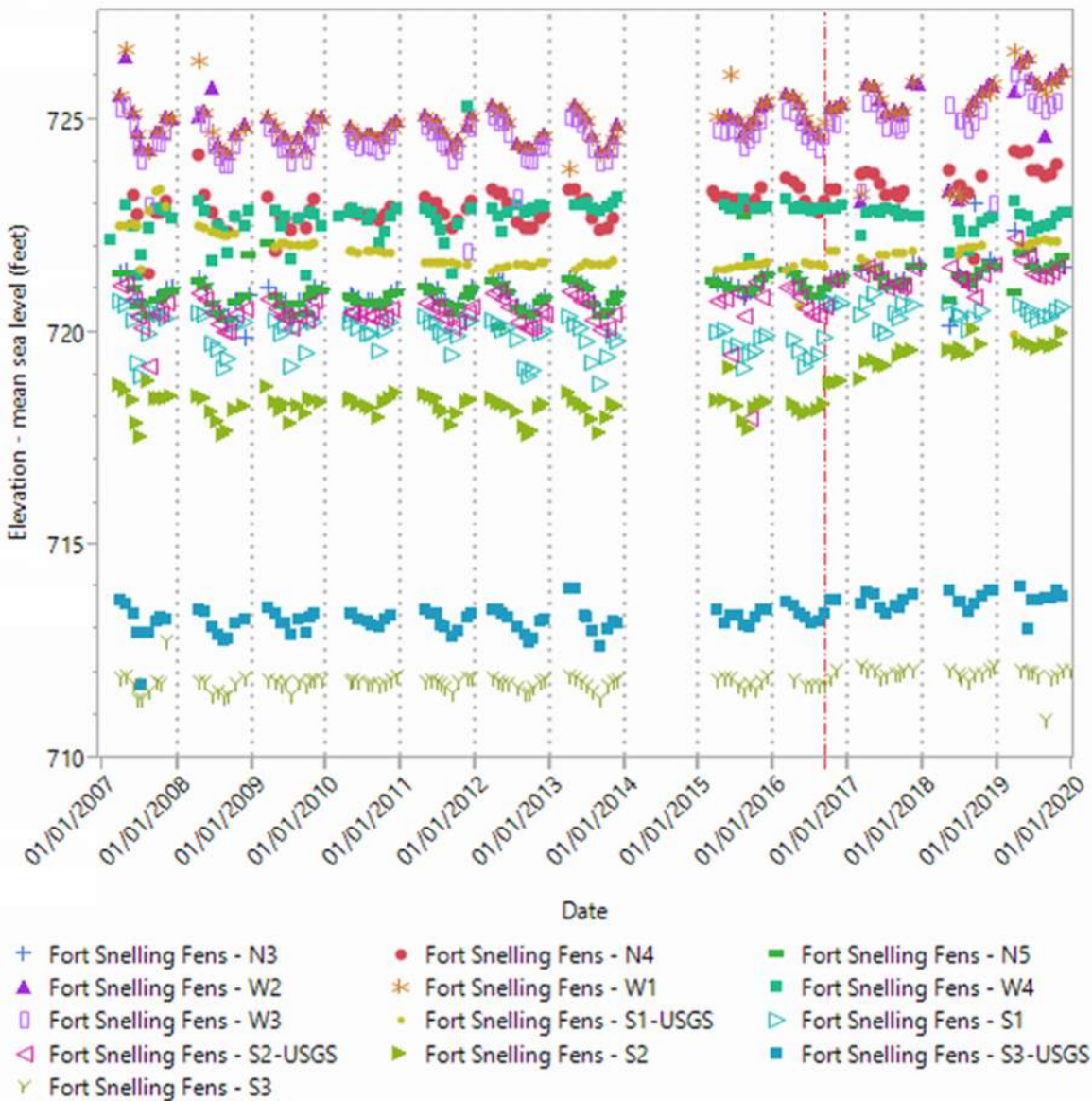
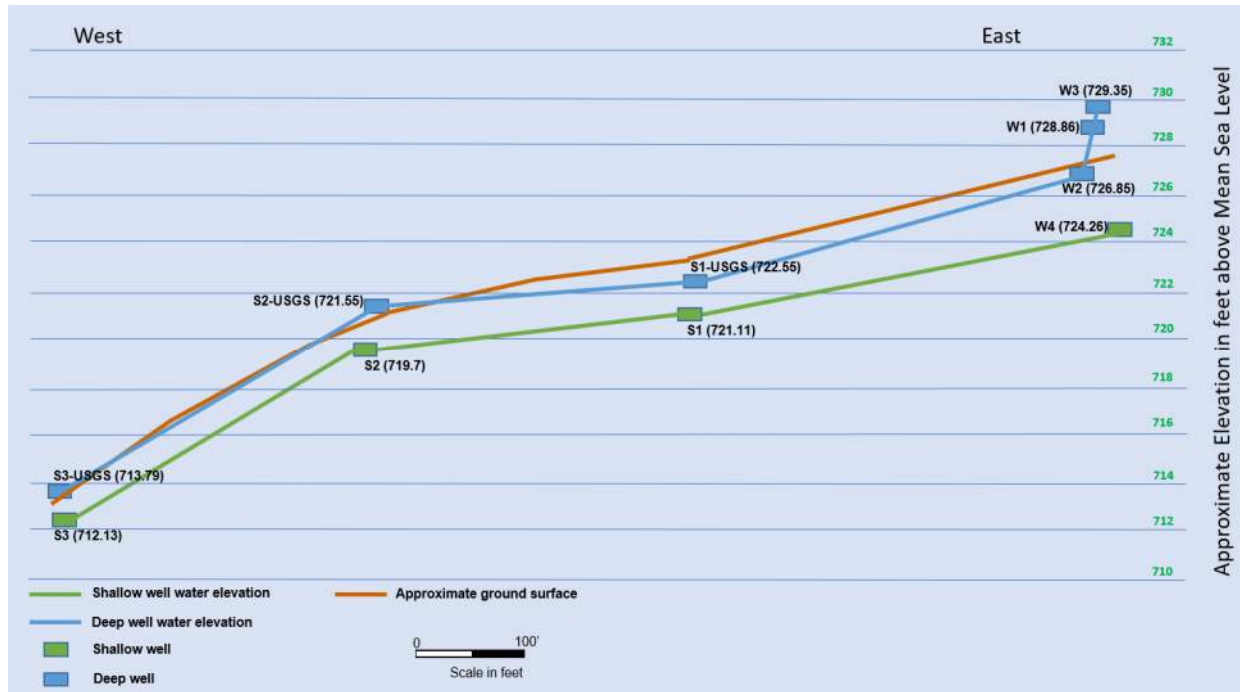


Figure 9 provides a cross section of the most recent groundwater elevations taken within the South Fen for wells shown in the Figure 6 cross section. Groundwater elevations were measured in November 2022 or March 2023 (MNDNR, 2023). The groundwater elevations, representative of the potentiometric surface of the groundwater, are near the ground surface level at all locations. The deep wells show a potentiometric surface above that of the shallow wells, which results in an upgradient of groundwater that pushes water upward. The elevations of the groundwater generally are at or below the ground surface. This condition is not consistent with a healthy fen, which relies on the upward movement of groundwater to sustain the fen.

Figure 9. Gun Club Lake South Fen Recent Groundwater Elevations



The groundwater monitoring network is an important part of the stewardship of the Gun Club Lake Fens. Water level monitoring adds to the baseline from which detrimental changes to groundwater levels can be identified. Additional shallow and deep paired wells will help identify whether upwelling groundwater needed for a healthy fen has been established and is maintained. This network needs to be routinely evaluated and modified as needed.

Wildlife

European and domestic fen research has provided information about the communities of fauna that may find refuge in fens (Broads Authority, n.d.; Stokmane & Cera, 2018; Willis, 2008). Generally, fen ecosystems are understudied; however, they can include unique invertebrate populations, including insects, spiders, and snails, as well as vertebrate populations of amphibians, voles, mice, and lemmings, that provide a food source for predatory species, including snakes and birds. In addition, the generally open, diverse vegetation of fens with low shrubs often attracts small insects and swarms that can provide food for insectivorous birds, bats, and other insects. A researcher documenting spider populations at fens in Latvia suggested several species are unique to the fens studied (Stokmane & Cera, 2018).

Threatened and Endangered Species

The MNDNR through the Minnesota Endangered Species Statute (State of Minnesota, 2022) and the US Fish and Wildlife Service through the federal Endangered Species Act of 1973, plus amendments (USFWS, 2020), administer laws designed to protect threatened and endangered species from going extinct. Losing even a single species can alter the rest of the ecosystem. From potentially providing cures to diseases to maintaining natural ecosystems and improving overall quality of life, the benefits of preserving threatened and endangered species are incalculable (The National Wildlife Federation, 2022).

One federally listed endangered species, the rusty patched bumblebee, has been observed at nearby Nicols Meadow Fen (USFWS, 2019). The bumblebees' rapid decline has been partially attributed to a loss of prairie and grassland habitat and habitat fragmentation and degradation. The National Heritage Information System (NHIS) was queried to determine the occurrence of bat hibernation locations near the Gun Club Lake Fens. The NHIS does not provide specific locations but notes that the northern long-eared bat has been observed within the Gun Club Lake Fens HVRA and that nearly all nearby bridges are potential bat hibernacula locations. The northern long-eared bat has also been seen in the Minnesota Valley National Wildlife Refuge in Scott County (NRRI, 2018).

Vegetation Assessment

Fen plant communities are assessed using relevés that focus primarily on vascular plants, particularly documenting the presence and abundance of fen-indicator plants. However, some researchers suggest that other fen-indicator plants, such as bryophytes, which include mosses, liverworts, and hornworts, would provide a more robust and reproducible indicator of fen health (Janssens, 2014).

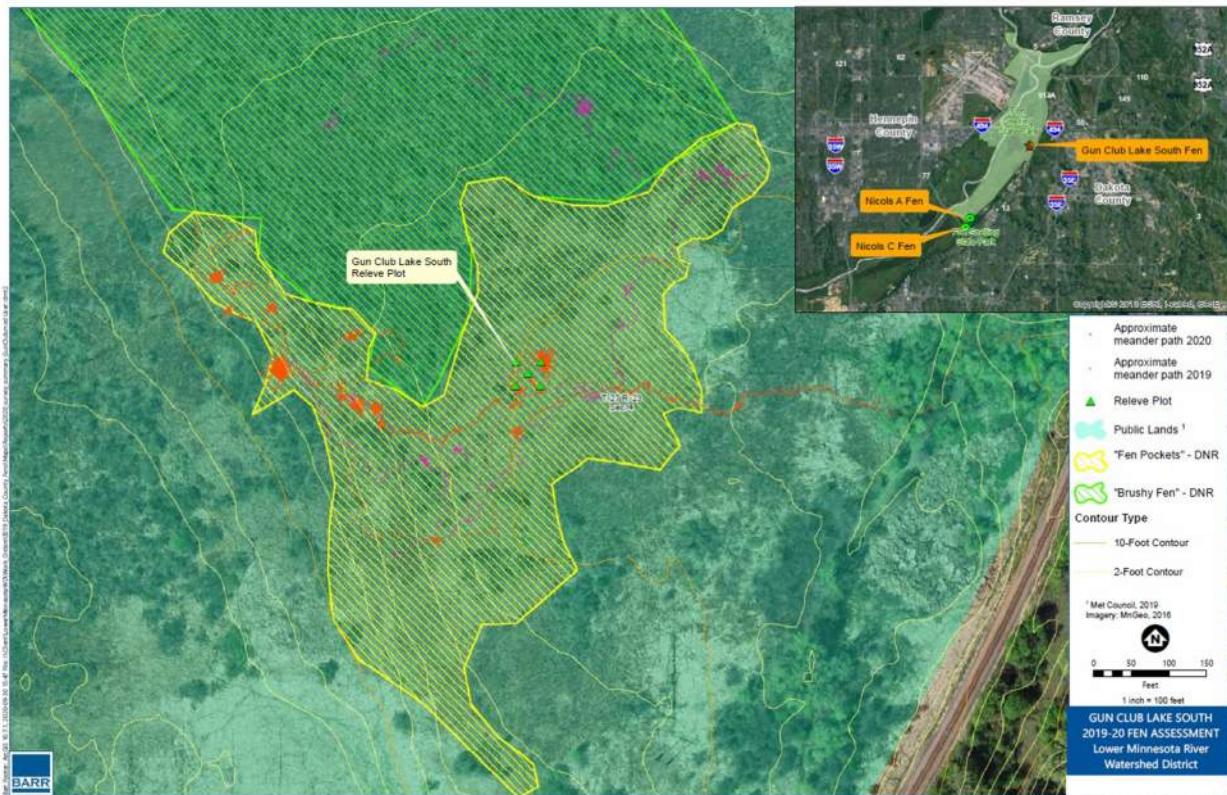
There is only one vegetation assessment known to have been conducted in the North Fen (Young Environmental, 2021). That assessment was conducted in 1994. Two fen-indicator species were documented during the assessment. Contrastingly, several formal and informal vegetation surveys have been conducted since the 1980s in the South Fen. The results of these surveys are described in Young Environmental (2021). Surveys from the 1980s and 1990s indicate the presence of various species indicative of a healthy fen ecosystem. Surveys from the early 2000s begin to describe degradation of the fens, noting severe erosion from stormwater discharges and an influx of invasive species.

Barr Engineering (Barr) conducted late and early season vegetation surveys in the South Fen in August 2019 and July 2020 (Tix, 2020). Plots in the South Fen were established in 2019 and revisited in 2020. In addition to the formal relevé, Barr completed meander surveys in and around the area to document any additional species not seen in the plots.

Figure 10 shows the location of the relevé plots and meander survey. A total of 86 species were found during the vegetation survey. Eight calcareous fen indicator species were found. These species are listed in The vegetation assessment shows a diverse population of native vegetation, however, there is evidence of invasive species encroachment. Buckthorn has been identified as the most invasive of the species. Buckthorn is aggressive and has the potential to shade out the native species, leading to loss of ground cover and creating erosion and drainage of the peat. This results in deterioration and loss of habitat. Other invasive species such as reed grasses and cattails were also found in the South Fen. Willow and dogwood species were found within the South Fen. Without proper management, the native vegetation could be overwhelmed by invasive species, and the fen community will decline.

Based on the indicator species found, the South Fen meets the requirements for calcareous fen classification. No state-listed threatened plant species were found during the survey.

Figure 10. Location of 2019–2020 Gun Club Lake South Fen Vegetation Survey Adapted from Tix (2020)



The vegetation assessment shows a diverse population of native vegetation, however, there is evidence of invasive species encroachment. Buckthorn has been identified as the most invasive of the species. Buckthorn is aggressive and has the potential to shade out the native species, leading to loss of ground cover and creating erosion and drainage of the peat. This results in deterioration and loss of habitat. Other invasive species such as reed grasses and cattails were also found in the South Fen. Willow and dogwood species were found within the South Fen. Without proper management, the native vegetation could be overwhelmed by invasive species, and the fen community will decline.

Table 2 Calcareous Fen-Indicator Species Found in Gun Club Lake Fens

Common Name	Scientific Name
Bog birch	<i>Betula pumila</i>
Crowned beggarticks	<i>Bidens coronate</i>
Fringed brome	<i>Bromus ciliata</i>
Spring cress	<i>Cardamine bulbosa</i>
Water sedge	<i>Carex aquatilis</i>
Porcupine sedge	<i>Carex hystericina</i>
Inland sedge	<i>Carex interior</i>
Prairie sedge	<i>Carex prairiea</i>

Invasive species management needs to be a focus of the stewardship of the Gun Club Lake Fens. It is evident that invasive species will continue to advance on the Fens unless they are controlled. While removing invasive plants is effective, maintaining a healthy fen environment that favors native plants is an important aspect of controlling invasive plants. Routine vegetation assessments will provide a measure of the success of controlling nonnative plant invasion.

Land Use

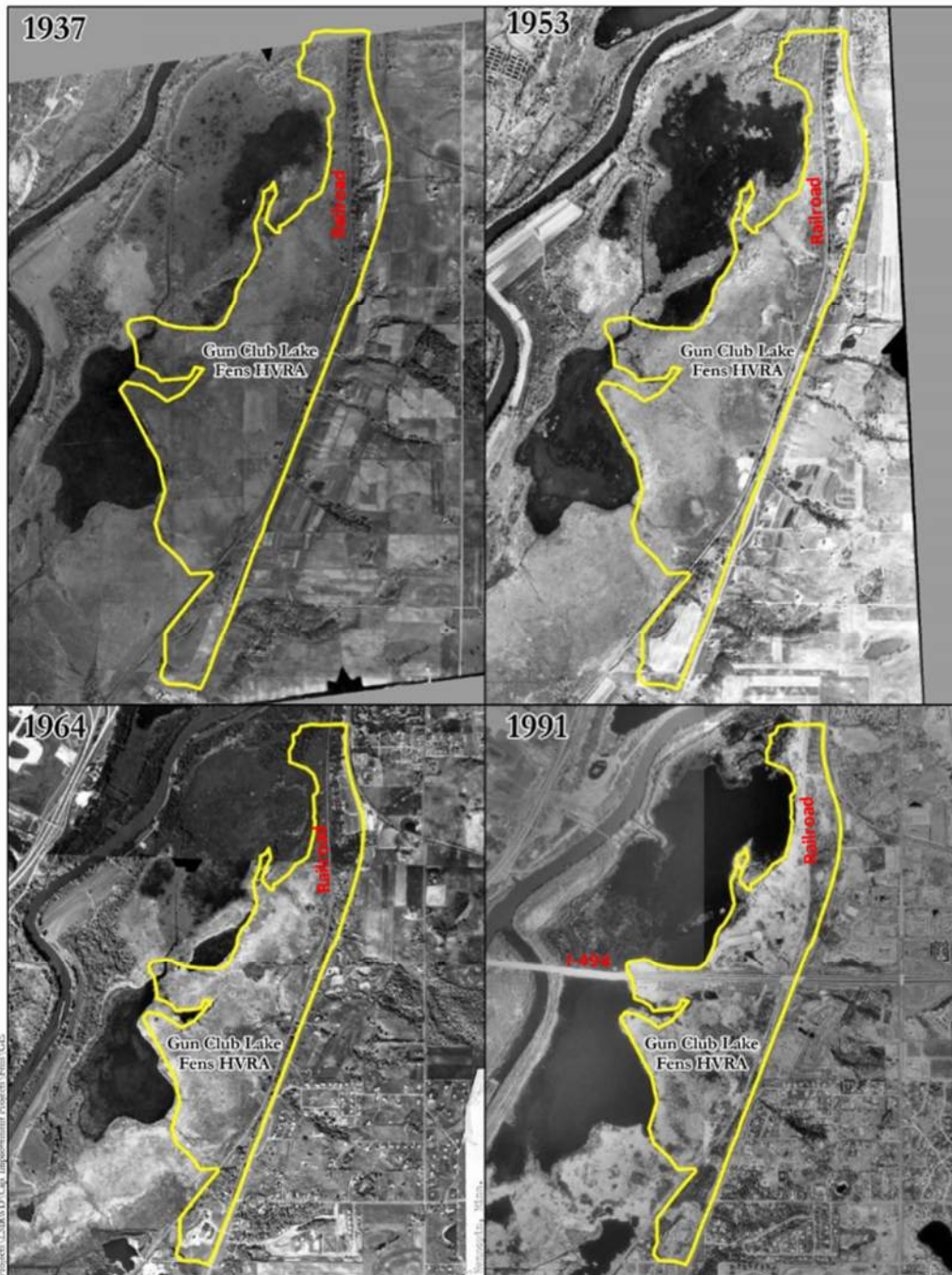
The land east of the Gun Club Lake Fens is highly urbanized and continues to experience urban growth as part of the Twin Cities Metropolitan Area. Summarized below are the historical and planned land uses for the area surrounding the Gun Club Lake Fens.

Historical

Figure 11 shows a series of aerial photographs showing the land use in and near the Gun Club Lake Fens HVRA. Images were obtained from Minnesota Historical Aerial Photographs Online (MHAPO), which is managed by the University of Minnesota Libraries (MHAPO, 2015). Each image was cropped from a larger image to center on the Gun Club Lake Fens. The most recent images from MHAPO in this area were taken in the 1960s. More recent images were obtained from the Minnesota Geospatial Information Office (MnGeo, n.d.). Each photograph in Figure 11 shows the HVRA boundary outlined in yellow with labels for the Minnesota River, the railroad, and I-494 when visible to help orient the reader between the different images. It should be noted that TH 13 is not labeled because it creates and is covered by the eastern HVRA border.

Imagery spanning from 1937 to 1991 shows a clear progression in and around the HVRA from rural agricultural use to urban development. The image from 1937 shows a few developments and roads within and around the Gun Club Lake Fens HVRA. Less than twenty years later, the image taken in 1953 shows a greater quantity of roads west of the HVRA. The image from 1964 shows a great increase in development to the east within the cities of Eagan and Mendota Heights. The southernmost portion of the HVRA area has also experienced minor development. The image from 1991 shows another jump in development, more densely in the City of Eagan. It was between the 1970s and 1990s that the City of Eagan experienced its most rapid development (WSB & Associates, Inc., 2008); however, imagery between the 1960s and 1990s in this region was not found. The 1991 image shows nearly complete development within both the City of Eagan and the City of Mendota Heights. Most notable is the construction of I-494, which divided the North and South Fens.

Figure 11. Historical Aerial Imagery of Gun Club Lake Fens High Value Resource Area



Recent and Planned

Figure 12 provides a recent aerial image taken in 2020. The image shows significant changes to the area east of the Gun Club Lake Fens. Undeveloped areas are nearly entirely gone, replaced by a mix of industrial, commercial, and residential land uses. Although development has expanded, it should be noted that it has not encroached on the fens west of the railroad because that area is part of Fort Snelling State Park.

The most recent land use data for the area surrounding the Gun Club Lake Fens is shown in Figure 13.

The land use information is compiled by the Metropolitan Council of the Twin Cities from information provided by local government units (Metropolitan Council, 2023). The fens have been threatened by pressures from rapid development having large quantities of impervious surfaces that increase runoff and reduce groundwater recharge. With few exceptions, the area east of the fens has been converted to industrial, commercial, and residential spaces that are unlikely to change.

Projected land use in 2040 shows conversion of the limited undeveloped areas east of the fens to commercial and office, industrial, and residential uses. Additionally, several areas have changed from industrial and residential to commercial and office uses. The proposed developments could continue to cause changes to the area hydrology. Commercial and other developments will create greater impervious areas, potentially increasing runoff and decreasing groundwater recharge. New construction may require dewatering, which affects runoff and groundwater recharge.

Because the Gun Club Lake Fens rely on the sustained flow of upwelling groundwater, the land use in areas east of the railroad and TH 13, where recharge to the groundwater supply occurs, is critically important to the long-term health of the fens. The sequence of historic to recent aerial photographs shows a transition from rural to highly developed, a change unlikely to be reversed. The Gun Club Lake Fens are ecologically significant and dynamic ecosystems that interact with other nearby ecosystems. The wetland habitat connections to nearby resources have been affected by roads, altered land uses, and other changes, which can create barriers for birds, amphibians, fish, aquatic invertebrates, and wetland plants. Improved understanding of the value of the Gun Club Lake Fens and surrounding lands may foster increased efforts to protect those resources. Development and redevelopment in the surrounding areas should prioritize and incorporate low-impact development strategies to increase groundwater recharge, remove urban runoff pollutants, and maintain or reduce runoff flows and volumes.

Figure 12. Recent Aerial Image of Gun Club Lake Fens and the Surrounding Area

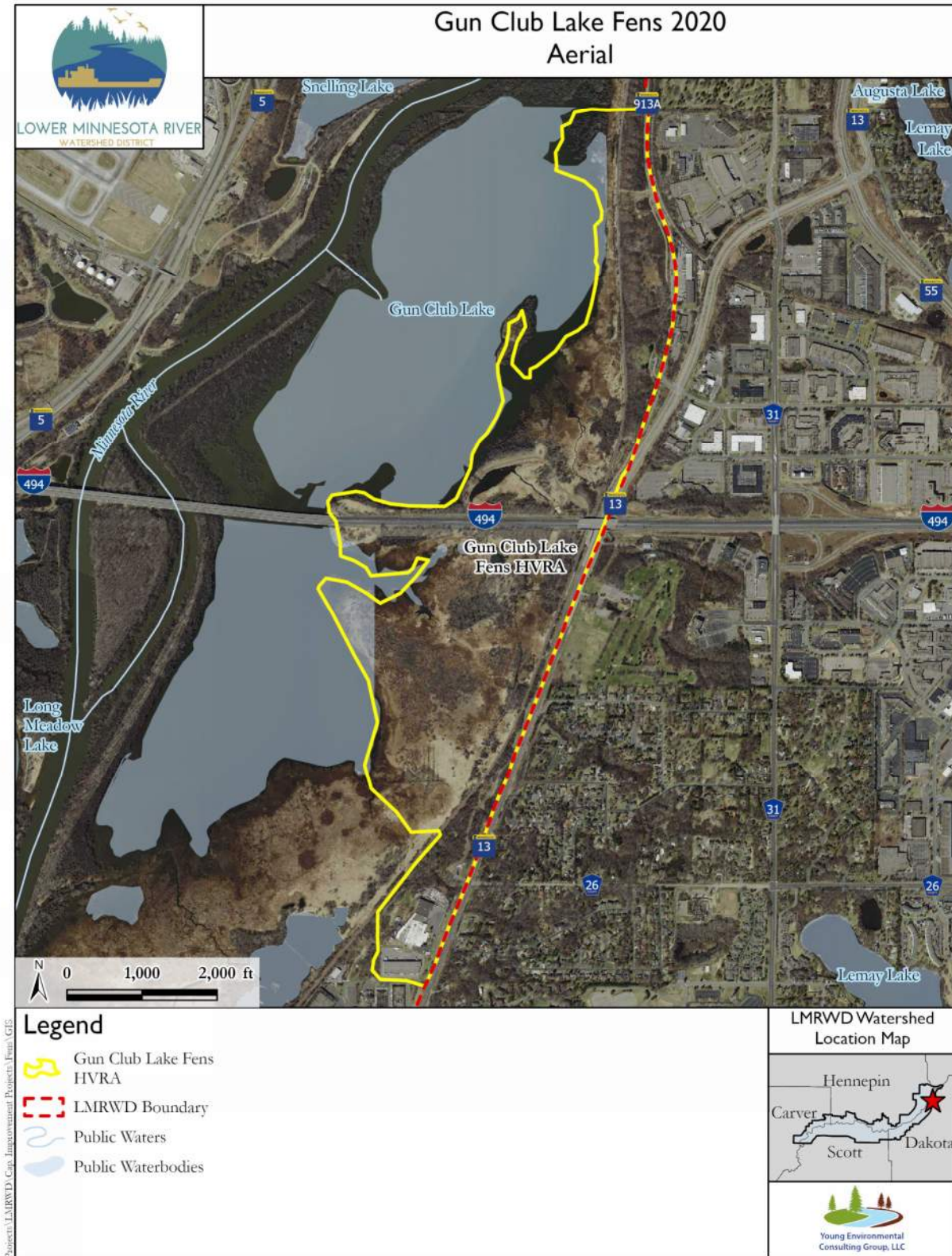
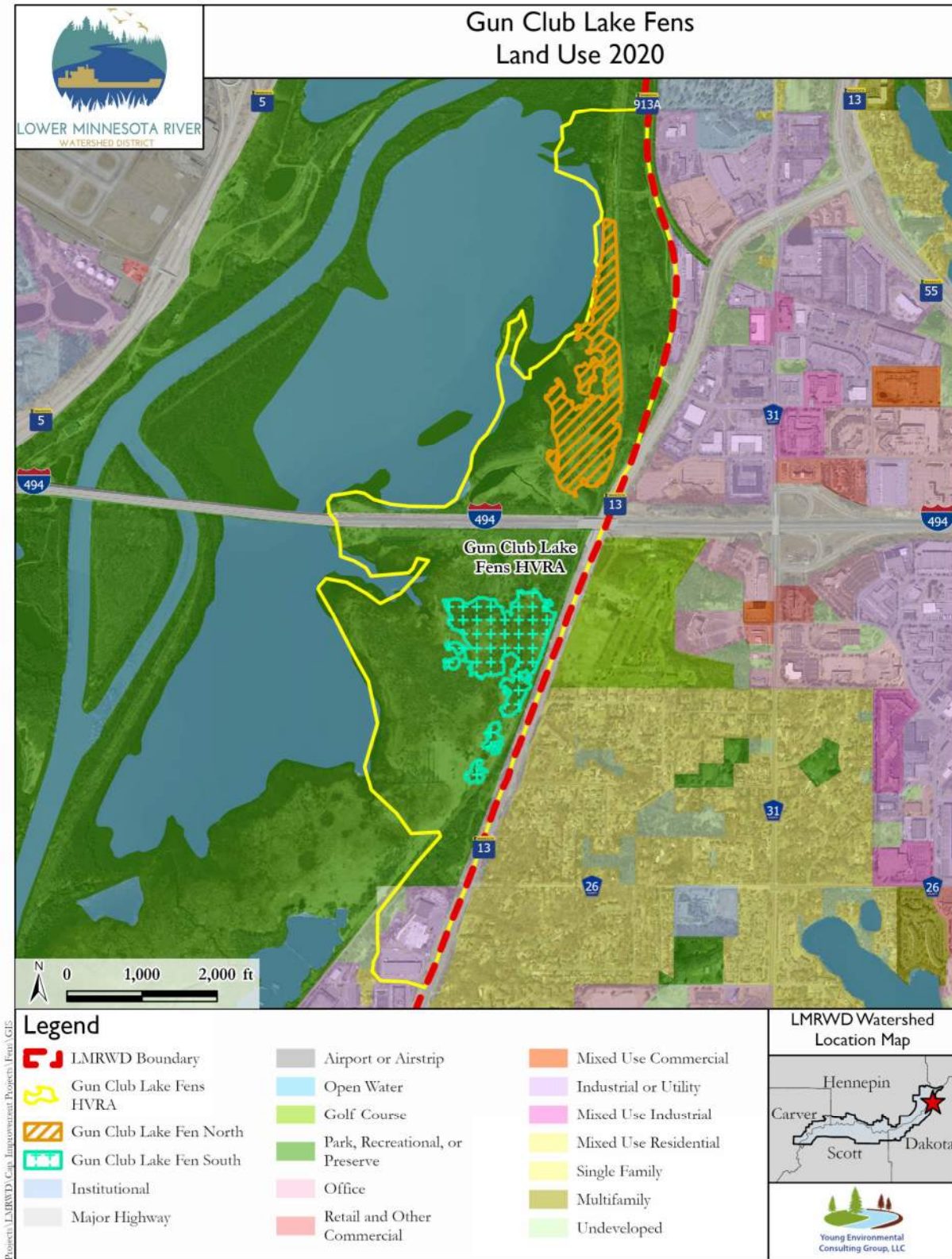


Figure 13. 2020 Land Use near Gun Club Lake Fens



Conclusions

The Gun Club Lake Fens are the product of geologic, climatic, and evolutionary forces that resulted in the unique ecosystem supported by the accumulation of poorly decomposed peat present today.

Although the Gun Club Lake Fens are protected as a part of Fort Snelling State Park, relatively recent pressures of changing land use, competition for groundwater and other resources, and other factors have measurably stressed the ecosystem. Agricultural activity, road and railroad construction, and recharge area development have all had an impact on the fens' ecosystem. The most notable effect on the Gun Club Lake Fens is the eroded channel that has developed in the North Fen.

Groundwater elevations at both Gun Club Lake Fens are below the ground surface at many locations, leaving the potential for vegetation desiccation. Additionally, the North Fen does not display an upward gradient of groundwater typical to fens and shows potentially decreasing groundwater elevations. There is currently a lack of information associated with the North Fen. Additional groundwater monitoring wells should be installed, and vegetation assessments should be conducted to provide a comprehensive picture of the health of the North Fen. Once an assessment of the North Fen has been completed, the MNDNR can determine what if any mitigation strategies should be applied to the eroded channel.

Significantly more information is available for the South Fen. The South Fen is adequately covered by groundwater monitoring wells, and several vegetation assessments have been conducted. The most recent vegetation assessment found sufficient indicators of calcareous fen vegetation. However, vegetation assessments also show some growth of invasive, nonnative species that could disrupt existing vegetation and the fen ecosystem. Many of the invasives, including reed grasses and shrubs, such as buckthorn, shade the native plants, depriving them of sunlight and interfering with life-cycle functions. Aggressive efforts to control invasive plants are needed to protect the fen community.

Recent and planned activities around the Gun Club Lake Fens have the potential to further lower groundwater levels within the fens. With development of currently undeveloped areas in and east of the HVRA, less water may be available to recharge the fens' groundwater supply. Education opportunities could be pursued to inform landowners and developers of the importance of calcareous fen communities and the impacts of development on fen health.

Natural resources managers are making important contributions to our understanding of fens by supporting important data collection programs and resource investigations. Educational institutions, environmental organizations, nonprofit organizations, and others are encouraged to support or conduct research that helps support or enhance our understanding of these threatened ecosystems. New and creative approaches to understanding and characterizing the Gun Club Lake Fens will help foster additional opportunities for studies and provide broader protections for the fens and similarly rare and threatened resources.

References

- Almendinger, J. E., & Leete, J. H. (1998a). Peat characteristics and groundwater geochemistry of calcareous fens in the Minnesota River Basin, USA. *Biogeochemistry*, 17–41.
- Almendinger, J., & Leete, J. (1998b). Regional and local hydrogeology of calcareous fens in the Minnesota River Basin, USA. *Wetlands*.
- Balaban, N., & Hobbs, H. (1990). C-06 Geologic Atlas of Dakota County, Minnesota. Minnesota Geological Survey.
- Burns & McDonnell. (2015). *Groundwater and Fen Evaluation Summary Report*. Minneapolis: Lower Minnesota River Watershed District.
- Carrington, D. (2020, September 29). *40% of World's Plant Species at Risk of Extinction*. Retrieved from <https://www.theguardian.com/environment/2020/sep/30/world-plant-species-risk-extinction-fungi-earth>
- Cooper, W. A. (2009). *What is a Fen?* Retrieved from U.S. Forest Service: https://www.fs.fed.us/wildflowers/beauty/California_Fens/what.shtml
- Dakota County SWCD. (2021). *2021 Fen Well Monitoring Report*. Minneapolis, Minnesota: Lower Minnesota River Watershed District.
- House, D. V. (2021, June 30). *Bryophytes as Key Indicators of Ecosystems Function and Structure of Northern Peatlands*. Retrieved from https://www.researchgate.net/publication/352854061_Bryophytes_as_key_indicators_of_ecosystem_function_and_structure_of_northern_peatlands
- Janssens, J. (2014). *Field Guide to Mosses & Liverworts of Minnesota's Calcareous Fens*. Minnesota Department of Natural Resources.
- Metropolitan Council. (2023, March 20). *Regional Planned Land Use - Twin Cities Metropolitan Area*. Retrieved from Minnesota Geospatial Commons: <https://gisdata.mn.gov/dataset/us-mn-state-metc-plan-pland-land-use>
- MHAPO. (2015, February 16). *Minnesota Historical Aerial Photographs Online*. Retrieved from <https://apps.lib.umn.edu/mhapo/>
- MNDNR. (2023). *Cooperative Groundwater Monitoring*. Retrieved from <https://www.dnr.state.mn.us/waters/cgm/index.html>
- MnGeo. (n.d.). *Aerial Photography of Minnesota*. Retrieved from <https://www.mngeo.state.mn.us/chouse/airphoto/#>
- MPCA. (2022). *Seminary Fen*. Retrieved from <https://www.pca.state.mn.us/waste/cleanup-stories/seminary-fen>

- NRRI, U. (2018). *Northern Long Eared Bat Roost Tree Characteristics 2015-2017*. Natural Resources Research Institute, Biology. Duluth, MN: University of Minnesota, Duluth. Retrieved Feb 23, 2022, from <https://conservancy.umn.edu/bitstream/handle/11299/204334/NRRI-TR-2018-41.pdf?sequence=1&isAllowed=y>
- Schmidt, A. J., Pratt, D. R., Vermeer, A. C., & Bradley, B. H. (2007). *Minnesota Statewide Historic Railroads Study*. Minnesota Department of Transportation.
- State of Minnesota. (2022). Protection of Threatened and Endangered Species. *Minnesota Statutes*. Retrieved from <https://www.revisor.mn.gov/statutes/>
- Stokmane, M., & Cera, I. (2018). *Revision of the Calcareous Fen Arachnofauna: Habitat Affinities of the Fen-Inhabiting Spiders*. University of Latvia, Biology. Riga, Latvia: ZooKeys 802. Retrieved Feb. 14, 2022, from <https://doi.org/10.3897/zookeys.802.26449>
- The National Wildlife Federation. (2022, February 23). *What is an “Endangered Species”?* Retrieved from <https://www.nwf.org/Educational-Resources/Wildlife-Guide/Understanding-Conservation/Endangered-Species>
- Tix, D. (2020). *Dakota County Fen Assessment Summary 2019–2020*. Minneapolis, MN: Barr Engineering Co.
- USDA. (n.d.). *Web Soil Survey*. Retrieved from Web Soil Survey: <https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>
- USFWS. (2019, May 29). *Fact Sheet Rusty Patched Bumble Bee (Bombus affinis)*. Retrieved from <https://www.fws.gov/midwest/endangered/insects/rpbb/factsheetrpbb.html>
- USFWS. (2020, January 30). *Endangered Species Act | Overview*. Retrieved from U.S. Fish and Wildlife Service, Endangered Species: <https://www.fws.gov/endangered/laws-policies/>
- WSB & Associates, Inc. (2008). *Environmental Monitoring of Nicols Fen, Conservation Partnership Grant #CP05-14*.
- Young Environmental. (2021). *Fens Sustainability Gaps Analysis - Carver, Dakota, and Scott Counties, Minnesota*. Minneapolis, Minnesota: Lower Minnesota River Watershed District.
- Young Environmental. (2022a). *Gun Club Stormwater Intrusion Study*. Chaska, Minnesota: Lower Minnesota River Watershed District.
- Young Environmental. (2022b). *Seminary Fen Stewardship Plan*. Chaska, Minnesota: Lower Minnesota River Watershed District.