Prepared for

LOWER MINNESOTA RIVER
WATERSHED DISTRICT

February 2024

Nicols Meadow Fen Stewardship Plan

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Chaska, Minnesota

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
SWCD	Soil Water Conservation District
HVRA	High Value Resource Area
LMRWD	Lower Minnesota River Watershed District
MCES	Metropolitan Council Environmental Services
MGY	Millions of Gallons per Year
MNDNR	Minnesota Department of Natural Resources
MSL	Mean Sea Level
NHIS	National Heritage Information System
WWTP	Wastewater Treatment Plant
TH	Trunk Highway
USDA	United States Department of Agriculture

INTRODUCTION

Nicols Meadow Fen, composed of three clusters of unique wetlands classified as calcareous fens, is situated southeast of the Minnesota River, northeast of Trunk Highway 77, northwest of Trunk Highway 13, and southwest of the Seneca Wastewater Treatment Plant in Dakota County. The three clusters of wetlands that make up the fen are named Nicols Meadow Fen A, B, and C (Figure 1). This document refers to the three clusters collectively when describing Nicols Meadow Fen. 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. Fen ecosystems support unique plant communities that can contain rare and endangered plant species not found in other environments. Nicols Meadow Fen is approximately 14.2 acres in size, but like most fens, the borders and fen-community locations tend to be indeterminate. Nicols Meadow Fen is closely associated with two trout streams, Kennaley's Creek, which flows through the northeastern portion of the fen, and Harnack (also known as Unnamed 1) Creek, which flows through the southwestern portion of the fen. These creeks likely receive baseflow upwelling from the same groundwater that supplies Nicols Meadow Fen.

Nicols Meadow Fen has a lengthy history of disturbances, including residential and agricultural activity within the fen, road and railroad construction, nearby dewatering, and development in the groundwater recharge area. These activities have resulted in lowered groundwater elevations and a decline in calcareous fen vegetation.

A well-managed groundwater-level data-collection network helps to monitor the groundwater supply in Nicols Meadow Fen, although more data collection is required to understand the quality of the groundwater. Recent data show that nearby dewatering has a profound effect on the fen's groundwater supply. Additionally, nearby planned development has the potential to infringe on the fen's groundwater supply and on the fen itself. This plan proposes that undeveloped and privately owned areas within and around Nicols Meadow Fen be considered for purchase and managed to prevent further degradation of the fen.

Recent vegetation assessments summarized in this report identify a lack of calcareous fen vegetation and the growth of invasive, nonnative species that disrupt native vegetation. This plan proposes development of a vegetation management program to control invasive, nonnative species and to propagate native fen vegetation communities in Nicols Meadow Fen.

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 to help protect and sustain these valuable resources into the future. In response to the Gaps Analysis' recommendation, this Nicols Meadow Fen Stewardship Plan (Stewardship Plan) has been prepared and identifies stewardship and management actions, areas of additional study, and education and outreach opportunities for Nicols Meadow Fen, which is located partially within Fort Snelling State Park in the City of Eagan. This Stewardship Plan represents the continued commitment to the LMRWD's goal to protect, enhance, and sustain the valuable resources, such as Nicols Meadow Fen, that lie within its boundaries.

Figure 1. Nicols Meadow Fen Location

The Stewardship Plan's focus is to outline stewardship and management needs and actions to protect, restore, and sustain Nicols Meadow Fen. Those stewardship needs and actions are presented early in the plan to highlight their importance. Information and data on Nicols Meadow Fen 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.

Nicols Meadow Fen is within one of the LMRWD High Value Resource Areas (HVRAs), which require special consideration and adherence to protection standards as specified in the LMRWD's 2018 Comprehensive Watershed Management Plan (2018 Plan). The Nicols Meadow Fen HVRA is approximately 438 acres. The HVRAs are a management strategy, adopted as part of the 2018 Plan, that consists of managing areas directly draining into calcareous fens and trout waters through the formation of HVRA overlay districts. The goals of the 2018 Plan and the corresponding HVRA overlay districts are to understand, preserve, protect, and restore unique and high-value natural resources while critically evaluating projects that propose to alter them.

This Stewardship Plan is intended to create awareness of the value and uniqueness of Nicols Meadow Fen and guide future stewardship aimed at creating a collective commitment among stakeholders to protect the fen. Based on analysis of past fen studies, vegetation assessments, and groundwater monitoring data described throughout this document, this Stewardship Plan proposes data collection, resource investigation, and stewardship actions to be implemented by the Minnesota Department of Natural Resources (MNDNR), the LMRWD, and other stakeholders to help protect and sustain Nicols Meadow Fen. These stewardship actions include:

- Conducting vegetation surveys within the fen and developing and implementing programs to control nonnative, invasive species as well as propagate and reintroduce native fen species;
- Continuing groundwater monitoring efforts to build on the existing body of groundwater monitoring data, develop a more robust monitoring network by adding monitoring wells as needed, and collect groundwater quality data in the fen to help better understand the quality and sustainability of the groundwater supply;
- Evaluating and pursuing the purchase of undeveloped and privately owned lands in and around Nicols Meadow Fen to protect the fen from further development pressures and allow for more efficient monitoring; and
- Encouraging stakeholder engagement in protecting Nicols Meadow Fen by developing education and outreach materials and activities that inform stakeholders, encouraging conservation, and providing stewardship and engagement opportunities for the public. Increased awareness and understanding of these threatened ecosystems will help encourage protection of Nicols Meadow Fen into the future.

This Stewardship Plan identifies stakeholders that can participate in the preservation and protection of Nicols Meadow Fen and recommends stewardship actions aimed at protecting and enhancing the fen ecosystem and mitigating risks of degradation.

STAKEHOLDER ENGAGEMENT

The MNDNR and LMRWD play the lead roles in planning and implementing ongoing studies, monitoring, stewardship actions, and education and outreach for Nicols Meadow Fen.

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 Nicols Meadow Fen, the Cooperative Groundwater Monitoring Network. It is also responsible for coordinating increased monitoring efforts associated with the Seneca Wastewater Treatment Plant (WWTP). The MNDNR is a key collaborator in the analysis and distribution of groundwater data. Additionally, the MNDNR has conducted several vegetation surveys and could collaborate on future surveys of Nicols Meadow Fen and the removal of invasive species such as buckthorn. Due to their extensive knowledge of calcareous fen resources, the MNDNR is instrumental in education and outreach efforts. The MNDNR will also be a key collaborator in any land purchasing efforts.

The LMRWD is responsible for regulating development projects that occur within the Nicols Meadow Fen HVRA and surrounding areas within the district and will play the primary 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 Nicols Meadow Fen is key to making informed management decisions and implementing actions that will protect and sustain the fens. In addition to 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, provide Nicols Meadow Fen data and information, 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, Seneca WWTP, City Eagan, Dakota County Soil and Water Conservation District, National Audubon Society, Trout Unlimited, Minnesota Landscape Arboretum, Minnesota Native Plant Society, Science Museum of Minnesota, Great River Greening, private property owners in the vicinity of Nicols Meadow Fen, and prospective developers of nearby properties.

Many organizations and individuals would likely support the protection and enhancement of Nicols Meadow Fen and its associated resources. However, many of those stakeholders may be unaware of the unique ecosystem that exists in the fen. 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 Nicols Meadow Fen. 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 Nicols Meadow Fen. This may include collaborating with purchasing entities on property acquisitions, coordinating volunteer efforts to help with the removal of invasive, nonnative vegetation species, and working with MNDNR and the Minnesota Landscape Arboretum on opportunities to conduct plant propagation programs and seed collection 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 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 the existing and potential stakeholders to plan and implement continued monitoring, assessment, and other actions to mitigate threats to the health of Nicols Meadow Fen and enhance the fen ecosystem to sustain it into the future. Stewardship opportunities and actions are described below and in Table 1, which outlines proposed stewardship opportunities, actions, timelines, and estimated costs.

Vegetation Assessment

Vegetation relevés recommended by the Gaps Analysis were conducted in 2019 and 2020. Unfortunately, they were unable to identify significant quantities of fen indicator species. It is proposed that future vegetation surveys occur, planned at five-year intervals, to help determine vegetation trends and the benefits of future stewardship actions. Relevés plots established in Nicols Meadow Fen A and C should be maintained, and a new plot should be established in Nicols Meadow Fen B. Because Fen B is privately owned, MNDNR and LMRWD should engage with landowners to request permission to conduct vegetation surveys.

Vegetation Management

The presence of invasive species 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, and opportunities to work with others to apply and refine these techniques should be considered in lieu of riskier management techniques. Development of a vegetation management program is recommended for Nicols Meadow Fen to address threats from invasive, nonnative species. This program would identify vegetation management needs, identify volunteer groups and/or experienced vegetation management personnel to implement management actions, and utilize 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. There are several fens in the LMRWD in varying conditions, but the healthiest appear to have the most reliable supply of groundwater (Young Environmental, 2021). Researchers can use existing measures of fen health and records of groundwater elevations to determine the optimum water level that sustains healthy fen communities.

Nicols Meadow Fen's sustainability depends on a continuous supply of upwelling groundwater. If the groundwater supply is interrupted, the health of the fen may be irreversibly affected. Therefore, it is important to continue monitoring the groundwater elevations with the existing wells. Continued operation of automated recorders provides more detail and better resolution of changes in groundwater elevations as they change over time. As monitoring associated with the Seneca WWTP will be intensified, monitoring conducted by the Dakota County Soil Water Conservation District (SWCD) may be discontinued due to redundant and lower-resolution data (Andrews & Skancke, 2023). Continued coordination by the MNDNR with existing and potential users of the groundwater that sustains Nicols Meadow Fen is necessary to prevent overallocation to users and maintain optimum groundwater levels and conditions to sustain a healthy fen ecosystem.

Groundwater Quality Monitoring

Young Environmental (2021) noted a lack of water chemistry data available to describe the groundwater quality beneath Nicols Meadow Fen, except to note that testing done in the late 1990s showed altered carbonate content likely associated with dewatering and peat decomposition. Young Environmental recommended routine sampling to better describe the water quality and form the basis for identifying trends. The data will provide information about current ionic strength and 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 land use in the presumed groundwater recharge area and near Nicols Meadow Fen. Sampling pairs of shallow and deep wells is suggested, with the shallow well in the peat layer and deeper well in alluvial sands, because water chemistry in each of these environments may have characteristically distinct differences.

The annual samples collected should be accompanied by field measurements of water temperature, specific conductance, pH, and dissolved oxygen that are also used to determine if the water sample 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

these 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 the deep well until the age of the water supplying Nicols Meadow Fen is clearly understood. 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 Nicols Meadow Fen groundwaters. Tritium analyses are indicative of water recharged in the 1950s and 1960s, chlorofluorocarbons indicate waters 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 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 should also be considered because it can document characteristics of the water that provides recharge to the aquifers supplying Nicols Meadow Fen.

Private Property Assessment and Acquisition

Purchase by the MNDNR of privately owned properties in and around Fen A, Fen C, and the fen buffer area would protect those areas and facilitate additional monitoring and vegetation surveys. Approximately 43 acres of private property in and around Nicols Meadow Fen has been preliminarily assessed for purchase. Purchasing these properties would be a key stewardship action to further protect the Fen and surrounding ecosystem.

Kennaley's Creek and Harnack Creek

Stewardship of Nicols Meadow Fen should include consideration of the adjacent Kennaley's and Harnack Creek trout streams. Although neither creek presently appears to support a trout population, reaches of each appear to have necessary habitat characteristics. The creeks are sustained by the same groundwater source as Nicols Meadow Fen. Improved understanding of the ecological connection of Nicols Meadow Fen and these creeks and holistic management of these resources are critical to their sustainability.

Education and Outreach

Partnerships with interested stakeholders will help broaden support and increase understanding of the value of calcareous fens needed to support Nicols Meadow Fen 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 Nicols Meadow Fen.

Stewardship Strategy Table

Table 1provides recommendations for the various stewardship strategies to protect and restore Nicols Meadow Fen. The lead agency or organization in most of these efforts is MNDNR as managers of Fort Snelling State Park. Persons wanting to transfer private property to MNDNR public ownership should contact MNDNR to learn about the benefits and directions on how to proceed. Additionally, the MNDNR provides education and outreach opportunities.

Table 1 - Nicole Meadow Fens Stewardship Strategies

Item	Stewardship Strategy	Category	Lead Agency	Considerations for Scaling and Feasibility	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 Nicols Meadow Fen.	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 utilizing the vegetation plots established in the 2019–2020 relevé.	Vegetation	MNDNR and LMRWD	Two relevé sites are located within Nicols Meadow Fen in Fen clusters A and C. No plot is located in Fen B because it is private property.		Repeat Survey		
3	Establish a relevé plot in Fen B and conduct plan surveys at five-year intervals.	Vegetation	MNDNR and LMRWD	The MNDNR and LMRWD can engage with landowners to request permission to conduct vegetative surveys.	Engage with Landowners	Start Surveys		
4	Develop a native species propagation program to collect seeds and replant threatened and endangered fen species in strategic locations to provide ecosystem uplift.	Vegetation	MNDNR and LMRWD	Coordinate with MNDNR, Minnesota Landscape Arboretum, and other stakeholders to develop this program. Initial efforts would be focused on public lands and could be scaled to include private lands. The goal is to enhance and restore native vegetation at Nicols Meadow Fen and develop tools and methods that can be applied to restore and enhance fen ecosystems more broadly.	Outreach and Development			
5	Continue research and validation of tools for fen identification and indicators of fen vigor and the chemistry that sustains the fen.	Vegetation	MNDNR and LMRWD	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.	Ongoing			
6	Assess acquisition of private properties within and around the fen, including the buffer area planned for development. Purchase of properties by the MNDNR would result in enhanced protection of Nicols Meadow Fen.	Property Assessment and Acquisition	MNDNR	The MNDNR can accept ownership of properties adjacent to MNDNR land. The LMRWD can assist in coordination with the property owners but would not own properties.	Acquisition Assessment			
7	Purchase the land in and around Fen B for conservation within Fort Snelling State Park, approximately 6.5 acres. See Residential and other developments will increase impervious area cover and may require substantial dewatering to establish foundations. Dewatering, even if temporary or seasonal, has been shown to have prolonged effects on fen health and sustainability. Any developments including below-grade basements may require sustained dewatering to keep those basements dry. Improved understanding of the value of Nicols Meadow Fen and the buffer provided by surrounding lands may foster increased efforts to protect those resources. Planned developments may be altered to add protection to Nicols Meadow Fen and the adjacent areas. The MNDNR, other agencies, and nongovernment conservation organizations should continue to pursue opportunities to acquire additional property for inclusion and protection as part of Fort Snelling State Park or other protected lands. Figure 13 displays the future planned land use with areas highlighted for purchase consideration.	Property Assessment and Acquisition	MNDNR	The MNDNR should pursue purchase of the land containing the fens and the adjacent properties. Funding sources are available for purchase of conservation lands, including the Legislative–Citizen Commission on Minnesota Resources and the Trust for Public.	Ongoing			

Item	Stewardship Strategy	Category	Lead Agency	Considerations for Scaling and Feasibility	2024	2025	2026	2027
	Of highest priority is the area in and around Fen B currently under private ownership. The area is approximately 6.5 acres. According to the 2022 assessed value, the area would cost approximately $174,000 to purchase. For additional purchase consideration, the area south of the railroad containing portions of Fen A and the buffer is approximately 36.5 acres and would cost $415,000 to purchase. 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. Because Nicols Meadow Fen relies on the sustained flow of upwelling groundwater, the land use in areas south of the railroad and TH 13, where recharge to the groundwater supply is believed to occur, is critically important to the long-term health of the fen. The sequence of historic to recent aerial photographs shows a transition from rural to highly developed, a change unlikely to be reversed. Nicols Meadow Fen is an ecologically significant, dynamic ecosystem that interacts with other nearby ecosystems. The wetland habitat connections to nearby resources have been affected by roads, altered land uses, and other habitat changes. These features can create barriers for birds, amphibians, fish, aquatic invertebrates, and wetland plants, as described by Johnson and Walz. Maintaining and restoring these connections is important to consider in evaluating the actions to improve the long-term sustainability of the fen.							
8	Sample at least two groundwater wells for field measurements, major ions, and nutrients. Rotate sampling of age-dating indicators each year.	Property Assessment and Acquisition	MNDNR	The MNDNR should pursue purchase of the land containing the fens and the adjacent properties. Funding sources are available for purchase of conservation lands, including the Legislative–Citizen Commission on Minnesota Resources and the Trust for Public.	Ongoing			
9	Continue to evaluate and enhance the groundwater monitoring network by installing additional wells if needed. Eliminate redundancies as opportunities arise.	Groundwater Monitoring	MNDNR and MCES	The MNDNR or Metropolitan Council—Environmental Services (MCES) could do this work. The monitoring program could be expanded to collect additional samples and request additional analyses by qualified laboratories.	Ongoing Sampling and Evaluation			

ENVIRONMENTAL SETTING

Located on the south side of the Minnesota River, Nicols Meadow fen is in Dakota County in the City of Eagan, Minnesota (see Figure 1). Approximately 11.5 acres of the fen are protected as a part of Fort Snelling State Park and managed by the MNDNR, leaving approximately 2.7 acres of the fen under private ownership. The fen is bordered by Trunk Highway (TH) 77, also known as Cedar Avenue, to the southwest, and TH 13 to the southeast.

Nicols Meadow Fen is in the Minnesota River Valley at an average ground surface elevation of 720 feet mean sea level (MSL), above the 714.6 feet MSL 100-year flood elevation of the Minnesota River. The valley was created when glacial River Warren drained glacial Lake Agassiz after the last period of glaciation (Young Environmental, 2022a). Almendinger and Leete (1998a) estimated the age of nearby fens as over 10,000 years old. However, because of observed degradation within Nicols Meadow Fen, age-dating tests were not done on the fen as they would not be representative of a typical calcareous fen. Nicols Meadow Fen has a long history of disturbances and alterations. Figure 2 highlights these disturbances.

Known disturbances within the fen began in the 1860s with the construction of the railroad that transects Fen A and separates Fen B from Fen C, and the construction of Nicols Flag Station (WSB & Associates, Inc., 2008). Not long after this construction, a few buildings and homes were built to form the town of Nicols. The town of Nicols, located at the corner of Nicols Road and the railroad, was listed on maps but was not an official town (Dakota County Historical Society, 1989). It was instead a rural location within Eagan Township that never contained greater than 18 adults at one time. Despite its small size, Nicols had a large commercial impact and left its footprint on Nicols Meadow Fen and the surrounding area. Nicols made the map because of the area's agricultural production and molding sand excavations, both of which altered area hydrology. Several drain tiles were installed for the agricultural activities in the area, but the exact location of these tiles is unknown (WSB & Associates, Inc., 2008). Additionally, the town dump and a spoil pile may have contributed to the decline of the fen.

As the Twin Cities Metropolitan Area developed, greater city services were required. In 1959, the City of Eagan constructed a storm sewer outfall directly to Nicols Meadow Fen (WSB & Associates, Inc., 2008). A large storm in 2000 caused severe erosion at the outfall, creating a cavity approximately 20 feet deep and 30 feet in diameter at the surface (Young Environmental, 2021). The eroded cavity was subsequently restored, the outfall was abandoned, and the storm sewer was rerouted away from the fen (WSB & Associates, Inc., 2008). The most rapid development of the City of Eagan occurred from the 1970s to the 1990s, changing much of the fen's recharge area to industrial, commercial, and residential land uses. To accommodate this development, construction to upgrade TH 77 was started in 1977. It is believed that Nicols Meadow Fen and Black Dog Lake North Fen, which is on the southwest side of TH 77, may have been part of the same fen complex prior to the construction of TH 77.

Along with this development came the Seneca WWTP. The plant was built in 1972 and an expansion was completed in 1992 (WSB & Associates, Inc., 2008). In anticipation of the plant's construction, a pipe was constructed in 1971 transporting wastewater from the City of Bloomington to the Seneca WWTP. In the 1990s, two new pipes were installed, and the existing pipe was rehabilitated. The plant is allocated dewatering appropriations under two MNDNR permits, Permit 1990-6262 for dewatering the plant's underdrain system and Permit 1991-6073 for dewatering the

plant expansion to the west (Seaberg, 2022). Permit 1990-6262 authorizes appropriations of 329 million gallons of water per year (MGY), although usage has never exceeded 122.7 MGY. Permit 1991-6073 authorizes appropriation of up to 438 MGY. Plant operations have been linked to several instances of groundwater decline, described in subsequent sections of this report.

Figure 2. Disturbances within Nicols Meadow Fen

GEOLOGY

The bedrock geology beneath Nicols Meadow Fen lies approximately 100–150 feet below the ground surface and consists predominantly of the Prairie du Chien Group (Young Environmental, 2021). In the northeastern part of the fen, near Nicols Meadow Fen A, a bedrock valley exposes Jordan sandstone to the St. Lawrence and Franconia formations. The Prairie du Chien Group consists of the dolostone that makes up the Shakopee Formation overlaying Oneota Dolomite (Balaban & Hobbs, 1990). The upper portion of the Jordan Sandstone formation is composed of medium- to coarse-grained quartzose sandstone on top of fine-grained sandstone. The underlying St. Lawrence and Franconia formations are composed of dolomitic shale, siltstone, and sandstone. Surface geology of the fen consists of organic material above alluvial sand deposits that are part of the St. Croix glacial moraine (Young Environmental, 2021). Due to the depth of the bedrock, it is unlikely that bedrock materials contribute to carbonate minerals discharging to the fen (Almendinger & Leete, 1998b; Almendinger & Leete, 1998a; Young Environmental, 2021).

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 soils can range from neutral to strongly alkaline. The soils are typically rich in calcium bicarbonate, with tufa that resembles gritty chalk, sometimes identified as marls.

According to the USDA Soils Map (USDA , 2021), Nicols Meadow Fen is characterized primarily by muck with some loamy muck on the northeastern side near Nicols Meadow Fen A. The majority of the muck comprising the fen is referred to as the Seelyeville series with some Rondeau series muck near the center of the fen and Klossner series loamy muck near Fen A. All three series present within Nicols Meadow Fen are 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 data from the past help us 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 fen 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 with fewer extreme cold-temperature events. The report also shows that average high temperatures have remained consistent; however, long-term climate predictions suggest our summers will continue to get hotter with longer growing seasons. Other identified trends include an increase in intense and heavy precipitation events.

Research cited by 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. It is not known how changes in precipitation might affect the fen, which is reliant on upwelling groundwater. Extreme runoff events might cut channels through the fen, which would

drain water from below the fen surface, removing the water that sustains the fen vegetation. Rising temperatures could favor warm-climate plants, including invasives, while being detrimental to native fen plants that evolved in a cooler temperature regime. This would disrupt the Nicols Meadow Fen ecosystem. 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 Nicols Meadow Fen is a complex association between upwelling calcium- and magnesium-rich groundwater, unique plant communities, climate, and surface water. Aerial photographs (Figure 1) show that Nicols Meadow Fen has a strong association with both Kennaley's Creek and Harnack Creek. Kennaley's Creek crosses the fen HVRA to the north of Fen A, and Harnack Creek crosses on the southeast side of Fens B and C. Although both creeks associated with Nicols Meadow Fen are listed as trout waters, neither currently supports trout populations (Young Environmental, 2022b).

Nicols Meadow Fen and the water that sustains it have been altered by residential development within the fen, agricultural activity, roadways, railways, and other development within the fen's recharge area. Figure 2 displays the many alterations that have occurred in and around the fen over the years. Currently, there is potential for the fen to be threatened by runoff containing chlorides and other contaminants from roadways, other impervious surfaces, and municipal maintenance activities that can negatively affect plants in the calcareous fen.

GROUNDWATER

Groundwater characteristics of the Nicols Meadow Fen include an evaluation of groundwater flow from upgradient areas that are likely to 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. 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 evenly spaced elevation points 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 to 2022 (MGS and MDH, 2023). This data variability creates some uncertainty in potentiometric surface elevations.

Figure 3 Potentiometric Surface Map of the Prairie du Chien Aquifer

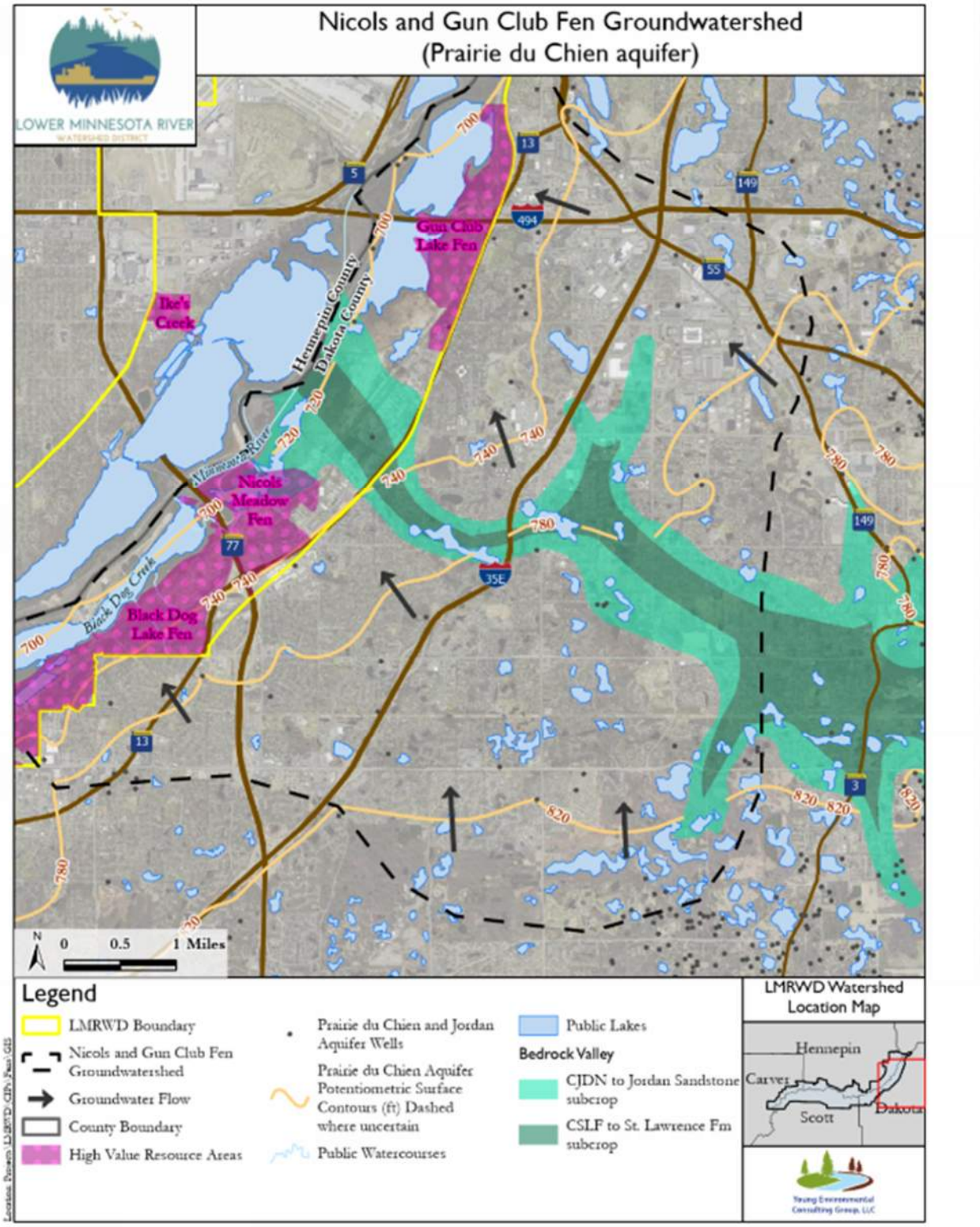


Figure 3 shows a consistent pattern of flow away from the topographically highest parts of Dakota county toward the discharge areas along the Minnesota River. An approximate groundwater-shed for the Gun Club Lake fens and Nicols Fen is shown with a dashed line to highlight a general recharge area of these groundwater discharge features. Maintaining and enhancing these recharge areas should be a focus of fen stewardship because they are the source of groundwater that discharges at the fen and maintains fen viability.

On a more local scale, both the Metropolitan Council Environmental Services (MCES) and Dakota County SWCD have been collaborating with the MNDNR and the LMRWD for several years to monitor groundwater elevations associated with Nicols Meadow Fen. The Fen Gaps Report (Young Environmental, 2021) provides detailed information about the wells located in Nicols Meadow Fen.

What follows is a summary of historical and current groundwater information for Nicols Meadow Fen. Figure 4 shows groups of monitoring wells within and around Nicols Meadow Fen. Thirteen monitoring wells are located within the fen, and the MCES monitors additional wells associated with permitting obligations to the Seneca WWTP (Young Environmental, 2021). These wells provide additional information about the fen and surrounding areas.

Historical Groundwater Data

Nicols Meadow Fen has a long history of disturbance. Groundwater hydrology within the area has been disturbed by construction, dewatering, and recharge area development. In late 1989, preparation for the Seneca WWTP expansion began (Leete & Gullett, 1989). Construction dewatering impacts on the fen were noticed by MNDNR staff, prompting the installation of wells F1–F4. These are two sets of nested wells that were constructed adjacent but driven to different depths to determine the vertical gradient of the groundwater. Groundwater estimates in these wells indicated downward movement of water as the dewatering volume increased. By the end of the 1989 growing season, Nicols Meadow Fen groundwater elevations were at least four feet below the estimated seasonal level. A letter in 1996 also describes the plant's underdrain system as a likely contributor to lowering water levels beneath the fen (Young Environmental, 2021). Subsequently, measurements taken in the late 1990s show lowered water levels below the peat surface (Almendinger & Leete, 1998a; WSB & Associates, Inc., 2008). Generally, wells show seasonal variability, and data from the late 2000s and early 2010s show relatively stable groundwater elevations. Data from this period indicate changes related to precipitation with a 1–2-year response time (Dakota County SWCD, 2021). More recent data may show the effects of nearby dewatering (Seaberg, 2022).

Figure 4. General Location of Monitoring Wells in and near Nicols Meadow Fen

Hydrogeology

Nicols Meadow Fen relies on a constant groundwater supply. Figure 4 shows a cross section of the fen from Burns & McDonnel (2015) at the location of two sets of nested wells installed in 1989. Wells F1 and F2 are located on the northeastern side of the fen, and wells F3 and F4 are on the southwest side. Wells F1 and F3 are deep wells, while F2 and F4 are shallow wells. Soil borings taken near these wells provide further insight into the geology under Nicols Meadow Fen and inform Figure 4. Well records indicate an upward vertical gradient of water, typical of fen systems. Deeper water travels upward through alluvial sands and into peat before upwelling to the surface. A clay layer of unknown size exists between the peat and deeper alluvial sands (Young Environmental, 2021). This clay layer could prevent groundwater from upwelling or surface water from infiltrating. The horizontal gradient indicates water traveling northeast across the fen toward the MN River.

The groundwater that supplies Nicols Meadow Fen recharges from the southeast. WSB estimated the one-year groundwater travel time to the fen is bound by TH 13 (WSB & Associates, Inc., 2008). Approximately half a mile south of TH 13, the travel time for groundwater increases to 10 years. This recharge area is heavily developed, decreasing the amount of precipitation available to infiltrate and recharge the fen. Accompanying development and the construction of impervious surfaces and groundwater pumping has had a significant degrading influence. The Seneca WWTP is the only high-capacity groundwater appropriator within 1 mile of the fen. The treatment plant is authorized to dewater up to 438 MGY for the west side of the plant and up to 329 MGY for the portion of the plant constructed in 1972 (Seaberg, 2022). Additionally, Eagan has municipal wells within the Jordan, Mt. Simon and Prairie du Chien-Jordan, and Franconia-Mt. Simon bedrock aquifers within 3 miles of the fen (Young Environmental, 2021).

Current Groundwater Hydrology

As shown in Figure 4, Nicols Meadow fen is adequately covered by monitoring wells. Groundwater elevations are measured in and around the fen by MNDNR, Dakota County SWCD, and MCES (Young Environmental, 2021). Because the Seneca WWTP is in close proximity to the fen, MCES monitors wells as part of its permitting obligations associated with the plant's operations. Dakota County SWCD and MNDNR monitor wells closer to and within the fen. Both datasets are uploaded to the Cooperative Groundwater Monitoring Network. The LMRWD supports the ongoing efforts by Dakota County SWCD at 13 dedicated wells that are completed and screened at selected depths in and around the fen (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 every year.

Figure 5 provides a cross section of fen well depths. Well nest F1 and F2 and well nest F3 and F4 have been monitored since 1993. Water table wells (WT-1–WT-5) were also installed in 1989 and have been consistently monitored since 2008. Shallow well WN1 (also known as QBAA) is a USGS well and has been monitored since 1993. Figure 6 provides a cross section of the most recent water elevations (as of April 3, 2023) within the fen for the wells shown in the Figure 5 cross section (MNDNR, 2023).

Figure 5. Cross Section of Nicols Meadow Fen Adapted from Burns & McDonnell (2015)

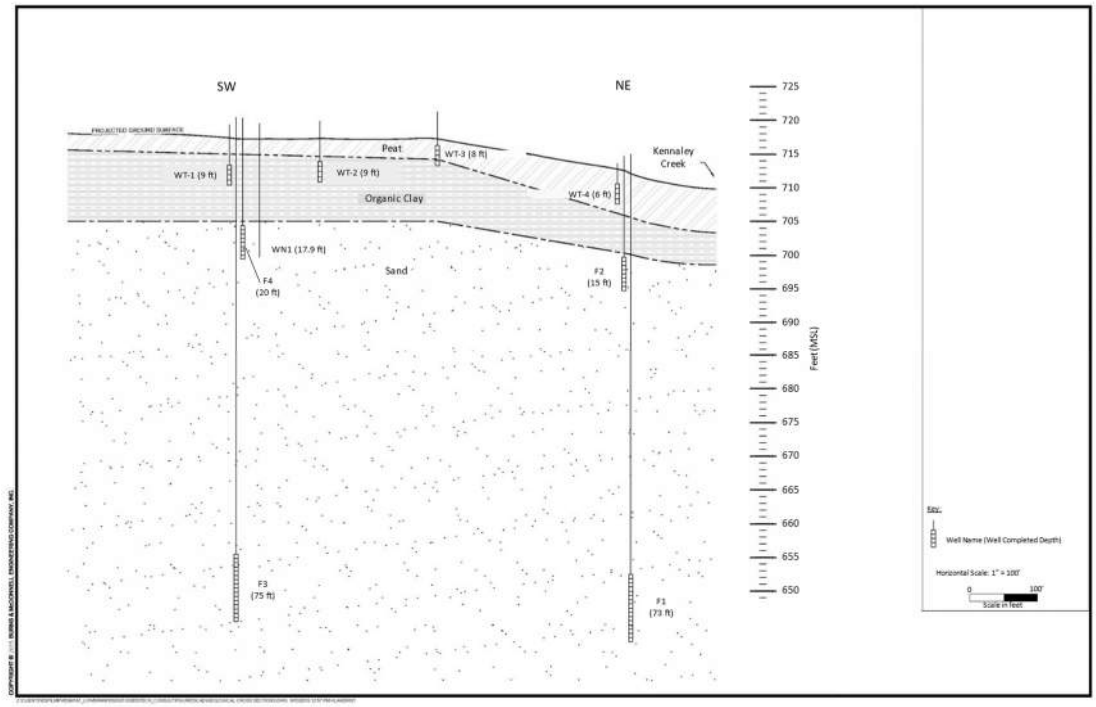
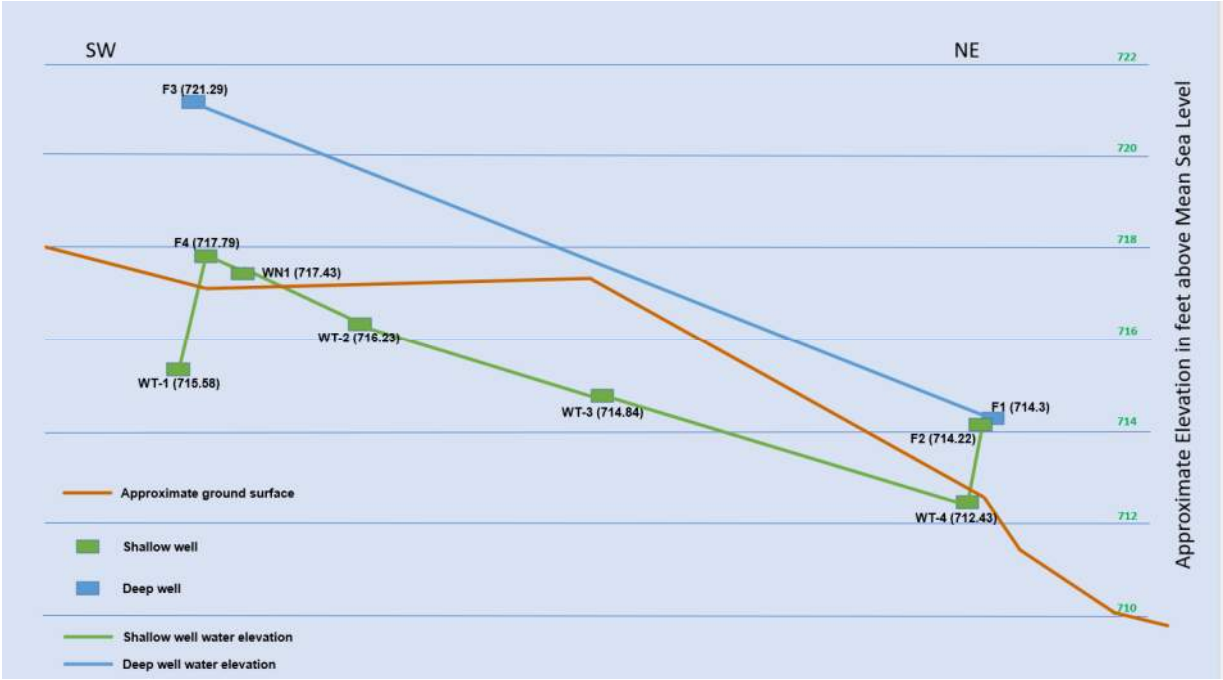


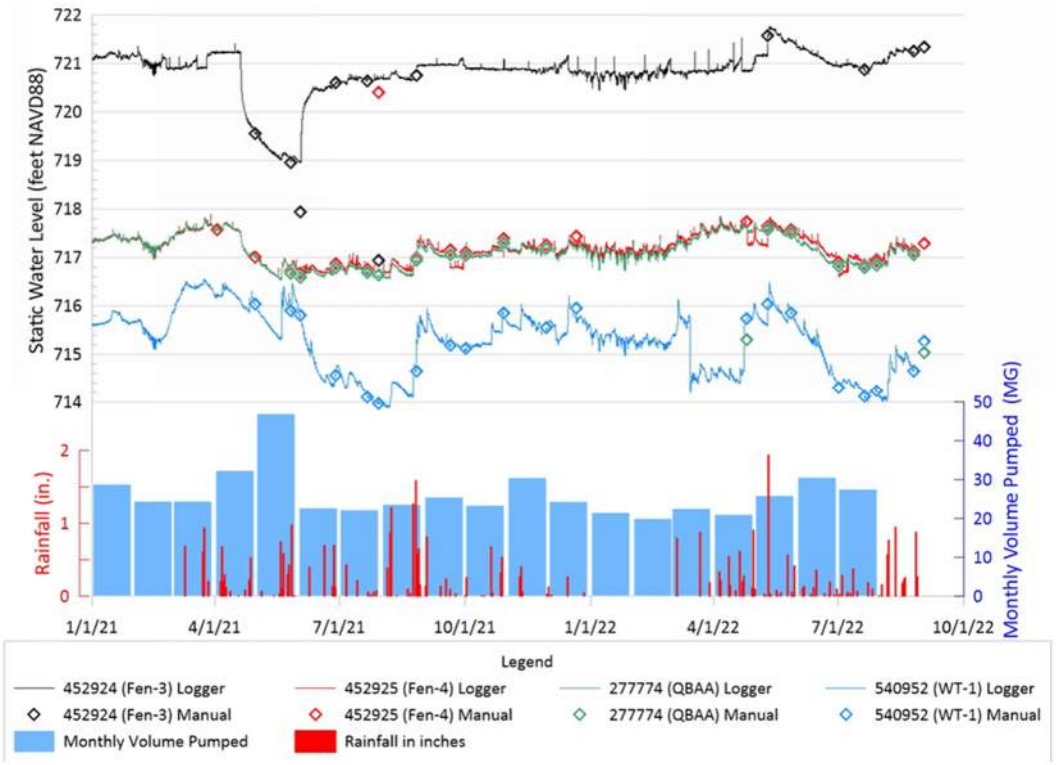
Figure 6. Cross Section of Recent Groundwater Elevations in Nicols Meadow Fen



The water level, representative of the potentiometric surface of the groundwater, is above the ground surface at several locations. The deep wells show a potentiometric surface above that of the shallow wells. This results in an upgradient of groundwater that pushes water up to saturate the land surface. This saturation is necessary to sustain the fen. These effects are seen to a greater extent farther from the Minnesota River and the Seneca WWTP. Unfortunately, groundwater elevations in all the water table wells shown are below the ground surface, indicating that portions of the fen land surface may be dry. This could cause the desiccation of important fen vegetation.

A groundwater technical review on Nicols Meadow Fen was completed in 2022 by John Seaberg, a groundwater specialist at the DNR, because of decreased groundwater elevations observed in 2021. Groundwater elevations within the fen showed a significant drawdown in the spring of 2021. Simultaneously, normally flowing wells were found to be below the ground surface and springs were dry. It was later discovered that the Seneca WWTP had conducted extended dewatering for maintenance of its westernmost clarifier. Measured groundwater elevations remained low throughout this maintenance period and recovered following a return to normal pumping. Additionally, smaller increases in dewatering during May and June 2022 show similar decreases in groundwater elevations. These two incidents indicate that pumping at the Seneca WWTP affects the groundwater that supplies the fen. Figure 7 from the report shows the decreased groundwater elevations and increased pumping at Seneca WWTP Well 1 associated with Permit 1991-6073.

Figure 7. 2021–2022 Groundwater Elevations, Measurable Rainfall, and Water Extracted from Well 1 Taken from Seaberg (2022)



Due to potential dewatering effects on the fen, the MNDNR will be coordinating intensive groundwater monitoring at increased frequencies with the Seneca WWTP in addition to creating a calcareous fen management plan (Andrews & Skancke, 2023). As such, MNDNR representatives

have stated that continued monitoring efforts by the Dakota County SWCD and LMRWD may be redundant.

WILDLIFE

European and domestic fen studies have 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 that several spider species were 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 US Fish and Wildlife Service through the federal Endangered Species Act of 1973 plus amendments (USFWS, 2020) both 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 to improving overall quality of life, the benefits of preserving threatened and endangered species are incalculable (The National Wildlife Federation, 2022).

In Minnesota, there are three distinctions for imperiled species: endangered, threatened, and species of special concern (State of Minnesota, 2022). Endangered species are threatened with extinction throughout all or a significant portion of their extent of occurrence. Threatened species will likely become endangered within the foreseeable future throughout all or a significant portion of their extent of occurrence. Special concern species are those that are uncommon in Minnesota or have unique or highly specific habitat requirements and deserve careful monitoring.

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

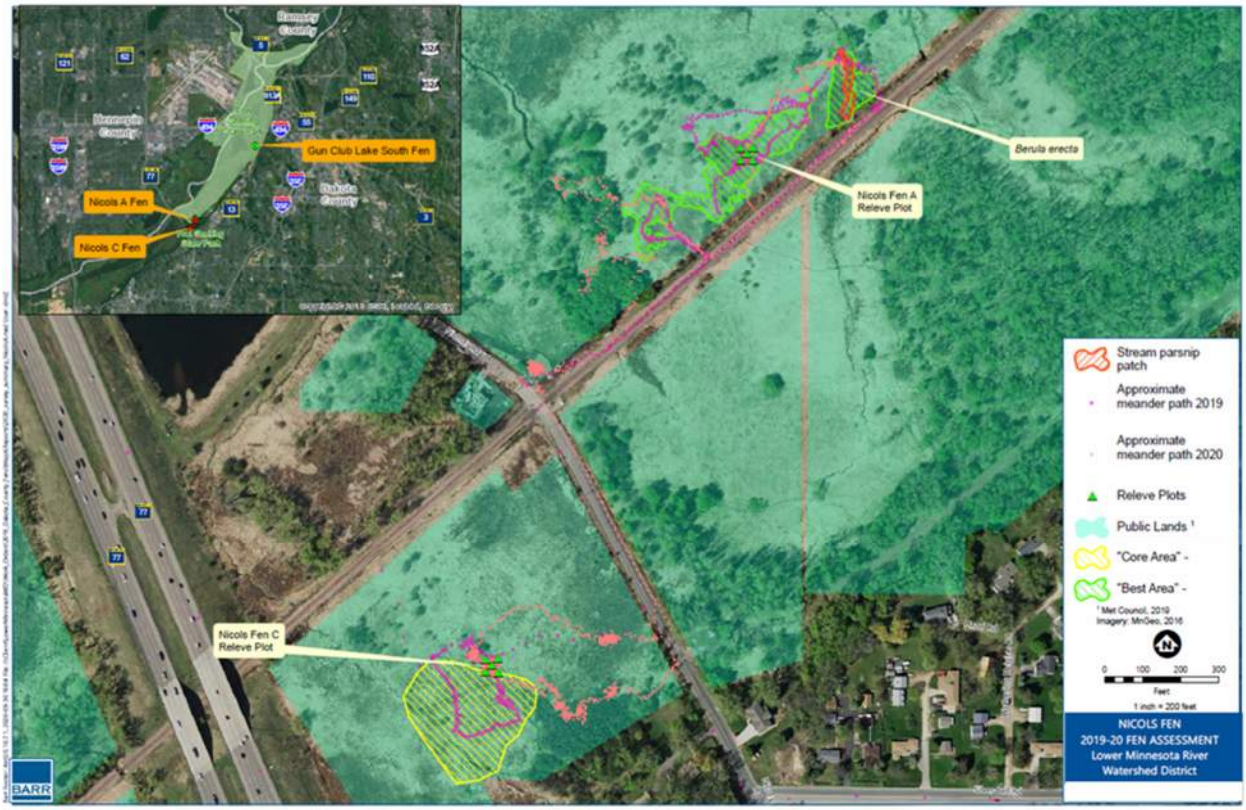
VEGETATION

Fen plant communities are assessed using formal vegetation surveys called 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).

Several formal and informal vegetation surveys of Nicols Meadow Fen have been conducted since the 1980s. The results of these surveys are described by Young Environmental (2021). Briefly, early surveys identified several indicator species and healthy fen vegetation. Follow-up surveys show a decline in calcareous fen indicator species and increases in undesirable plant species as well as increasingly dry peat. Several surveys in the early 2000s note an overabundance of invasive reed grass, *phragmites*. Young Environmental contracted Barr Engineering (Barr) on behalf of the LMRWD to conduct late and early season vegetative surveys in August 2019 and July 2020, respectively. Relevés were conducted in Nicols Meadow Fens A and C (Tix, 2020). Plots were established in 2019 and returned to in 2020. In addition to the formal relevés, Barr completed meander surveys in the area to document any additional species not seen in the plots. Figure 8 shows the location of the relevé plots and meander surveys.

Figure 8. Location of 2019–2020 Nicols Meadow Fen Vegetative Surveys Adapted from Tix (2020)



Nicols Meadow Fen A and C were both surveyed on August 30, 2019, and July 8, 2020. A total of 73 species were found within each fen cluster. However, only two calcareous fen indicator species were found. Fringed brome (*Bromus ciliata*) was found in both clusters. Fen A also contained stream parsnip (*Berula erecta*) while Fen C contained porcupine sedge (*Carex hystericina*). Unfortunately, because of the lack of calcareous fen indicator species observed, neither Fen A nor Fen C meet the requirements for calcareous fen classification. Instead, area vegetation is consistent with a native Seepage Meadow/Carr–Tussock Sedge subtype. Only one state-listed threatened plant species was found during the relevés—cut-leaf water parsnip found on the eastern side of Nicols Meadow Fen A.

Despite the lack of calcareous fen indicator species, the vegetation survey showed 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 peat. This results in deterioration and loss of habitat. Other invasive species such as reed grasses and cattails were also found in the fen. Some woody vegetation is native to Minnesota but not to the fen ecosystem. Willow and dogwood species were found within both fen clusters. Without proper management, the native vegetation could be overwhelmed, and the fen community will continue to decline.

An important strategy of the Nicols Meadow Fen Stewardship Plan is the routine assessment of fen vegetation. Because vegetation is the identifying characteristic of fens, information from routine assessments will become part of the baseline from which to determine whether fen health is improving or declining. Vegetation assessments are also a tool from which to monitor the encroachment by invasive species and a means to assess the effectiveness of controlling invasives. Developing additional tools to characterize calcareous fens could enhance and expedite fen identification and assessment.

LAND USE

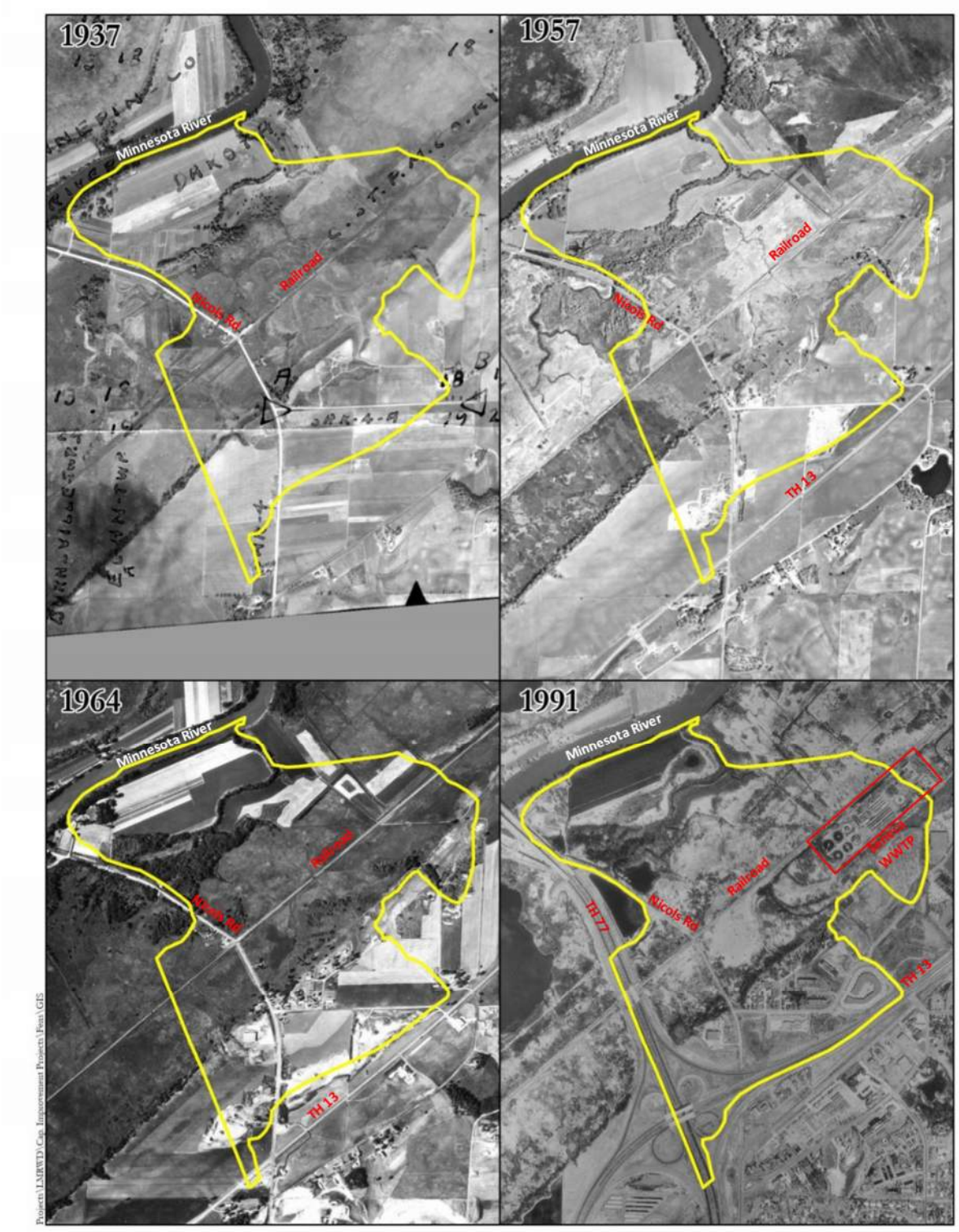
The land surrounding Nicols Meadow Fen is highly urbanized and continues to experience urban growth. Although the fen contained residences during the short tenure of Nicols town, the soils of the fen were unsuitable for most uses. The historical and planned land uses for the area surrounding Nicols Meadow Fen are summarized as follows.

Historical

Figure 9 shows a series of aerial photographs of the Nicols Meadow Fen HVRA. Images were taken from the Minnesota Historical Aerial Photographs Online (MHAPO), managed by the University of Minnesota Libraries (MHAPO, 2015). Each image is cropped from a larger image to center on Nicols Meadow Fen. The photographs show the progression of land use and cover within the Nicols Meadow Fen HVRA. The most recent images from MHAPO in this area were taken in the early 1960s. More recent images were taken from the National Agriculture Imagery Program (USDA, 2022).

Each photograph in Figure 9 shows the HVRA boundary outlined in yellow along with labels for the Minnesota River, Nicols Road, the railroad, TH 13, TH 77, and the Seneca WWTP when visible to help orient the reader between the different images. Imagery spans from 1937 to 1991 and shows a clear progression from rural agricultural use to urban development. The image from 1937 shows little development, with only a few clusters of homes at Nicols town and south of the fen HVRA. Nicols Meadow and Black Dog Fens have not yet been separated. Greater road construction is visible in the following 1957 image. Roads were constructed in the northwest corner of the HVRA along with TH 13. The 1964 image shows further development with increased building construction within and southwest of the fen HVRA.

Figure 9. Historical Aerial Photographs of Nicols Meadow Fen HVRA



The final image from 1991 shows the greatest increase in development. The City of Eagan experienced its most rapid development between the 1970s and 1990s (WSB & Associates, Inc., 2008). Unfortunately, imagery between the 1960s and 1990s in this region is limited. The 1991 image shows that the area south of the HVRA is nearly completely developed. Trunk Highway 77 has been constructed, splitting Nicols Meadow Fen from Black Dog Fen. Additionally, development southeast of the railroad and within the HVRA has started with several buildings and the Seneca WWTP. By 1991, little undeveloped area remains.

Recent and Planned

Figure 10 provides a recent aerial image taken in 2019. The image shows significant changes to the area south and east of Nicols Meadow Fen. Undeveloped areas are nearly nonexistent, replaced by a mix of industrial, commercial, and residential land uses. Although development has expanded, it should be noted that it has not yet encroached on the fen northwest of the railroad.

Current land use data for the area surrounding Nicols Meadow Fen are shown in Figure 11. The land use information is compiled by the Metropolitan Council of the Twin Cities (Metropolitan Council, 2023) from information provided by local government units. The fen has been threatened with pressures from rapid development to high-risk land uses with large quantities of impervious surfaces. With few exceptions, the area has been converted to industrial, commercial, and residential spaces that are unlikely to change once established. Nicols Meadow Fen and the area north to the Minnesota River are designated as park, recreation, and preserve as a part of Fort Snelling State Park. A small strip of land, approximately 52 acres, classified as undeveloped, provides a buffer between the developed lands to the southeast and Nicols Meadow Fen.

Figure 12 shows the planned land use for the areas surrounding Nicols Meadow Fen in 2040. The planned land use suggests that development could infringe on the minimal buffer currently available for Nicols Meadow Fen. Planned land use proposes to eliminate portions of the undeveloped land southeast of the railroad for industrial, commercial, and mixed land uses. Most critically, approximately 1.2 acres within the fen itself are planned for commercial development. The proposed development will have a direct impact on Nicols Meadow Fen, drastically altering rare wetland habitats. The remaining undeveloped areas of Nicols Meadow Fen will be affected by the proposed development because changes to the area hydrology would occur with development.

Figure 10. Recent Aerial Imagery of Nicols Meadow Fen and the Surrounding Area

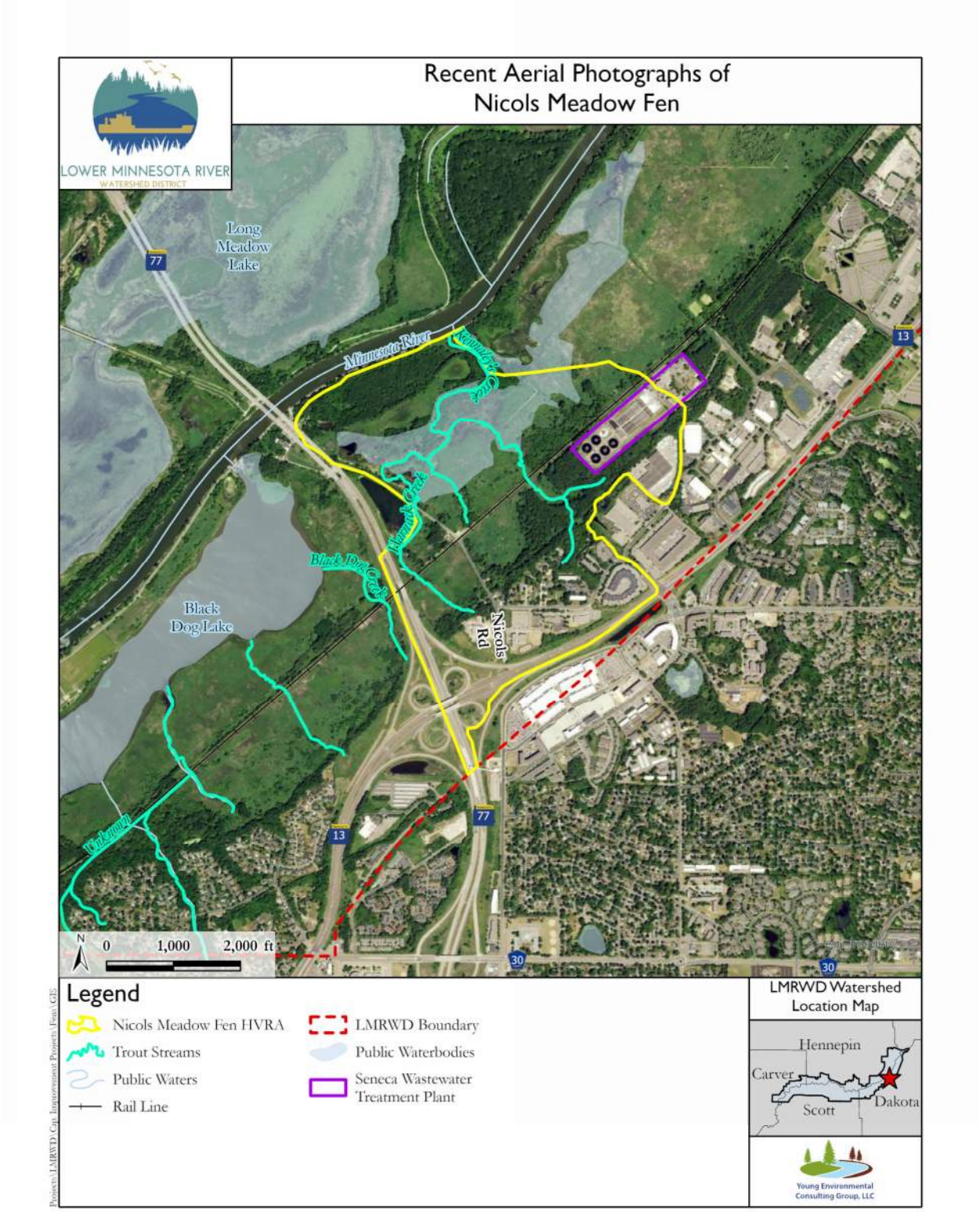


Figure 11. 2020 Land Use near Nicols Meadow Fen

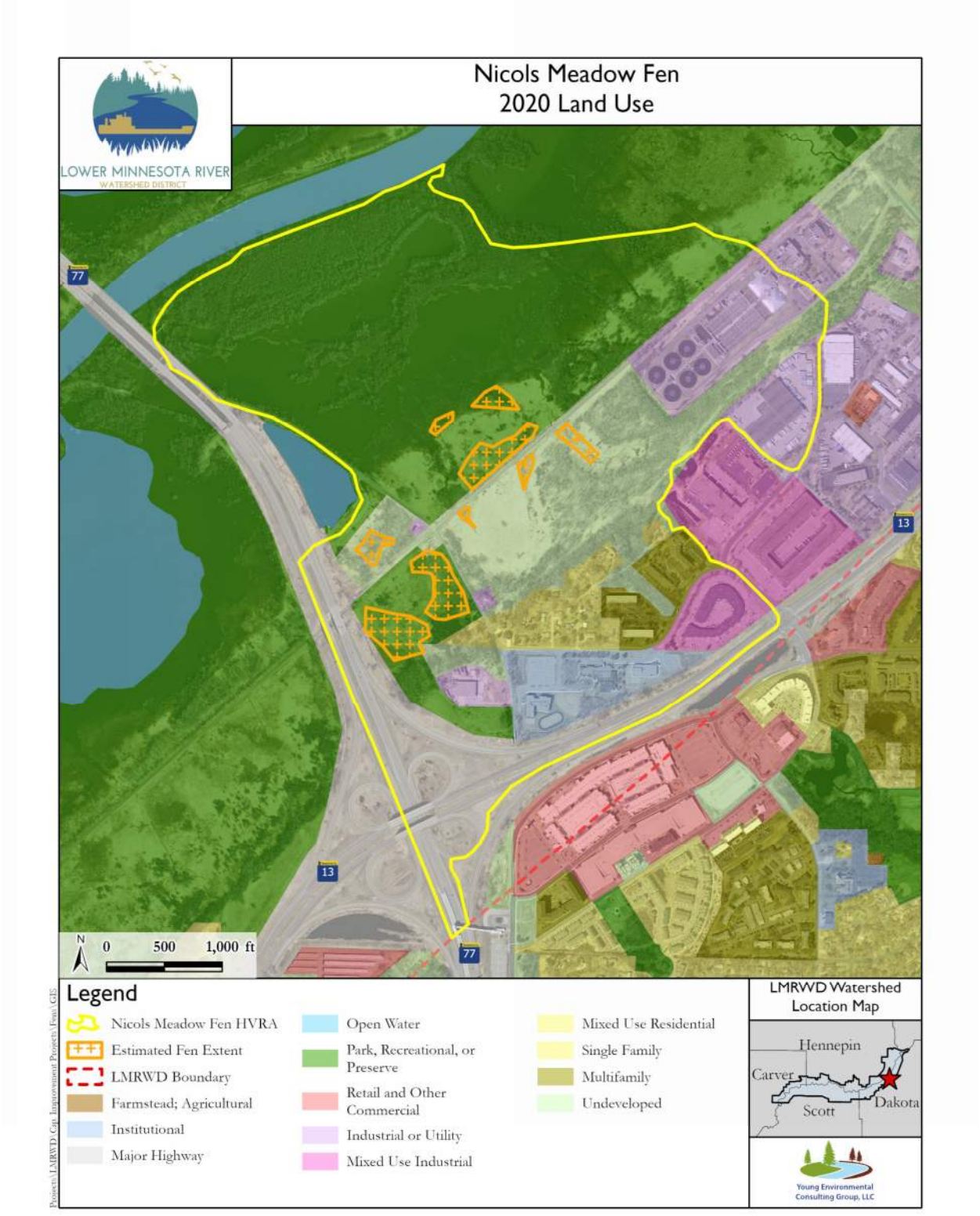
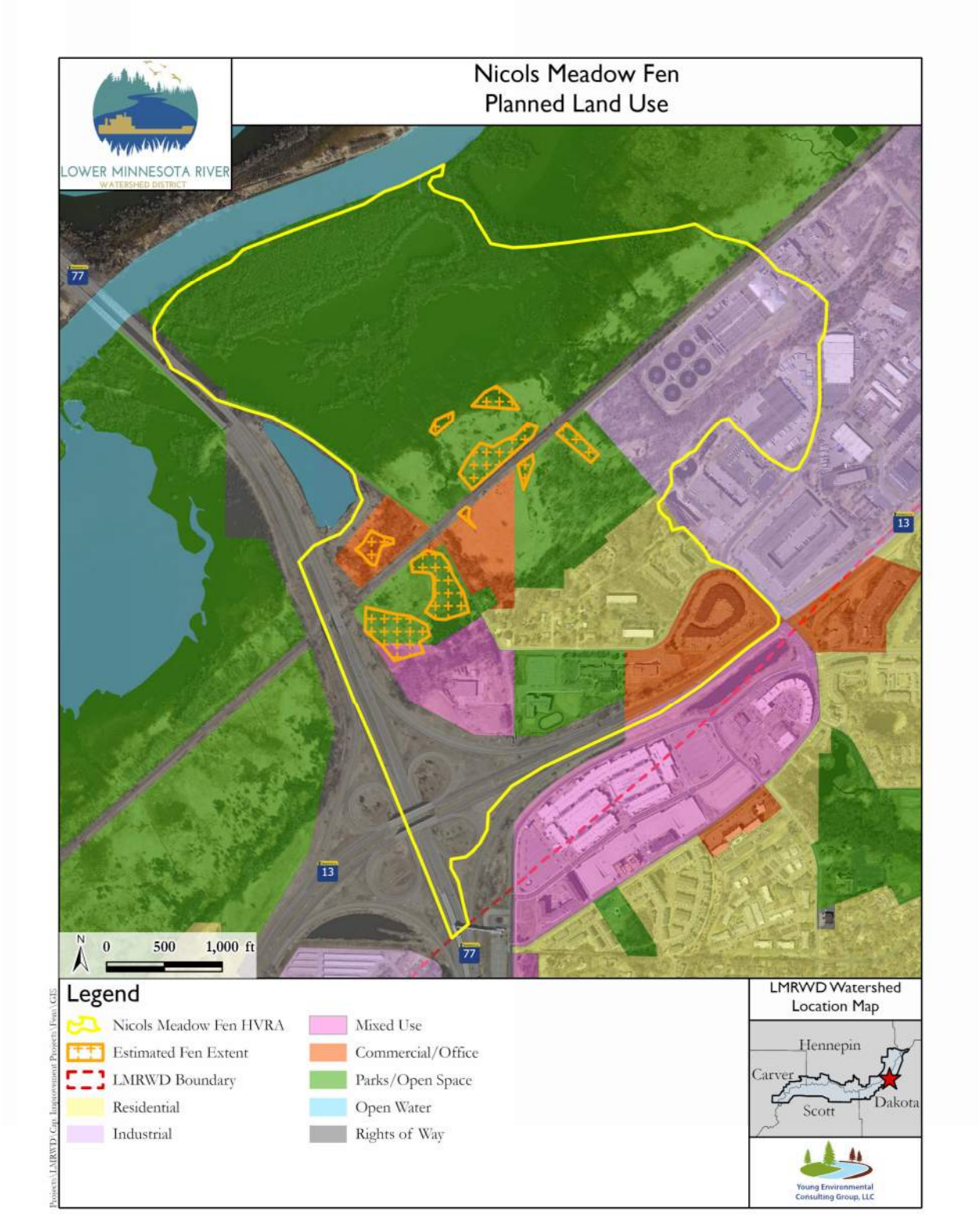


Figure 12. Land Use near Nicols Meadow Fen Planned for 2040

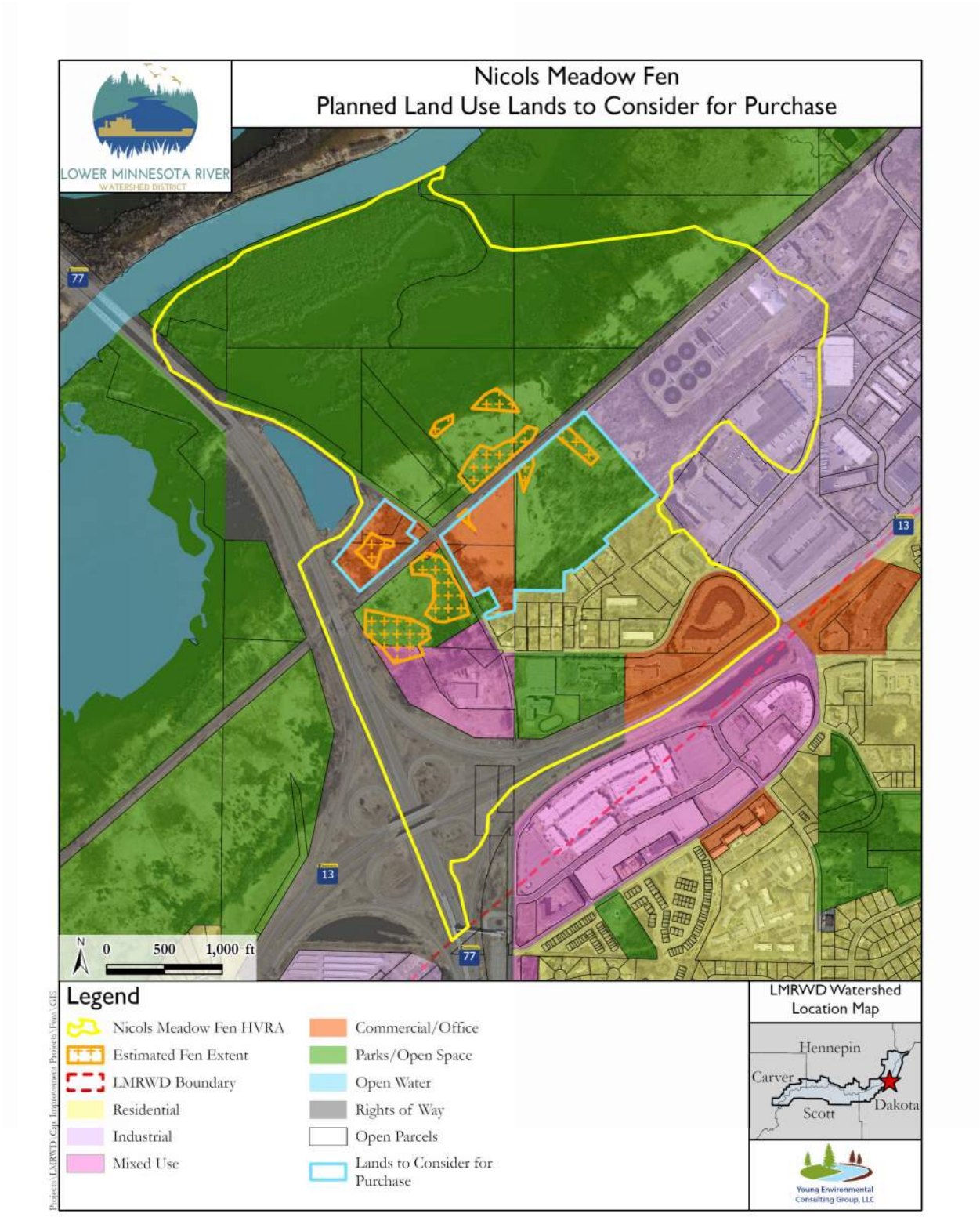


Residential and other developments will increase impervious area cover and may require substantial dewatering to establish foundations. Dewatering, even if temporary or seasonal, has been shown to have prolonged effects on fen health and sustainability. Any developments including below-grade basements may require sustained dewatering to keep those basements dry.

Improved understanding of the value of Nicols Meadow Fen and the buffer provided by surrounding lands may foster increased efforts to protect those resources. Planned developments may be altered to add protection to Nicols Meadow Fen and the adjacent areas. The MNDNR, other agencies, and nongovernment conservation organizations should continue to pursue opportunities to acquire additional property for inclusion and protection as part of Fort Snelling State Park or other protected lands. Figure 13 displays the future planned land use with areas highlighted for purchase consideration. Of highest priority is the area in and around Fen B currently under private ownership. The area is approximately 6.5 acres. According to the 2022 assessed value, the area would cost approximately $174,000 to purchase (Dakota County, 2023). For additional purchase consideration, the area south of the railroad containing portions of Fen A and the buffer is approximately 36.5 acres and would cost $415,000 to purchase (Dakota County, 2023). 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.

Because Nicols Meadow Fen relies on the sustained flow of upwelling groundwater, the land use in areas south of the railroad and TH 13, where recharge to the groundwater supply is believed to occur, is critically important to the long-term health of the fen. The sequence of historic to recent aerial photographs shows a transition from rural to highly developed, a change unlikely to be reversed. Nicols Meadow Fen is an ecologically significant, dynamic ecosystem that interacts with other nearby ecosystems. The wetland habitat connections to nearby resources have been affected by roads, altered land uses, and other habitat changes. These features can create barriers for birds, amphibians, fish, aquatic invertebrates, and wetland plants, as described by Johnson and Walz (2013). Maintaining and restoring these connections is important to consider in evaluating the actions to improve the long-term sustainability of the fen.

Figure 13. Nicols Meadow Fen 2040 Planned Land Use Noting Lands for Purchase



Proactively monitoring development in and near Nicols Meadow Fen is an important strategy in the stewardship of the fen. The stewardship will include mitigating development that has the potential to alter the hydrology, vegetation, and other land uses that could adversely affect the fen. There may be opportunities to expand viable portions of the fen by acquiring adjacent properties through land swaps or outright purchases. Stewardship also includes looking for opportunities to enhance the hydrologic system that sustains the fen with the possibility of restoring resources that have been depleted by historical uses of the land and water.

CONCLUSIONS

Nicols Meadow Fen is the product of climate and evolutionary forces that resulted in the unique ecosystem engendered by the accumulation of poorly decomposed peat present today. Although fen ecosystems are poorly understood, it is obvious that recent pressures of changing land use, competition for groundwater and other resources, and other factors have measurably stressed the ecosystem. Nicols Meadow Fen has been degraded by residence and agricultural activities within the fen, road and railroad construction, nearby dewatering, and recharge area development.

Recent vegetation surveys show the lack of sufficient indicators to confirm the presence of a healthy calcareous fen plant community. Additionally, vegetation surveys show the incursion of invasive, nonnative species that could further disrupt existing vegetation and the fen ecosystem. Many of the invasive plants, 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 in and around Nicols Meadow Fen have the potential to continue to degrade the fen. Nearby dewatering has been shown to lower groundwater elevations, and planned development within the Nicols Meadow Fen HVRA will directly infringe upon the fen. Fen areas that are not currently protected by Fort Snelling State Park should be considered for purchase to provide additional protection.

Natural resource managers are making important contributions to our understanding of Nicols Meadow Fen by supporting important data collection programs and resource investigations. Data collection programs and resource investigations associated with groundwater elevations and vegetation must continue within Nicols Meadow Fen to continue informing management decisions. Educational institutions, environmental organizations, nonprofit organizations, and others can support or conduct research that helps support or enhance our understanding of the Nicols Meadow Fen ecosystem. New and creative approaches to understanding and characterizing the fen and its associated resources might help foster additional opportunities for study, provide broader fen protections, and inform management and restoration efforts for Nicols Meadow Fen and similarly rare and threatened resources.

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