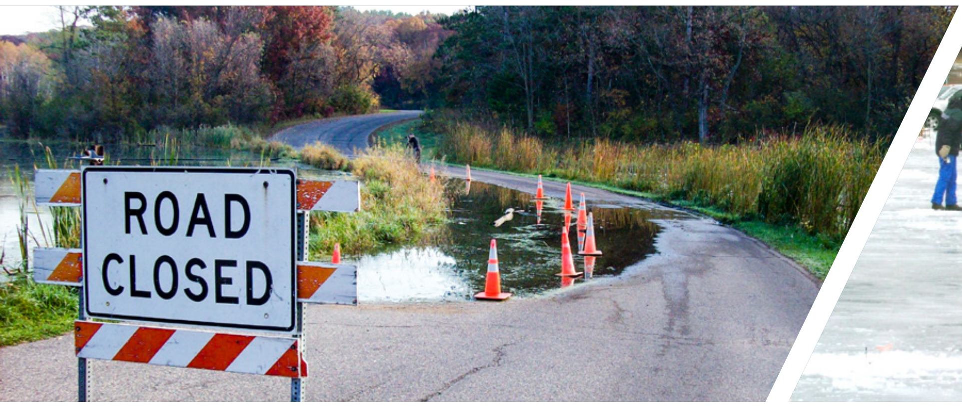


South Washington Watershed District

Climate Resiliency Plan

March
2018

South Washington WATERSHED DISTRICT

This report prepared by Barr Engineering Co.

Contents

1

Introduction

The South Washington Watershed District (SWWD), through its watershed management planning process, identified addressing climate change as a top priority, with a stated goal of facilitating "increased resilience of District resources and public infrastructure through development of information and strategies and implementation of accepted climate adaptation practices."

As a step toward achieving that goal, SWWD collaborated with its member communities and stakeholders to identify its top concerns and priorities relative to climate change. Ultimately, the SWWD and the communities hope to reduce climate-related risks by increasing the resilience of infrastructure and social and natural resources.

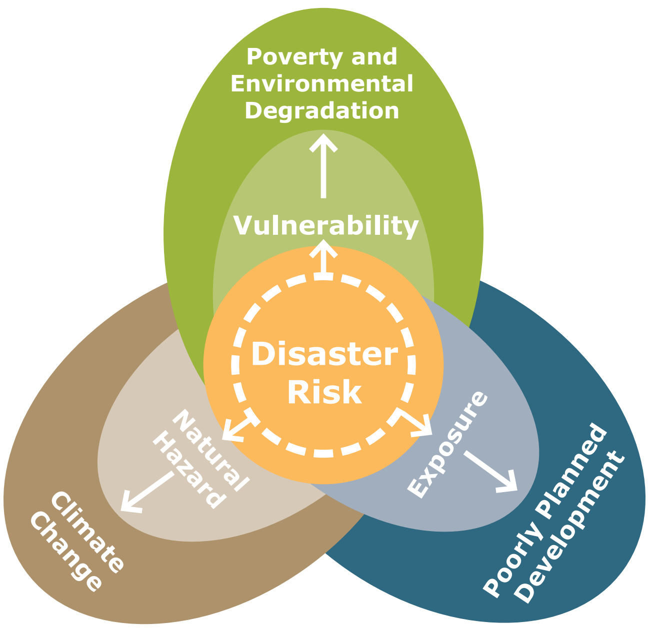


Figure 1-1: *Disaster Risk (World Bank, 2013, adapted from IPCC)*

1.1 Workshops

Barr Engineering Co. (Barr) and the Freshwater Society assisted the SWWD in facilitating a two-day workshop on promoting climate-change resiliency in September 2017, hosting over 60 staff and stakeholders from many of its member communities, including the cities of Cottage Grove, Woodbury, Newport, St. Paul Park, and Oakdale. Other stakeholders participated, including staff from Washington County, Ramsey-Washington Metro Watershed District, Browns Creek Watershed District, Washington Conservation District, and SWWD staff and board members.

During the workshops, the participants learned about the changing climate of the area and the current and anticipated effects it will have on infrastructure and social and natural resources in the SWWD.

The workshop participants developed a list of climate hazards (e.g., increasing winter temperatures, increased precipitation, etc.) and then identified how those hazards affect the resources specific to their community or stakeholder group. For example, the representatives from the City of Cottage Grove identified that they are concerned about extreme rainfall—particularly its effects on critical infrastructure such as Highway 61.

The participants then identified and prioritized actions to address their specific issues of concern. SWWD summarized the results of the workshops by community and stakeholder group, with an emphasis on specific actions that can be included in each community's comprehensive plan to reduce risk through building climate resiliency. The summaries are included as **Appendix A**.

1.2 Focus Areas

Through the community workshop engagement process, the SWWD identified three areas of climate resilience for further assessment:

For the groundwater and natural resources assessments (**Sections 2 and 3**), Barr performed an inventory of the specific climate-related issues confronting those resources and provided recommended actions to reduce related risks. We summarized the recommended actions in the following categories, which align with the District's implementation strategies:

1. **Planning Efforts:** Recommendations for performing or collaborating on inventories, plans, and feasibility studies to address the effects of climate change.
2. **Policy Development Actions:** Recommendations to improve existing or develop new regulations, standards, policies, or guidelines to protect the District's resources from climate-change effects.

3. **Projects and Programs:** Recommendations to construct projects or implement monitoring programs to address specific risks to the District's resources.
4. **Education and Outreach:** Recommendations to engage stakeholders and District residents to support, advocate for, and implement efforts to protect the District's resources.

The workshop participants identified risk of flooding as a primary concern and identified specific actions to address flooding risk. One suggestion was to study the risk of failure of the stormwater infrastructure in the SWWD. For the Stormwater Infrastructure assessment (**Section 4**), Barr performed a risk analysis of the storm sewer infrastructure in the District, using available geospatial data to determine the likelihood and consequences of failure of each of approximately 24,000 pipes to compute an overall risk of failure score for each individual pipe. Based on that risk score, we recommended a prioritization for inspection and/or maintenance of the storm sewer infrastructure in the District.

2

Groundwater

Climate change could put additional stress on the District's groundwater system. Groundwater is important for the health of the public, the ecology, and the District's economy. All communities within the SWWD obtain their drinking water from groundwater sources, and many agricultural and industrial facilities within the SWWD rely on groundwater for their operations. In addition, surface waters often depend on groundwater seepage to maintain water levels or "baseflows," and groundwater is critical to maintaining cool water temperatures for trout streams.

The South Washington Watershed District (SWWD) October 2016 Watershed Management Plan (Plan) acknowledges the important role that the District plays in groundwater management and identifies climate change and development as potential stressors to the groundwater system. Stakeholders who attended the District's workshop on climate-change resiliency also identified these stressors. The following sections describe groundwater quantity and quantity issues that could be affected by climate change. **Table 2-1** provides recommendations and strategies to address these complex issues through planning, policy, projects, programs, and education.

2.1 Quantity

2.1.1 Groundwater Recharge

The primary source of water for the SWWD's groundwater system is recharge from infiltration of precipitation. Results from a soil water balance (SWB) model of the Twin Cities metropolitan area (Barr Engineering Co., 2012) indicate that groundwater recharge across the SWWD averages 10 inches per year, ranging from 5 to 17 inches. Recharge is typically greater in areas of southwest Cottage Grove and St. Paul Park where soils tend to be sandier (**Figure 2-1**). The amount of recharge that occurs in a given year is primarily dependent on the amount of precipitation and when the precipitation occurs. A wet summer does not necessarily lead to higher groundwater recharge as summer precipitation that does not run off to surface water is primarily lost to evapotranspiration. Years with a wet spring or fall are typically years with the highest recharge. Water also enters the groundwater system via seepage from lakes, "losing reaches" of streams (a stream above the groundwater table that loses water through infiltration), and infiltration stormwater practices. However, cumulatively, these processes make up a small fraction compared to recharge from areal infiltration over the entire SWWD.

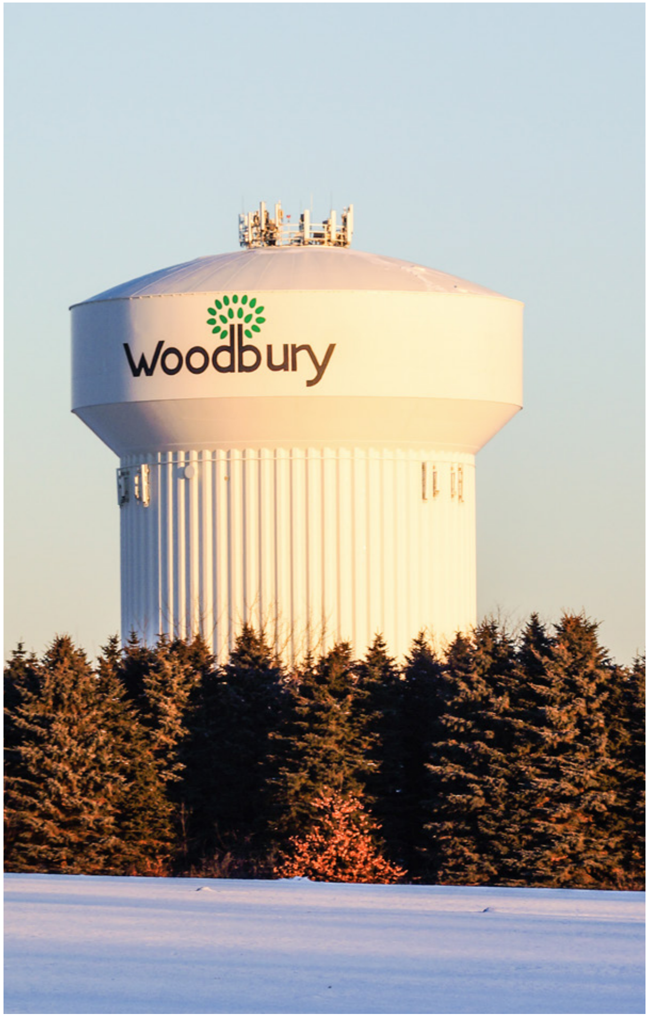
Projected changes to the climate could alter the quantity and timing of groundwater recharge across the SWWD. Warmer temperatures increase the length of the growing season; this, in turn, increases the amount of potential evapotranspiration. Research performed by Hunt et al. (2016) in a mostly rural watershed in central Wisconsin predicted that in future climates, as projected by 13 different climate models, groundwater recharge would be reduced, on average, by approximately 10%. However, the reduction in recharge was less than the projected increase in actual evapotranspiration. With a warmer climate, more precipitation occurs as rain (instead of snow) during the winter months, a period of minimal evapotranspiration, allowing for more recharge to occur during this period. The overall importance of a pulse of spring recharge from a melting snow pack is projected to be less important in the future as fall and winter infiltration from liquid precipitation increases (Hunt et. al., 2016).

Hunt et al. (2016) also looked at how changes in land use could help to offset or mitigate the effects of climate change on groundwater recharge. They found that increases in low-impact development practices (e.g., rain gardens, infiltration basins, underground infiltration galleries) and reduction in soil compaction for agricultural areas have the potential to offset most of the reduction in groundwater recharge associated with climate change, if implemented correctly.

2.1.2 Groundwater Use

Between 2012 and 2016, the total volume of water pumped from aquifers in the SWWD by high-capacity wells (wells that pump more than 10,000 gallons a day or 1 million gallons a year), ranged from 6.1 to 7.2 billion gallons. An additional 0.8 to 1.2 billion gallons were pumped during this time from the city of Woodbury's main wellfield. While this field is located just outside the District, pumping from these wells affects the hydrogeologic system within the District—equating to 3.6 to 4.4 inches of annual recharge over the area of the District. This is approximately 40% of the total average recharge and nearly 100% of recharge that occurs during a dry year.

Based on population, the Metropolitan Council projects pumping by SWWD municipalities to increase by 1.2 billion gallons by 2040 (Metropolitan Council, 2015). During dry years, this increase



Climate change could reduce groundwater recharge and increase groundwater use. (Barr Engineering Co.)

would likely result in total pumping that exceeds groundwater recharge. No studies have evaluated the effect of climate change on regional groundwater use. However, longer growing seasons will likely result in additional irrigation for both agriculture and lawns. For the existing climate, summer groundwater use can be over two times winter use due to irrigation demands.

2.1.3 Groundwater-Dependent Natural Resources

Lakes, streams, and wetlands can interact with groundwater in several ways. Groundwater can flow into a surface waterbody; these waterbodies are referred to as "gaining streams" or discharge lakes/wetlands. Surface waterbodies can also lose water to the groundwater system; these are referred to as "losing streams" or recharge lakes/wetlands. "Flow-through" lakes or wetlands have both groundwater flowing into the waterbody and water flowing out to the groundwater. For both graining streams/discharge lakes and losing streams/recharge lakes, changes in groundwater levels can affect the water balance. If groundwater levels drop there can be less groundwater flow into a gaining stream/discharge lake. Also, a drop in groundwater levels can increase the rate at which water flows out of a losing stream/recharge lake to the groundwater system. In both instances a drop in lake stage or reduction in baseflow would likely occur. Surface waters where a change in groundwater has little-to-no effect on the water balance are considered disconnected or perched.

Brook trout are dependent on cool temperatures driven by groundwater. (Barr Engineering Co.)

Figure 2-2 shows the classification of the surface water to groundwater connection across the SWWD.

Once water enters the groundwater system it primarily leaves via two mechanisms: 1) discharge to surface waters or 2) pumping from wells. An increase in pumping will result in a decrease in groundwater discharge to gaining streams/discharge lakes or an increase in seepage to groundwater for losing streams/recharge lakes. Typically, surface waters closest to the pumping are most affected. The result of these changes is difficult to measure because the aquifer system has storage capacity that creates a response lag of years to decades. Also, pumping from a single well typically does not cause measurable effect; however, cumulatively, many wells can cause significant change. High-quality long-term monitoring of groundwater and water resources and groundwater models are the only way to quantitatively understand and manage the effects of pumping.

For future climates, groundwater-dependent natural resources could be affected in several ways. A potential reduction in groundwater recharge coupled with additional groundwater pumping may alter the hydrology of these natural resources. Lower groundwater levels and reductions in groundwater discharge to surface water may result in smaller baseflow to streams, lower lake levels, and drying of groundwater-dependent wetlands. The temperature of groundwater is directly dependent on surface temperatures; typically, shallow groundwater temperatures are close to the average annual surface temperature. A warmer climate will cause groundwater temperature to increase, which can negatively impact trout populations that rely on streams with cool groundwater.

2.2 QUALITY

The quality of groundwater is important for both human and ecological health. The Minnesota DNR classifies pollution sensitivity across the SWWD as primarily “high” or “karst” (also considered high) (**Figure 2-3**; Adams, 2016). Karst is landscape characterized by the dissolution of soluble rocks, including carbonates such as limestone and dolomite. Features such as sinkholes and dissolution-enlarged fractures are common in karst regions. In Minnesota, karst is often present in areas where carbonate bedrock is within 50 feet of the ground surface. In areas of karst, contaminants from the surface can rapidly transport to bedrock aquifers. Areas of karst are also considered to have a high level of pollution sensitivity. The high pollution sensitivity across much of the District makes groundwater vulnerable to contaminants from land practices at the surface, such as fertilizer application. In particular, nitrate and chloride contamination are a growing concern.

Climate change may cause more freeze-thaw cycles which will encourage more salt use on parking lots and roadways, posing a risk to groundwater quality. (Barr Engineering Co.)

2.2.1 Chloride

Chloride in groundwater can occur naturally, but also comes from fertilizer, road salt, septic systems, and industrial processes. While generally not considered a threat to human health, chloride can cause taste issues in water at concentrations exceeding 250 mg/L. More importantly, when groundwater with high chloride concentrations discharges to surface waters, it can be toxic for aquatic animals and plants. Minnesota has a chronic chloride water quality standard of 230 mg/L and an acute water-quality standard of 860 mg/L to protect aquatic plants and animals. Chloride in groundwater does not react or break down in a manner similar to other contaminants. The mass of chloride that enters the groundwater system will eventually leave via seepage to surface waters or water pumped from wells. Similarly, chloride cannot be treated or filtered with traditional BMPs.

The continual use of salt on roadways for deicing purposes has the potential to load the groundwater system with excessive chloride. In future climates, with greater potential for more icing events, use of salt on roadways may become even greater. Novotny et al. (2009) found that in the Twin Cities metropolitan area only 23 percent of chloride applied for de-icing left the region via stream flow. The remaining mass of chloride is in the area soil, groundwater, or surface waters. Chloride in groundwater can be a long-term source to surface waters. Even if chloride inputs from the surface were drastically reduced, chloride already in the groundwater system would continue to discharge to surface waters for decades.

2.2.2 Nitrates

While not closely related to climate change, nitrates in groundwater are a major concern of the SWWD and its member communities. A major source of nitrate in groundwater is from the application of fertilizers for agricultural production and turf maintenance. The southern portion of SWWD is considered particularly vulnerable to nitrate contamination. Due to this high vulnerability, the Minnesota Department of Agriculture included Cottage Grove and Denmark Township in its regional well-testing program in 2014–2015 (MDA, 2017). Of 300 wells tested in Cottage Grove, 28.3% had nitrate-nitrogen concentrations over the Health Risk Limit of 10 mg/L. In Denmark Township, 13.7% of 226 wells tested had nitrate-nitrogen above the health risk limit.

2.2.3 Perfluorochemicals (PFCs)

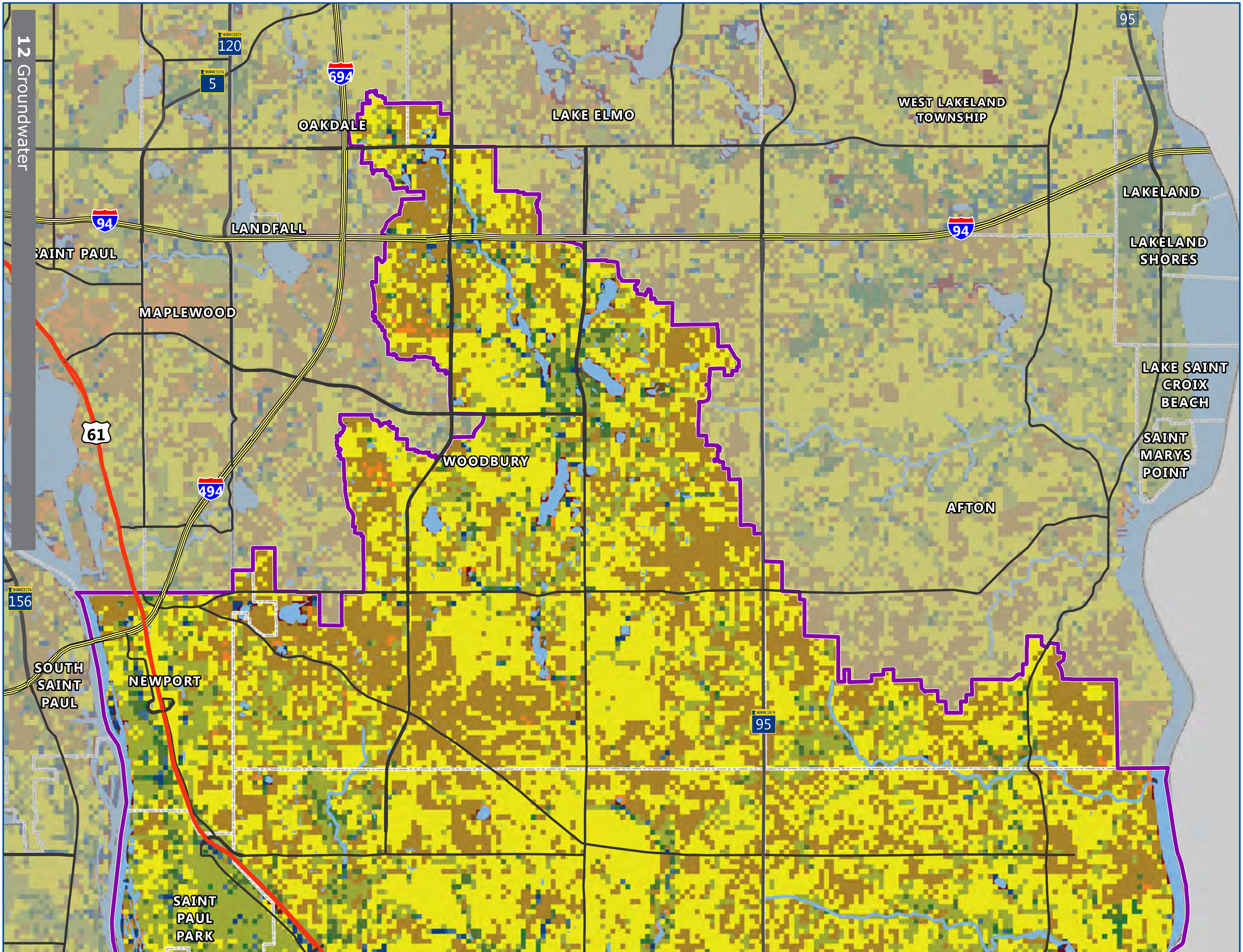
While not related to climate change, perfluoroalkyl substances (PFAS), also commonly referred to as perfluorochemicals (PFCs), have been detected in groundwater over a large area of southern Washington County. PFAS were used in the manufacture of many commercial materials for industrial, commercial, and residential use. They are a ubiquitous presence in most households and consequently are found in municipal waste streams and in most landfills. They are also found in biosolids (in part from municipal sewer sludge) used as amendments to soil in agricultural and landscaping applications. Locally, within the SWWD, 3M manufactured PFAS at its Cottage Grove facility from the 1940s to 2002 and wastes from the manufacturing process were disposed of both on site and at a disposal site located near the Woodbury and Cottage Grove border.

The PFAS of most concern in the SWWD are perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), perfluorobutanoic acid (PFBA). Recently, the Minnesota Department of Health updated drinking water guidance values for PFOA and PFOS to 35 parts per trillion and 27 parts per trillion respectively. The revised guidance caused several of Cottage Grove's wells to be shut down while additional treatment systems could be installed. Because of the well shutdowns, watering bans were in place for much of 2017 in Cottage Grove. The long-term prospects related to PFAS in SWWD groundwater are uncertain at this time. 3M and the state of Minnesota are currently in litigation and the groundwater standards are continually being reevaluated.

Table 2-1: *Groundwater Quality Recommendations and Strategies to Address Climate Change Issues*

Issue to be Addressed		Strategies to Address Issue: Planning Efforts
Groundwater Quantity	Groundwater Recharge	Quantify potential changes in groundwater recharge for projected future climates. Identify areas of high groundwater recharge. Areas of high groundwater recharge are also areas that have greater potential for aquifer contamination from infiltrating water.
	Groundwater Use	Evaluate resiliency of groundwater system during periods of increased water demand from long-term drought or population growth.
	Groundwater-Dependent Natural Resources	Update inventories of ecological resources (e.g., wetlands, fens, trout streams, etc.) that depend on groundwater. Evaluate resiliency of groundwater to maintain cool stream temperatures in trout streams for projected future climates and/or reductions in baseflow from increased pumping.
Groundwater Quality	Nitrates	Identify areas and/or update areas of high vulnerability for aquifer contamination from surface practices. Develop management plans for application of nitrogen in high vulnerability areas.
	Chlorides	Identify areas and/or update areas of high vulnerability for aquifer contamination from surface practices.
	Per- and Polyfluoroalkyl Substances (PFCs)	Establish plans for emergency and permanent backup water supplies or community interconnects. Work with Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Health (MDH) to identify surface waters that may be impacted by PFC contamination. Work with MPCA and MDH to understand potential threats in migrating PFC plumes from groundwater (and surface water) appropriations stormwater management practices.

Policy Development Actions	Projects and Programs	Education and Outreach
Work with communities to establish land use policies and implement best management practices in areas of high groundwater recharge to reduce the potential for contaminants at the surface reaching the groundwater.	Enhance groundwater recharge through stormwater infiltration where appropriate.	Educate the public about the local hydrologic cycle (e.g., water that infiltrates locally eventually becomes the water the public consumes).
Work with communities to develop watering ban policies, adjustments to water usage fee rates to incentivize lower usage, and water efficiency practices such as water reuse, cost-share programs for turf-to-prairie (xeriscape) conversion, and water efficient appliances and fixtures.	Develop water conservation demonstration sites and alternatives to lawns. Monitor groundwater levels.	Educate landowners on planting alternatives to lawn and low input lawn care. Educate the public about water conservation.
Establish thresholds for water stage, baseflow, and wetland hydrographs based on 2016 MNDNR threshold guidance [LINK]. Develop policy regarding groundwater use if thresholds are exceeded.	Monitor lake stage, stream base flow and temperature, and wetland levels. Implement enhanced infiltration or water conservation practices in areas that would benefit the most vulnerable ecological resources.	Educate the public on the relationship between groundwater and surface water.
Develop policies for stormwater management in high vulnerability areas.	Monitor nitrate levels in groundwater.	Educate landowners on planting alternatives to lawn and low input lawn care. Educate agricultural community about best management practices.
Develop policies for stormwater management and deicing practices in high vulnerability areas.	Develop demonstrations on effective deicing practices. Improve snow plows to reduce over application of chlorides.	Educate landowners, salt applicators, and communities about deicing best management practices.
	Monitor aquatic biota for PFC impacts.	Educate the public about where their drinking water comes from.



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694
OAKDALE
LAKE ELMO
WEST LAKELAND
TOWNSHIP
95
LAKELAND
94
LANDFALL
SAINT PAUL
LAKELAND
SHORES
MAPLEWOOD
LAKE SAINT
CROIX
BEACH
61
WOODBURY
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MARYS
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AFTON
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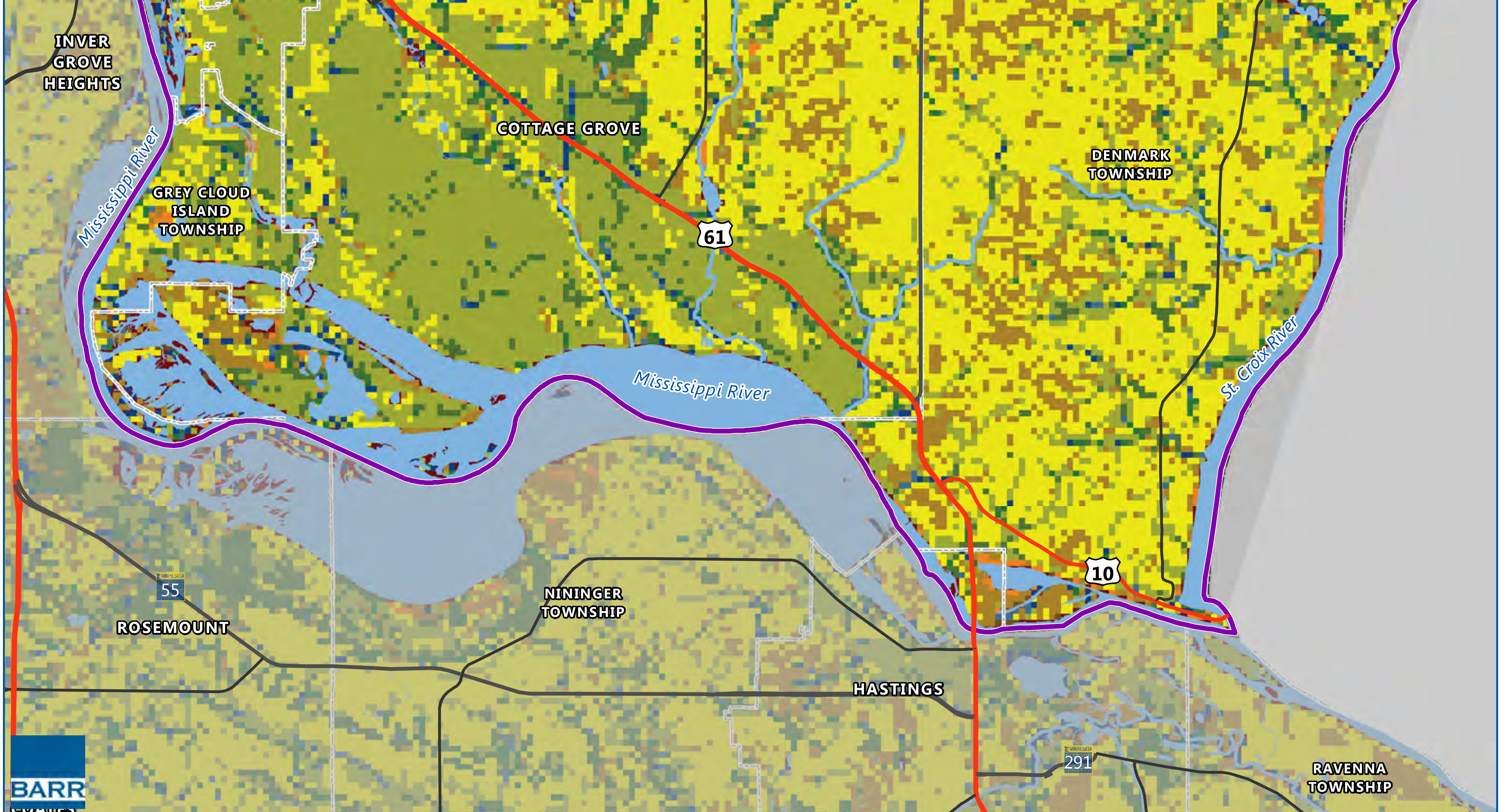


Average Annual Groundwater Recharge 1988-2011 (in/yr)

- 0.0 - 2.0
- 2.1 - 4.0
- 4.1 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 10.1 - 12.0
- 12.1 - 14.0
- 14.1 - 16.0
- 16.1 - 18.0
- > 18.0

- Lakes/Riverine/Ponds
- SWWD Boundary
- Municipal Boundary

N

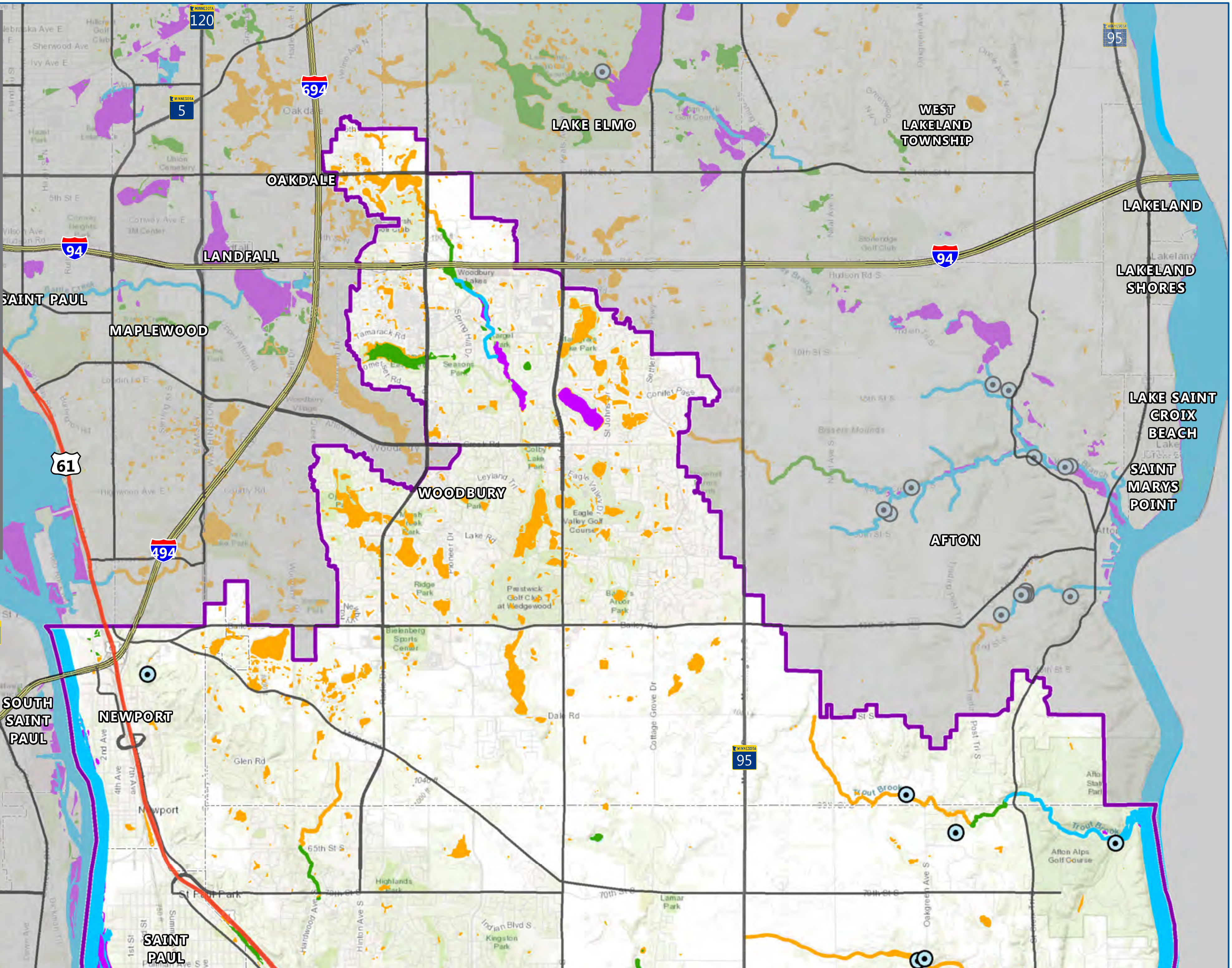
0 7,000 14,000
Feet
1 inch = 7,000 feet

Note:
Average Annual Groundwater Recharge from Barr Engineering. 2012. Using the Soil Water Balance Model (SWB) to Estimate Recharge for the Twin Cities Metropolitan Area Groundwater Model Version 3. Prepared for Metropolitan Council, December 2012

South Washington Watershed District

AVERAGE GROUNDWATER RECHARGE
South Washington Watershed District

FIGURE 2-1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LAKELAND SHORES
LAKE SAINT CROIX BEACH
SAINT MARYS POINT
AFTON
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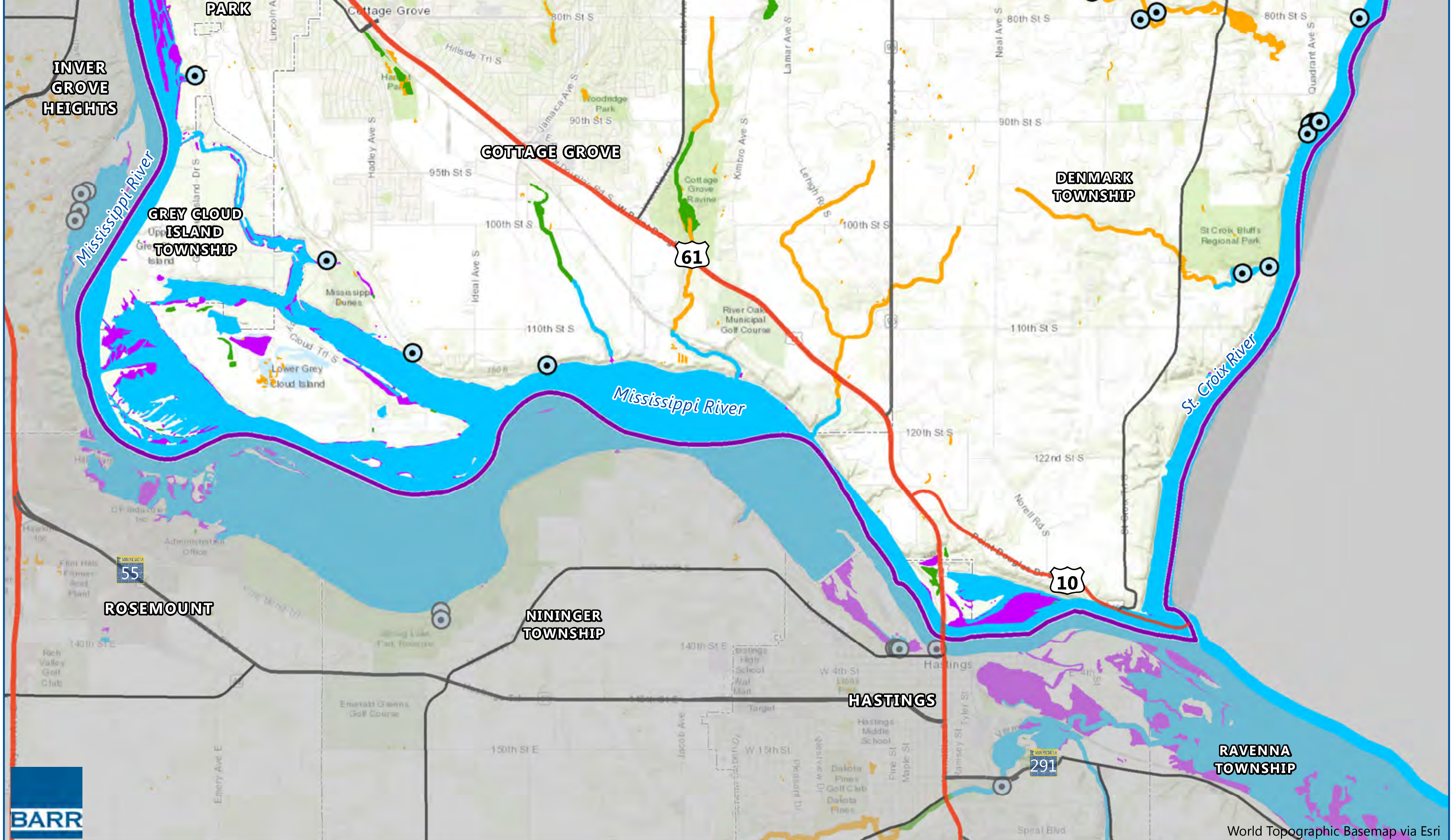


Springs

Surface Water Connection to Groundwater

- Connected - Discharge
- Connected - Flow Through
- Connected - Recharge
- Disconnected (Perched)
- SWWD Boundary
- Municipal Boundary

0 7,000 14,000

Feet

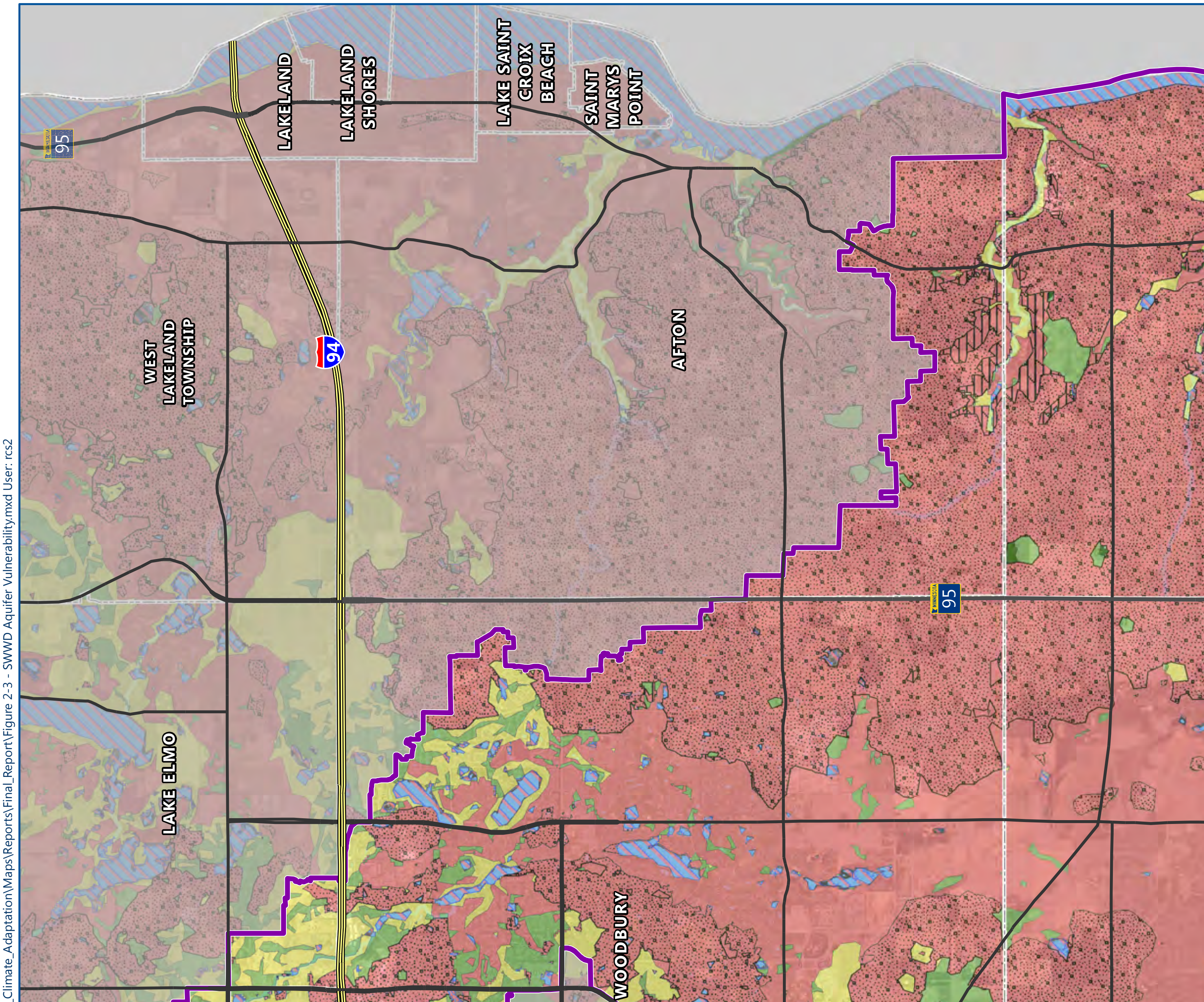
1 inch = 7,000 feet

Note:
Springs and Surface Water Connection to Groundwater from Barr Engineering. June 2010.

SOUTH WASHINGTON WATERSHED DISTRICT

SURFACE WATER CONNECTION TO GROUNDWATER
South Washington Watershed District

FIGURE 2-2


Barr Footer: ArcGIS 10.4.1, 2018-01-31 07:58 File: I:\Client\South_Washington_WD\Work_Orders\2017_Climate_Adaptation\Maps\Reports\Final_Report\Figure 2-3 - SWWD Aquifer Vulnerability.mxd User: rcs2
LAKELAND
LAKELAND SHORES
LAKE SAINT CROIX BEACH
SAINT MARYS POINT
WEST LAKELAND TOWNSHIP
AFTON
LAKE ELMO
WOODBURY
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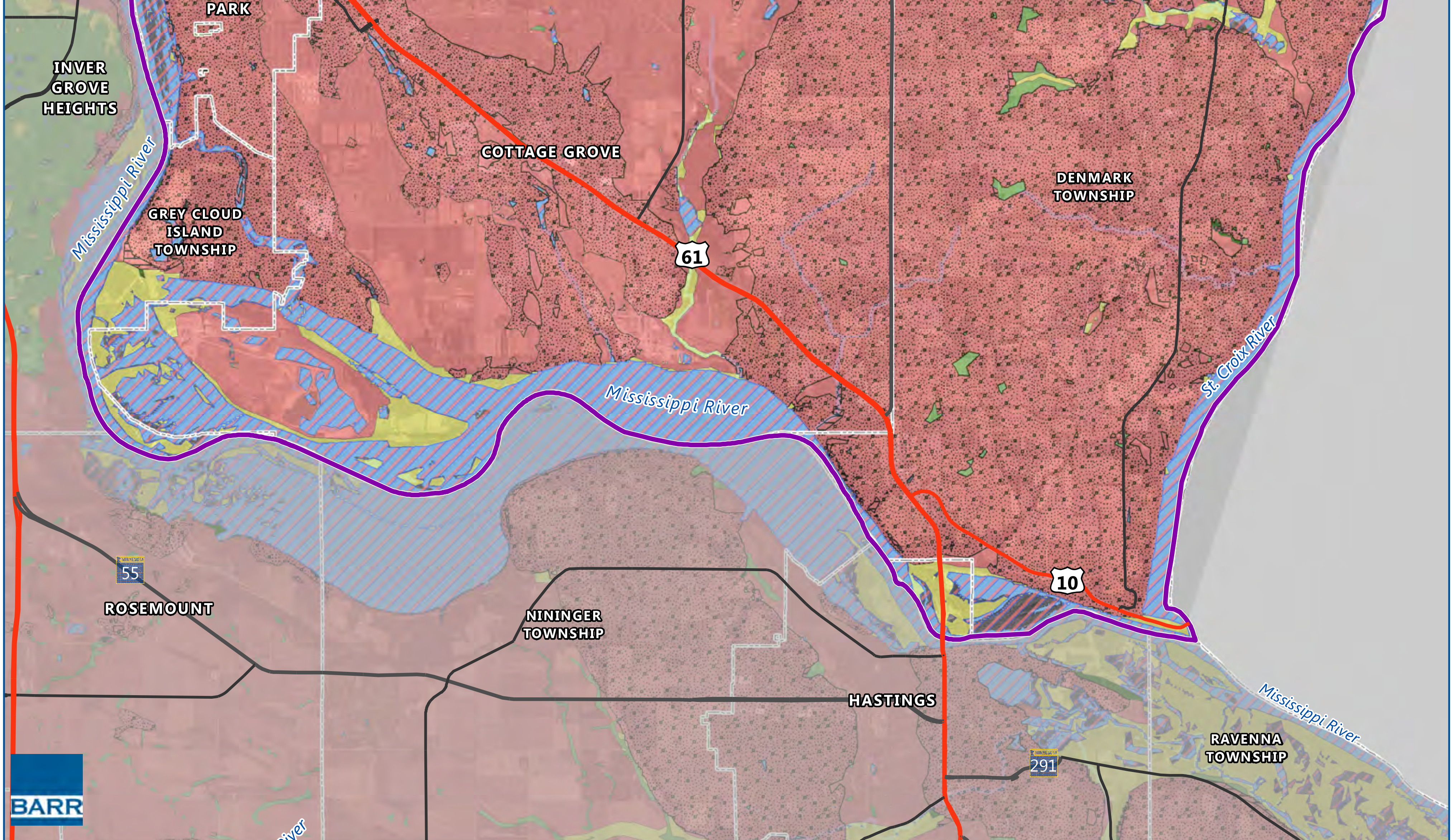


Groundwater Pollution Sensitivity

- High
- High (Bedrock at or near surface)
- High (Karst)
- High (Water)
- Moderate
- Low
- Very low

- SWWD Boundary
- Municipal Boundary

Note:
Pollution Sensitivity of Near Surface Materials from the Minnesota Department of Natural Resources (2016).

0 7,000 14,000
Feet
1 inch = 7,000 feet

SOUTH WASHINGTON WATERSHED DISTRICT

GROUNDWATER POLLUTION SENSITIVITY
South Washington Watershed District

FIGURE 2-3

3

Natural Resources

Our warmer and wetter climate, increasing winter minimum temperatures, and more frequent heavy rain events are effecting the natural resources of the SWWD in several ways. From aquatic to terrestrial, natural resources are threatened by climate change.

The following sections describe specific, critical issues regarding natural resources that the District and its stakeholders identified during the District's September 2017 climate-change-resilience workshops. **Table 3-1** provides recommendations and strategies to address these complex issues through planning, policy, projects, programs, and education.

Prior to European settlement much of the District was an oak savanna plant community. (Barr Engineering Co.)

3.1 Aquatic Invasive Species (AIS) and Terrestrial Invasive Species Management

As climate conditions veer away from historic norms, stress on native plants and organisms provides an advantage to invading non-native species. Much of the invasive species problems facing the District would be present without climate change, but stress from increased humidity, flooding, and warmer winters give many invasive species an edge over native species. In addition, warming winter minimum temperatures allow invasive species to extend their range north and west into the District because they are no longer killed by historically cold temperatures. Some of the predicted new arrivals include teasel, common reed grass, multiflora rose, and Japanese honeysuckle.

New invasive plant and animal species are arriving nearly every year. Invasive upland plant species are causing erosion and impacting water quality in the District. For example, garlic mustard (an invasive woodland species) outcompetes woodland native understory plants each spring with lush growth, but goes dormant in midsummer leaving soils open to erosion during our increasingly heavy storm events. Native aquatic organisms are also threatened by invasive species such as zebra mussels, starry stonewort, Eurasian water milfoil, bighead carp, and silver carp.

Addressing new invasive species as they arrive is the most effective approach. Long-established invasive species such as reed canary grass or common

Maple-Basswood forests of the area will likely be degraded by climate change. (Barr Engineering Co.)

buckthorn are difficult or impossible to eradicate and can only be expected to be controlled in areas of interest.

3.2 Natural Areas Preservation and Wildlife Corridor Enhancement

Natural areas provide valuable ecosystems that are essential for wildlife. They also benefit people by filtering air, providing groundwater recharge, and mitigating heat impacts. Climate change impacts on natural areas occur with both extreme events (e.g., flooding) and gradual changes such as increases in winter minimum temperatures. Increases in insect populations and diseases that thrive in this changing climate are affecting native tree species in the District, including green ash, red oak, birch, maple, basswood, and white pine.

Common reed grass is just beginning to establish in the District. In other parts of the Midwest this plant has damaged natural ecosystem processes as well as native plants and habitats. (Barr Engineering Co.)

Humans have destroyed and fragmented native habitats through urban development and agriculture. Remaining natural areas have become islands of native plant communities which, because of their isolation, are vulnerable to the effects of climate change. Most remnant plant communities in the District have been fractured into small acreages that do not support a high diversity of species. This prevents recovery from both climate and natural impacts.

To retain and improve valuable ecosystem functions, remnant natural areas in the District can be preserved and connected by expanding native plant communities through restoration. This will allow species movement between remnant natural areas, providing enhanced diversity. An example of an existing well-connected wildlife corridor is the St. Croix River valley with its continuous, unbroken habitats. Reinforcing existing corridors and establishing new corridors (such as the potential corridors identified in **Figure 3-1**) will help preserve our valuable natural heritage while allowing for ecosystems to change with the climate.

3.3 Lawn Reduction and Management

Lawn is an excellent ground cover where it is actively used, but much turf is touched by feet only when it's time to mow. Maintaining our lawns contributes to

Simple plantings of shrubs reduce maintenance and the need for polluting inputs. (Barr Engineering Co.)

climate change through the release of greenhouse gases through fertilizing. Nitrous oxide (N2O) released from fertilized lawns is one of the major greenhouse gases, with a global warming potential nearly 300 times that of carbon dioxide (CO2) (IPCC 2013). Beyond the release of greenhouse gases, maintaining lawn has other harmful effects, including releasing harmful nutrients into natural waterbodies through fertilizer use, harming pollinators and other organisms through pesticide use, and consuming Washington County's limited groundwater supply through irrigation. Reducing lawns can positively contribute to the environment and reduce the release of greenhouse gases.

We can shrink lawns to areas that are actively used through planting alternatives that do not require the harmful inputs used to manage turf. For example, native plantings such as prairie and woodland, or simple mass plantings of a few tough shrub species will reduce greenhouse gas release as well as sequester CO2 from the atmosphere. These plantings also provide habitat for birds and butterflies and improve water quality.

3.4 Ravine Erosion Control

The number and frequency of large precipitation events, including so-called "mega rain" events has rapidly increased over the past 2 decades; more of our precipitation now comes in heavy downpours as opposed to slow soaking events. As identified in SWWD's plan, surges of stormwater from new developments are eroding ravines in the District. Some ravines are more vulnerable than others, depending on the ravine's steepness, soil type, size, and land use within the ravine's watershed. Eroding ravines can cause property damage and send sediment into downstream waterbodies, including the Mississippi River (impaired for high levels of sediment) and the St. Croix River (impaired for excessive nutrients).

Controlling stormwater runoff before it reaches ravines is critical to prevent damage. The District has partnered and led several efforts to stabilize eroding ravines.

3.5 Natural Waterbodies Degradation

As identified in SWWD's plan, increased stormwater runoff volumes due to climate change have the potential to harm natural waterbodies in the District through destructive water-level bounces, increased pollutant loading, and temperature stressors. Additionally, as winter minimum temperatures increase, road salt usage increases. Chlorides from road salt are accumulating in Minnesota lakes and impacting biota in wetlands (Pioneer Press, 2018).

3.6 Urban Forest Enhancement

Trees in urban and suburban areas provide multiple benefits, including:

- Shading buildings and cars to reduce air conditioning needs.
- Reducing stormwater runoff by holding water on their leaves and bark for evaporation.
- Allowing better stormwater infiltration.
- Facilitating carbon sequestration of about a half ton of carbon dioxide per mature tree per year (Nowak, 2002).
- Removing air pollutants (particulates) from the atmosphere.

Trees provide social advantages as well, including shortened hospital stays and reduced workplace stress (Ulrich, 2013). Their values are many, but climate-related stresses, which lead to insects and disease, can reduce their life.

Additional nutrients coupled with warming water temperatures can cause algal blooms in lakes. Of particular concern are blue-green algae that can be toxic to people and pets. (Barr Engineering Co.)

Planting trees throughout the District can greatly benefit people and wildlife. In urban areas that have a lot of buildings and paved surfaces, trees are of particular value for summer cooling. In the presence of climate change, maintaining our existing trees and preserving our urban forest is critical. Regular pruning, especially when trees are young, will help shape a strong structure resilient to wind and resistant to insects and disease. Developing a tree succession plan for your property or community will help preserve our urban canopy in the face of unrelenting climate-change impacts.

3.7 Soil Degradation

Soil can be degraded by development and, in many cases, through agricultural processes. Degradation includes soil compaction, soil erosion, leaching of soil nutrients, and chemical contamination. It is exacerbated by the climate change effects of torrential rain and flooding. Loss of topsoil from erosion is of particular concern in the District. Intense rains on unvegetated landscapes and cropland wash away this precious, non-renewable resource which then becomes a pollutant as it is washed into natural waterbodies.

Our soils are critical, yet fragile. They are the source of our food and are the backbone of the ecosystem in which we live. Even without the effects of climate change, the need to protect our soils is important. In urbanizing areas, we should place and cultivate deep, loose, rich soils on construction sites after equipment leaves. In agricultural areas, a continuous vegetative cover, including winter cover crops, should be implemented to hold soils in place.

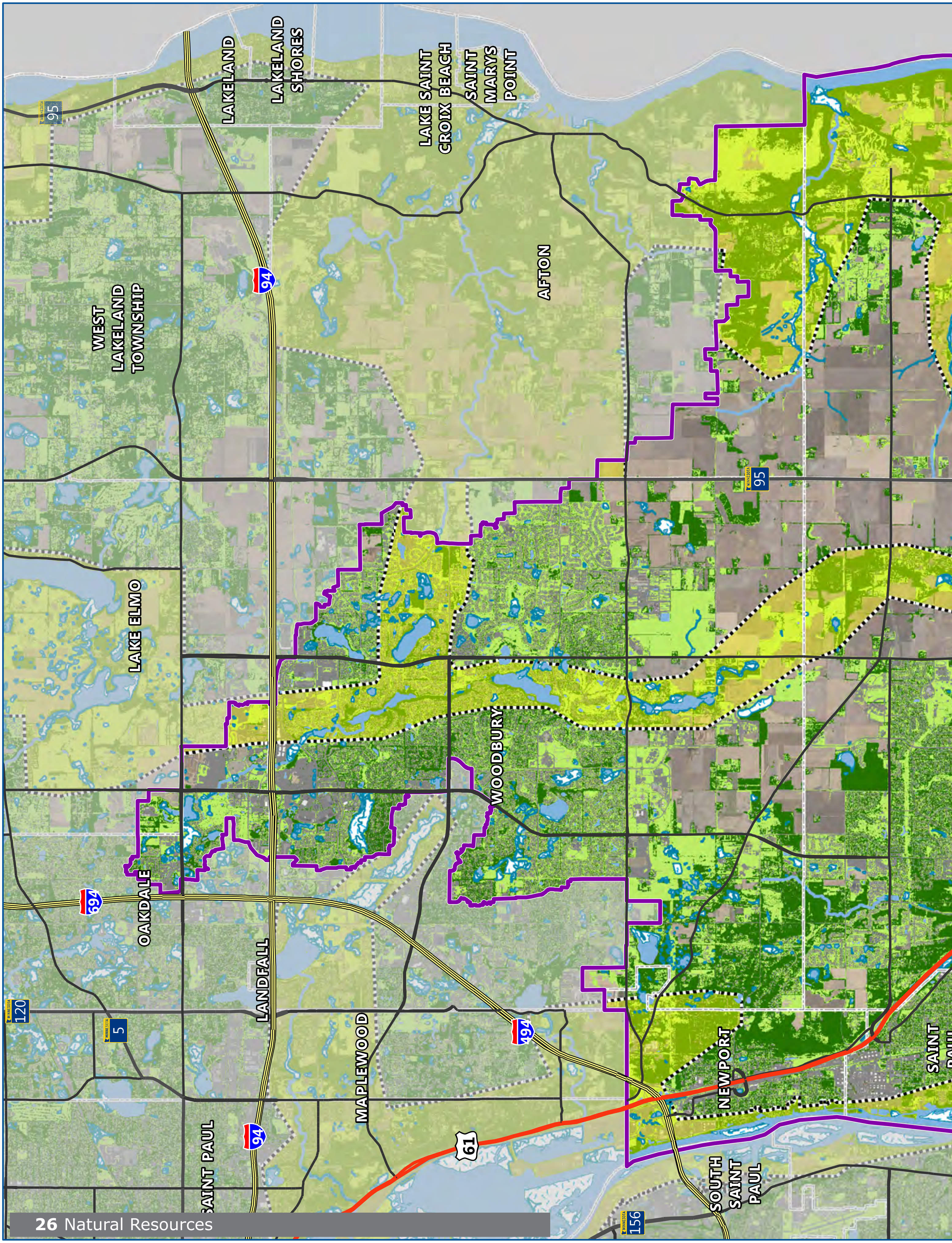
Healthy soils have a crumbly appearance as seen in an undisturbed prairie. It has large pore spaces for oxygen circulation to roots and is able to store lots of water. (Barr Engineering Co.)

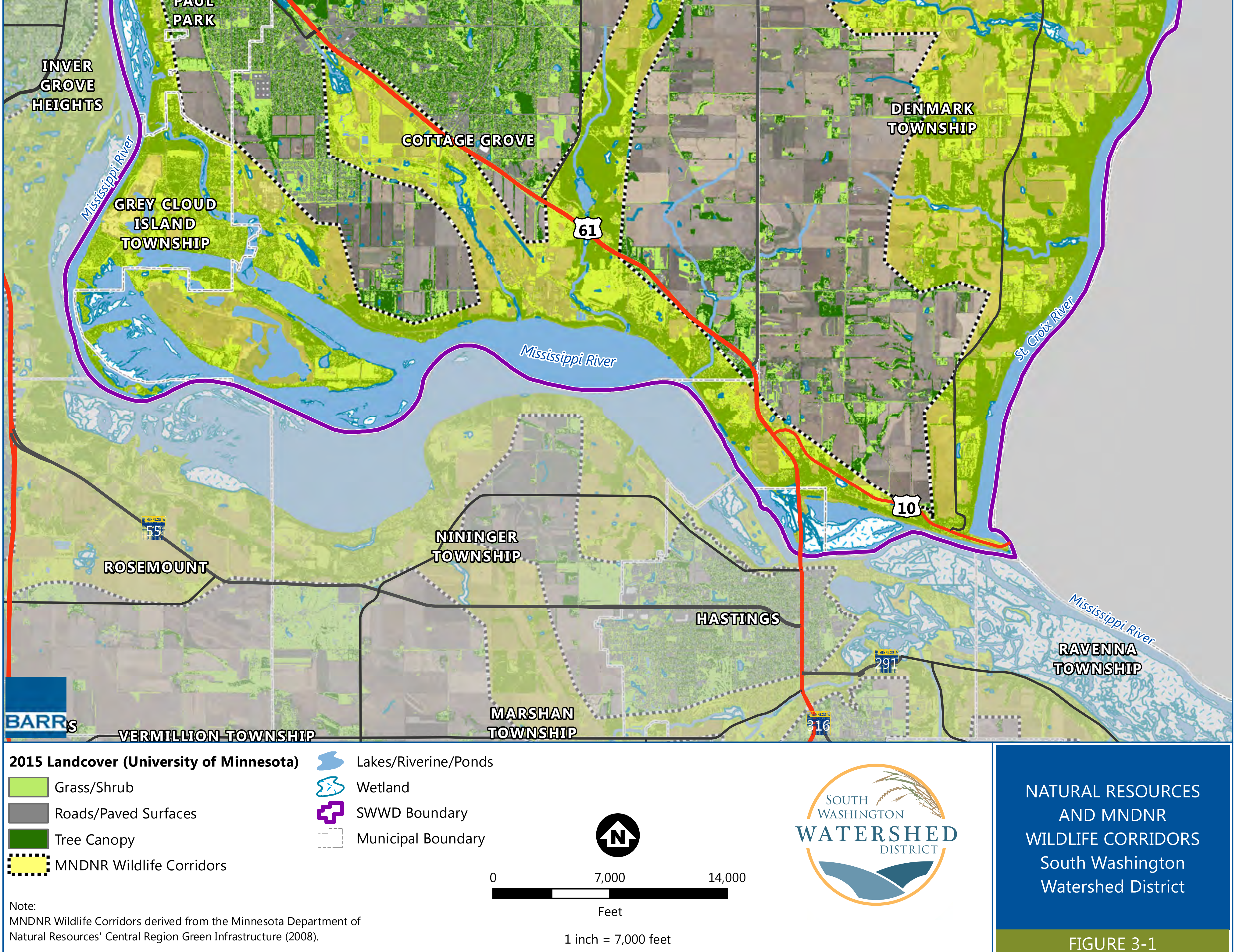
Table 3-1: Recommendations and Strategies to Address Critical Issues Related to Climate Change and Natural Resources

Issue to be Addressed	Strategies to Address Issue		
	Planning Efforts	Policy Development Actions	
Aquatic Invasive Species (AIS) Management	Create a District-wide invasive species monitoring and management plan that prioritizes species and emerging AIS of concern (such as zebra mussels, starry stonewort, Eurasian watermilfoil, bighead carp, and silver carp) and defines roles and actions of management partners. Work with stakeholders to develop an AIS rapid response plan.	Develop policy around SWWD role and responsibilities (including grant funding) of AIS management. Work with communities on herbicide and chemical treatment and mechanical removal policies.	
Terrestrial Invasive Species Management	Create a District-wide invasive species monitoring and management plan that prioritizes species and emerging invasive species of concern (such as jumping worms, common reed, and oriental bittersweet and Japanese barberry) and defines roles and actions of management partners. Work with stakeholders to develop a terrestrial invasive species rapid response plan.	Develop policy around SWWD role and responsibilities (including grant funding) of terrestrial invasive species management. Work with the Minnesota Department of Agriculture to update the Noxious Weed List with new invasive species such as jumping worms and common reed. Work with Minnesota Department of Natural Resources (MNDNR) to review possible species eligible for restricted status.	
Natural Areas Preservation and Wildlife Corridor Enhancement	Develop a natural areas preservation plan within the SWWD with appropriate partners such as the MNDNR and Washington County.	Work with MNDNR and other agencies to develop policies to preserve priority habitats.	
Lawn Reduction and Management	Identify areas with extensive, unused lawns, such as large landowners with a sustainability ethic (e.g., corporate headquarters and public institutions).	Work with cities to develop irrigation reduction policies. Work with cities to review and revise ordinances related to vegetation requirements of individual home sites, common space, and other non-impervious surfaces.	
Ravine Erosion Control	Analyze natural and stabilized ravines with projected climate change precipitation modeling to assess resilience.	Work with communities to develop a ravine setback policy. Create special drainage zones or overlay districts to establish more protective runoff standards upstream of sensitive ravines.	
Natural Waterbodies Degradation	Update current plan as needed to respond to new and emerging stressors and pollutants.	Work with communities to implement SWWD's permit requirements and achieve identified water quality goals.	
Urban Forest Enhancement	Identify native tree species and nearby native (Iowa) species suitable for the changing climate.	Work with cities to implement tree preservation ordinances.	
Soil Degradation	Work with Natural Resources Conservation Service to determine how to predict, monitor, and minimize potential soil degradation.	Work with communities to develop and implement a model soil ordinances.	

Projects and Programs	Education and Outreach
Implement AIS rapid response plan. Implement boat launch inspections at vulnerable locations. Work with partners to implement AIS management projects and programs, such as herbicide treatment of invasive plants and quarantine and chemical treatment of zebra mussels. Develop a volunteer program to identify early infestations, such as installing and inspecting zebra mussel plates.	Educate boat users on AIS and decontamination practices. Educate community and landowners along waterbodies on AIS identification to help find early infestations.
Work with partners to implement invasive species management projects and programs, such as common reed identification and control, and jumping worm spread prevention. Develop programs to encourage control and removal of invasive species on private property.	Educate landowners and public property land managers on critical invasive species identification and management techniques with the goal of controlling species just entering the SWWD as well as managing other invasive species.
Conduct natural resource inventories where necessary. Work with stakeholders, such as the State of Minnesota, non-profits, and Washington County through its Land and Water Legacy Program to fund projects that will protect /preserve land in MNDNR designated corridors and adjacent to scientific and natural areas. Develop a cost-share grant program for terrestrial invasive species management, such as a buckthorn removal program.	Educate landowners on the benefits and 'how to 'of native vegetation planting. Educate community groups on the importance natural area protection and the expansion of wildlife corridors. Promote SWWD's Water Quality Cost Share Program for native plantings.
Develop alternatives-to-lawn demonstration sites, similar to model home sites. Develop incentive programs to encourage developers and individual landowners to reduce lawn to encourage stormwater infiltration.	Educate developers and landowners on lawn alternatives. Educate landowners about low-input lawn care. Further fund SWWD's Water Quality Cost Share Program for native plantings.
Conduct an inventory of vulnerable slopes and ravines. Implement slope and ravine stabilization projects in high priority areas identified in the inventory.	Educate landowners about best practices to prevent ravine erosion.
Conduct wetlands and shorelines inventories. Monitor wetlands, lakes, and streams for destructive water level bounce, pollutant, and temperature stressors. Work with communities on street sweeping programs and other water quality best management strategies identified in SWWD's plan. Work with communities to implement chloride-reduction efforts, such as updating snowplows.	Educate public on individual steps that can be taken to improve water quality (e.g., keep leaves out of streets, planting buffers, construct a rain garden, etc.). Promote SWWD's Water Quality Cost Share Program. Work with commercial land management companies to reduce chloride impacts.
Develop a tree planting program using trees suitable for the changing climate.	Educate the public on the importance of urban tree canopy, what species are best to plant, and the best planting techniques. Use demonstration stormwater tree trench projects to show the benefits they provide to water quality along with the other multiple benefits trees provide.
Develop demonstration projects to show compacted soil loosening and improvement techniques, and to show the resulting improvement to stormwater infiltration and reduced runoff.	Develop and promote soils best practices educational materials. Educate developers on best practices for soils management and restoration. Work with farmers, nursery workers, landscapers, and the general public about the soil destruction and water quality implications of invasive species such as jumping worms.

Barr Footer: ArcGIS 10.4.1, 2018-01-31 08:00 File: I:\Client\South_Washington_WD\Work_Orders\2017_Climate_Adaptation\Maps\Reports\Final_Report\Figure 3-1 - SWWD Natural Resources and DNR Wildlife Corridors.mxd User: rcs2





Note:
MNDNR Wildlife Corridors derived from the Minnesota Department of Natural Resources' Central Region Green Infrastructure (2008).

NATURAL RESOURCES AND MNDNR WILDLIFE CORRIDORS
South Washington Watershed District

FIGURE 3-1


JOHN DEERE
SEWER

4

Storm Sewer Infrastructure Assessment

Storm sewer infrastructure within the SWWD is critical in providing flood protection. Any failures in the storm sewer system could flood structures, disrupt the transportation systems, cause slope failures, and injure humans. To maintain this critical infrastructure, the storm sewer system owners must perform inspections and maintenance. With limited resources, infrastructure owners need tools to prioritize these activities to reduce risk and build resilient systems.

As part of our scope of services related to developing a watershed climate adaptation and resiliency plan, Barr performed a qualitative risk analysis of storm sewer infrastructure located within the District. This analysis used spatial data of the storm sewer and other parameters related to topography, hydrology, soils, and critical infrastructure locations to evaluate the likelihood of storm sewer failure and the possible consequences. The product of the failure likelihood and consequences determined the relative failure risk of each storm sewer infrastructure component (**Figure 4-1**). Using the failure risk score, Barr developed recommendations for storm sewer inspection and replacement prioritization. This section describes the data used, assumptions made, methods used, and the results of the analysis. In all, Barr analyzed over 24,000 individual storm sewer pipe segments.

This analysis is not intended to identify all potential problems with the storm sewer infrastructure located in the District. There may be instances where a system failure occurs in an area that was either not identified or that was given lesser priority in this analysis than other system segments. This could be the result of specific installation issues, actions that occurred to damage the infrastructure, or incomplete data about the likelihood of failure. Additionally, this analysis does not consider all impacts resulting from storm sewer failure, such as potential downstream water quality impacts resulting from erosion or slope/roadway failure. Rather, the results of this analysis provide a tool for the owners of storm sewer in the SWWD to help them determine where to prioritize and focus much of their system's maintenance and renewal efforts.

This GIS-based storm sewer risk analysis provides a relative estimate of the likelihood and consequence of pipe failure and assigns a combined failure risk score. This method is useful for comparative analysis, but does not provide an absolute risk for any pipe or predict future failure. In addition, the risk analysis is performed using the best available data; however, there are other factors that impact deterioration of pipes that we were not able to consider due to lack of data (e.g., how a pipe was manufactured, construction defects that lead to pipe settlement, joint separation,

Figure 4-1: *Risk Diagram*

pipe cracking or collapsing, etc.).
Where data was missing, either assumptions were made to fill the data gaps (i.e., pipe material) or the data was not used in the risk assessment (i.e., pipe inverts to determine pipe slope).

This analysis is a tool intended to help the SWWD and its member communities and stakeholders:

- Prioritize efforts to inspect, repair/replace, and manage the pipe segments.
- Proactively identify and correct problems with the storm sewer system before the consequences of failure occur.

In many cases, if problems are found soon enough, relatively minor efforts to maintain and/or repair infrastructure may essentially renew or prolong the infrastructure's service life well beyond its design life.

4.1 Qualitative Risk Analysis Methods

The risk analysis process is aimed at estimating both the probability of failure of the stormwater infrastructure components and the consequences of failure. This process provides a framework for assessing the vulnerability of the storm sewer systems located in the SWWD. Barr's work included GIS analysis to:

1. Identify pipe segments with a higher likelihood of failure due to material, adjacent soil type, and ground slopes.
2. Assess the consequences of pipe failure, including the potential for roadway or railway inundation and washout, impacts to storm sewer trunk lines, inundation of structures, and slope failure.

Barr conducted a qualitative risk analysis rather than using a quantitative approach which would require estimated probabilities of occurrences. A qualitative approach can be used to apply risk analysis principles without the time, cost, and data required for a quantitative risk assessment. The goal of the qualitative approach is to develop relative risk estimates for each component or segment of the storm sewer system. This enabled Barr to evaluate the relative risk and identify high-risk portions of the storm sewer systems in the SWWD that should be prioritized for inspection and/or replacement.

Barr used a qualitative numerical scoring system to develop relative risk estimates to identify "high-risk" storm sewer segments based on likelihood of failure, consequences of failure, and combined failure risk. Using the storm sewer GIS databases provided by the SWWD, SWWD member communities, and Washington County, we applied the numerical scoring systems. This allows the process to be semi-automated and quickly updated as additional data becomes available. The GIS analysis and scoring system are described in the following sections.

Our quantitative scoring approach is subjective. For example, a 1.2 or 1.8 value does not mean that a system is 20% or 80% more likely to fail than a 1. The goal is to ultimately create manageable categories for storm sewer inspection and replacement prioritization.

4.2 Likelihood of Failure Data Inputs and Calculation

After acquiring storm sewer GIS databases from SWWD, SWWD member communities, and Washington County, Barr aggregated the data into one comprehensive GIS database. The database includes information about several pipe attributes that affect their likelihood of failure. The attributes used in this analysis include the following:

- Pipe material
- Susceptibility to corrosion
- Soil structural support capacity
- Frost action potential
- Ground slope

These attributes and how they affect pipe failure likelihood are described in the following sections. Barr also considered but rejected the inclusion of pipe age, pipe slope, and pipe depth of cover because not enough information was available. Barr recommends that this data be included in the analysis as it becomes available.

Based on the attributes considered and the completeness of the available data, Barr determined the potential likelihood of failure for each pipe segment in the District.

4.2.1 Pipe Material

The storm sewer pipes located in the SWWD are made of various material types. The majority of the pipes are reinforced concrete (RCP) as shown in **Chart 4-1**. For this study, pipes were classified into eight material groups (listed in order from least to greatest likelihood of failure):

- High-Density Polyethylene (HDPE)
- Polyvinyl Chloride (PVC)
- Reinforced Concrete (RCP)
- Ductile Iron (DIP)
- Corrugated Metal (CMP)
- Vitrified Clay (VCP)

We classified pipes with unknown material types as having a similar likelihood of failure as CMP, since they are primarily located in the cities of Newport and St. Paul Park, which are older municipalities, and thus more likely to have installed CMP as opposed to newer RCP. Pipes classified as "Lined Pipe" in **Chart 4-1** include pipes identified in the database as CIP (cured in place) or plastic liner. Pipes classified as "other" are all Minnesota Department of Transportation (MNDOT) owned storm sewer and are likely not CMP, RCP, HDPE, PVC, or lined pipes because these categories already exist in the MNDOT storm sewer database. Therefore, these pipes remain in their own material group.

Pipe material can affect the likelihood of pipe failure for a variety of reasons including, but not limited to, material strength, design life, sensitivity to corrosion, joint durability, frequency of joints, buoyancy, sensitivity to ultraviolet deterioration, and ease of proper installation.

High-density polyethylene (HDPE) pipe is highly resistant to corrosion and abrasion. Because the material is relatively new, the design life of HDPE culvert is relatively unknown; however, manufacturers estimate a life of approximately 100 years, which can vary depending on the type of HDPE (e.g., corrugated vs. smooth-walled, butt-fused vs. snap–fit-jointed, etc.). HDPE material is not significantly susceptible to freeze/thaw damage; however, it is susceptible to buoyancy and movement from freeze/thaw. The biggest concern with HDPE storm sewer is deflection, which is movement or deformation of the pipe itself when pipes are not properly installed. Large deflection can cause cracking of the pipe material.

Polyvinyl chloride (PVC) pipe is also highly resistant to corrosion and abrasion; however, it is susceptible to ultraviolet deterioration. PVC material is also brittle near and below freezing temperatures. PVC has an expected design life of 50 to 100 years. It can be easily damaged during or after installation if not handled carefully or installed correctly.

Reinforced-concrete pipe (RCP) is the most common rigid pipe used for storm sewers. It has high strength and is heavy enough to resist buoyancy forces that could cause the pipe to float upward in a flood. RCP has a long design life that can exceed 100 years when installed and maintained properly. Factors that can lead to deterioration of RCP include salt water environments, soils containing sulfates and carbonates, and acidic water with a pH of less than five. The most commonly seen failure mode of RCP culverts is joint separation when not installed properly.

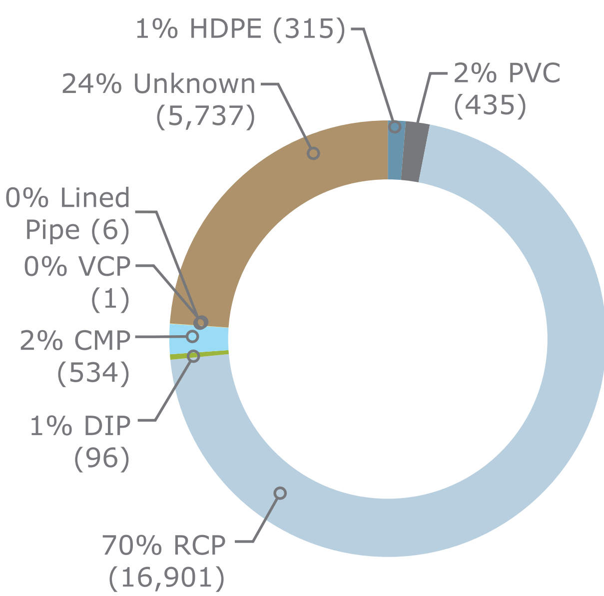


Chart 4-1: *Pipe Materials*

Ductile-iron pipe (DIP) is not commonly used for storm sewer due to the high cost of the material. It has high strength, durability, and corrosion resistance. DIP has an expected design life of approximately 100 years.

Cured in place (CIP) and plastic liner are rehabilitation methods used to extend the life of a pipe. Liners can be installed using trenchless methods, so they can be less expensive and more efficient than traditional open-cut pipe replacement. Manufacturers estimate the design life of CIP and plastic liners to be approximately 100 years; however, these lining methods have only been in practice for a few decades. Corrugated-metal pipe (CMP) was the most common flexible pipe used for storm sewers in the past century. CMP is easier to handle and install than RCP because it is light and flexible. While CMP itself has low strength, it gets strength from the surrounding soil envelope. CMP can be made of galvanized steel or aluminized steel. Galvanized steel pipes can have a much shorter design life (25–50 years) than CMP made out of aluminized steel, which can have a design life 2 to 6 times longer than galvanized pipe, depending on the environmental conditions. Galvanized steel can deteriorate when exposed to acidic or alkaline water and it can corrode from clay and organic soils. While CMP can be coated with polymer coatings that resist deterioration and corrosion, these coatings can be damaged during installation and by rocks and debris that pass through it during flows. Compared to other pipe material types, CMP inverts can more easily wear away or abrade from the movement of sediment. For this study, we did not have enough data to differentiate between the various types of CMP.

Historic, rigid materials, like **vitrified clay pipe (VCP)**, stone, or wood have not been widely used for several decades. VCP is a strong, rigid pipe with tight joints. It is resistant to abrasion and corrosion

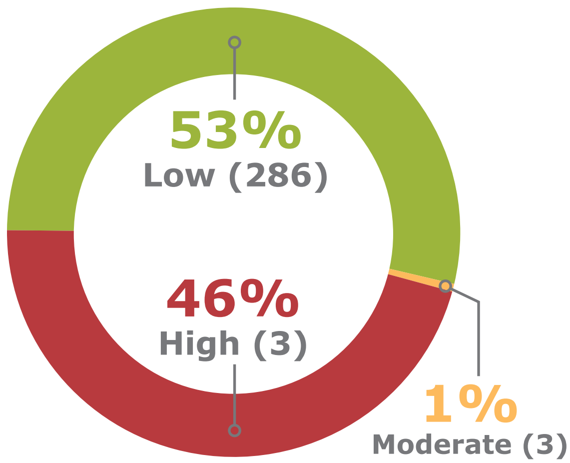


Chart 4-2: *Soil Corrosion Susceptibility of CMP Pipes*

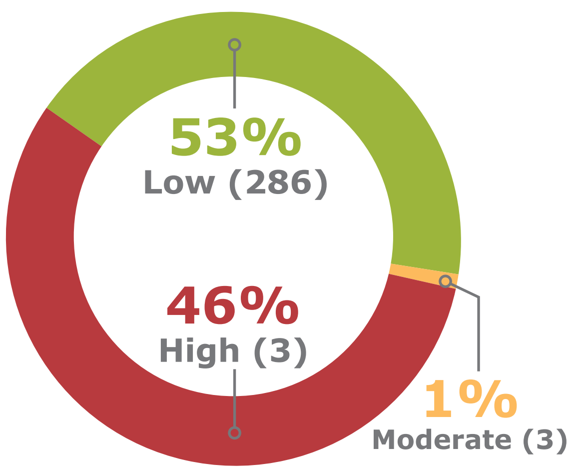


Chart 4-3: *Soil Corrosion Susceptibility of DIP Pipes*

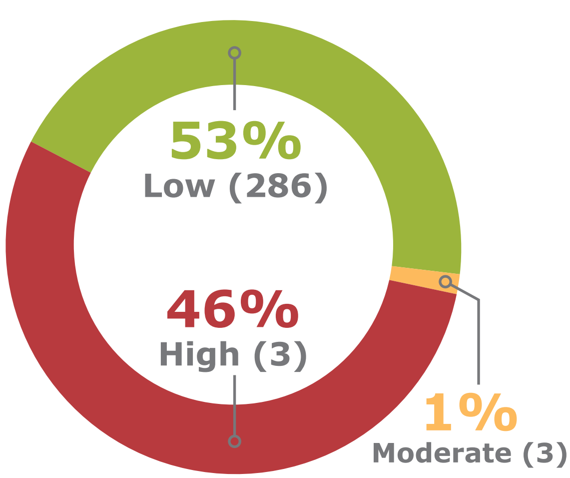


Chart 4-4: *Soil Corrosion Susceptibility of RCP Pipes*

and has a smooth interior. VCP segments are shorter; therefore, sewers made of VCP have more joints than sewers made of other pipe materials. According to the provided data, there is only one VCP pipe in Woodbury.

4.2.2 Susceptibility to Corrosion

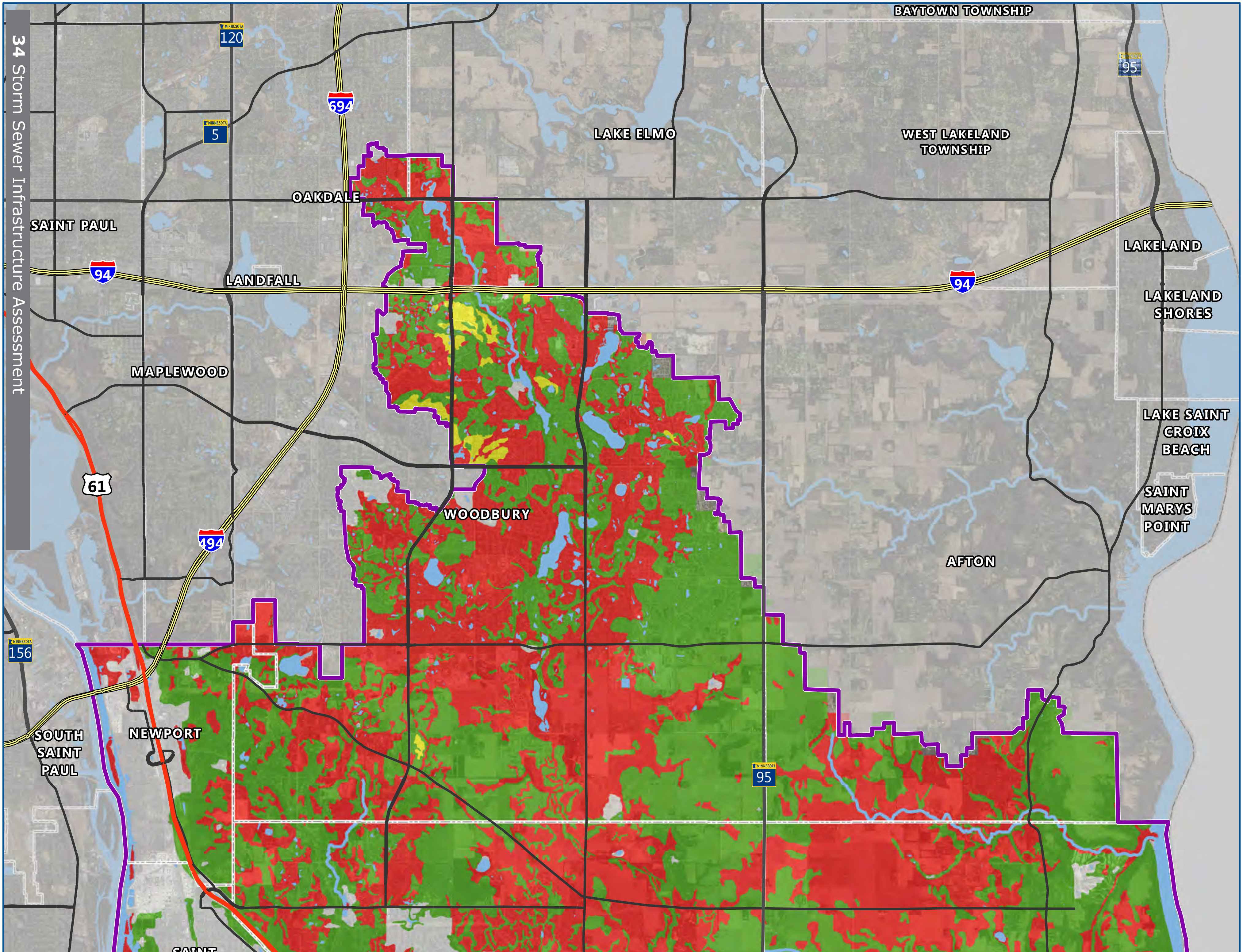
Pipes placed in the ground are susceptible to corrosion resulting from chemical reactions between the pipe material and surrounding soil over time. The National Resource Conservation Service (NRCS) publishes data classifying soils according to their potential to corrode steel and concrete (NRCS, 2016). The most important factors considered for the susceptibility to corrosion of uncoated steel are soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil. The most important factors considered for the susceptibility to corrosion of reinforced concrete are sulfate and sodium content, texture, moisture content, and acidity of the soil. The NRCS divides the likelihood of corrosion into the following categories:

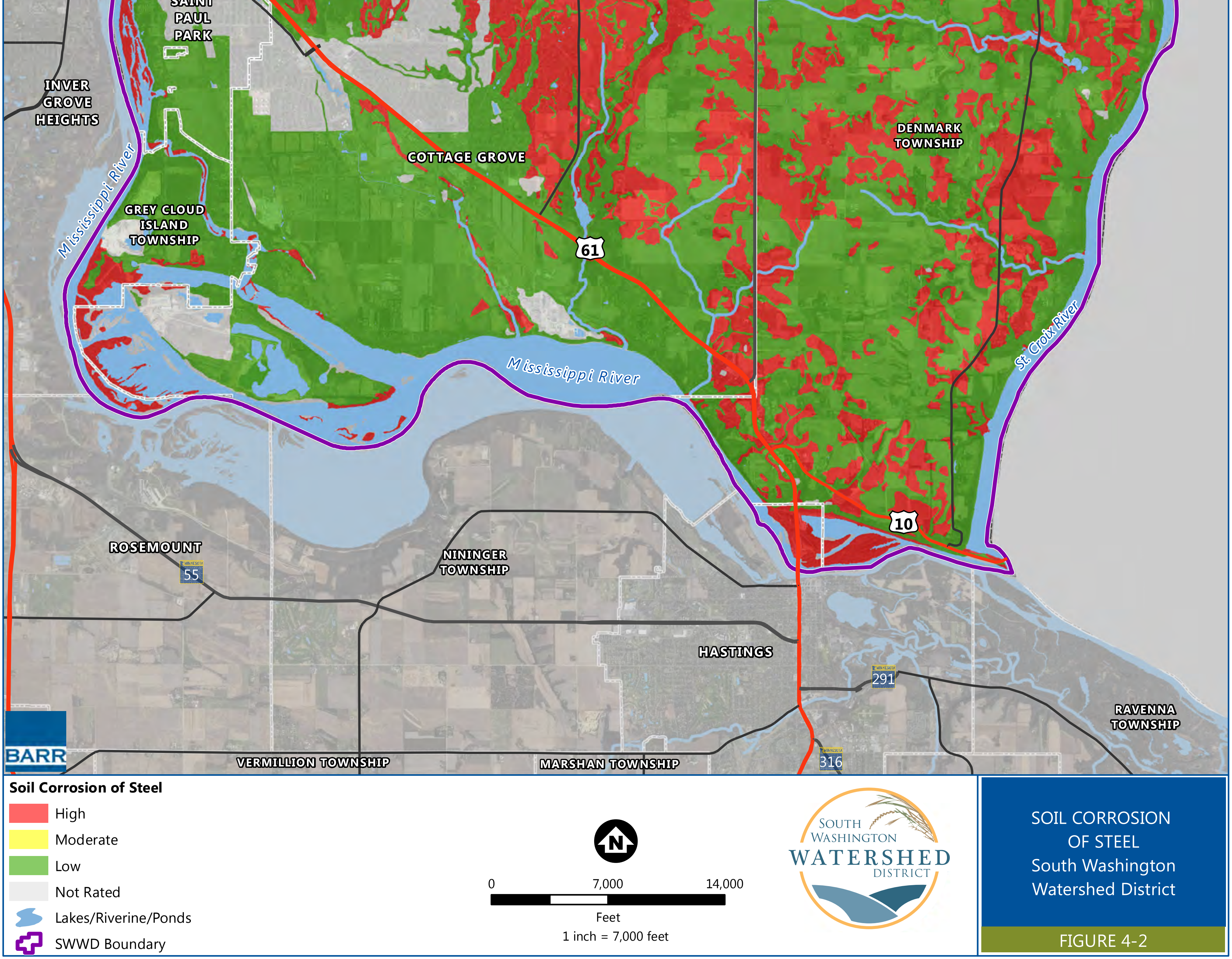
- Low
- Moderate
- High

The extents of soils in the SWWD with the potential to corrode steel and concrete are presented in **Figures 4-2 and 4-3**, respectively. Both CMP and DIP are susceptible to steel corrosion. The fractions of those pipes in soils classified as low, moderate, or highly corrosive are shown in **Chart 4-2** and **Chart 4-3**. RCP is susceptible to concrete corrosion; the fractions of those pipes in soils classified as low, moderately, or highly corrosive are shown in **Chart 4-4**.
Some areas of SWWD do not have identified soils. Those unmapped areas are mostly on the west side of the District in the communities that developed earlier, such as St. Paul Park and Newport. For the unmapped soils, we assumed that those soils are corrosive and the pipes within those areas are scored as more likely to fail.

4.2.3 Soil Structural Support Capacity

The capacity of the soil to support structures (e.g., pipes, manholes) affects the likelihood of these structures failing. The NRCS publishes spatial data regarding the load-bearing capacity of soils (NRCS, 2016). Specifically, the NRCS data set classifies soils according to their ability to support dwellings (i.e., spread footings of reinforced-concrete constructed at a depth of 7 feet on undisturbed soil). Soil factors

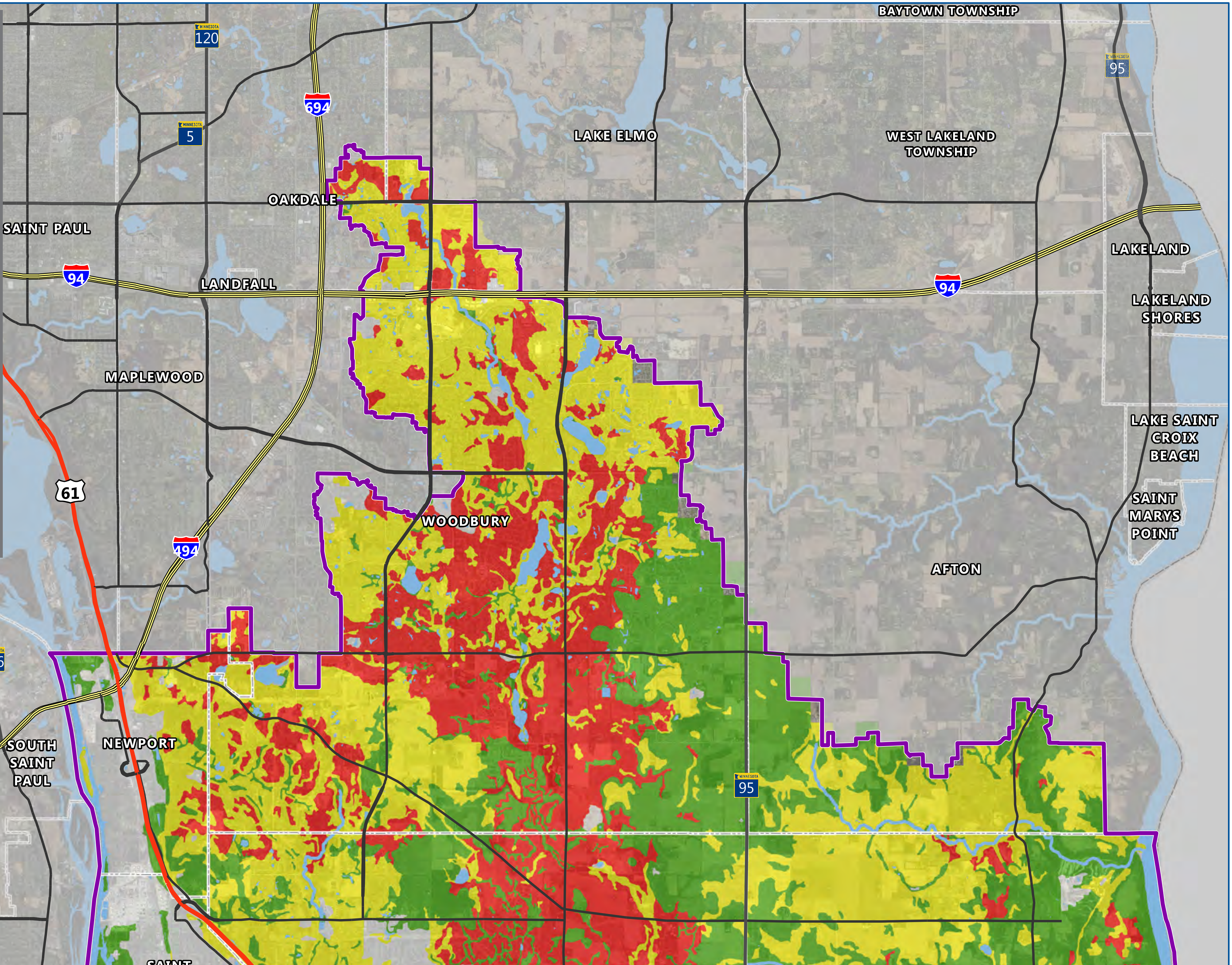

BAYTOWN TOWNSHIP
120
95
694
LAKE ELMO
WEST LAKELAND TOWNSHIP
5
OAKDALE
SAINT PAUL
LAKELAND
94
LANDFALL
94
LAKELAND SHORES
MAPLEWOOD
LAKE SAINT CROIX BEACH
61
WOODBURY
SAINT MARYS POINT
494
AFTON
156
SOUTH SAINT PAUL
NEWPORT
95

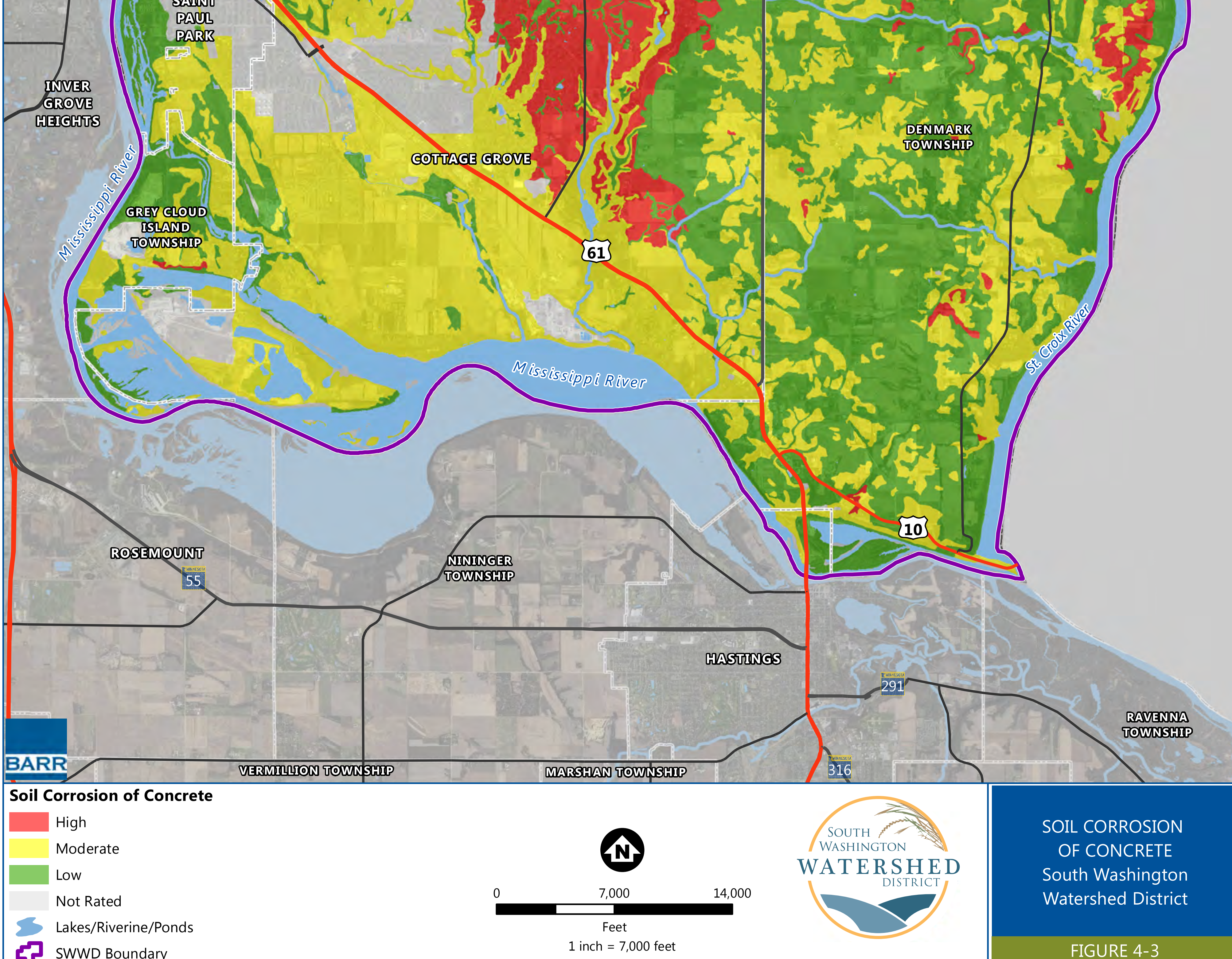


SOIL CORROSION OF STEEL
South Washington Watershed District

FIGURE 4-2

Barr Footer: ArcGIS 10.4.1, 2018-03-01 12:47 File: I:\Client\South_Washington_WD\Work_Orders\2017_Climate_Adaptation\Maps\Reports\Final_Report\Figure 4-3 - SWWD Soil Concrete Corrosion.mxd User: rcs2





SOUTH WASHINGTON WATERSHED DISTRICT

SOIL CORROSION OF CONCRETE
South Washington Watershed District

FIGURE 4-3

affecting structural support capacity include depth to a water table, ponding, flooding, subsidence, linear extensibility (shrink-swell potential), and compressibility. Barr divided the soils within the SWWD into the following categories based on the NRCS data:

- Not limited
- Somewhat limited
- Limited

The classification of “not limited” indicates that the soil has features that are very favorable to support structures. “Somewhat limited” indicates that the soil has features that are moderately favorable to support structures. “Limited” indicates that the soil has one or more features that are unfavorable to support structures without major soil reclamation, special design, or expensive installation procedures. Although the structures assumed in the development of this data set are not pipes, the relative classification of soil support capacity remains a useful surrogate to assess pipe failure likelihood. The extents of soils with somewhat limited or limited load-bearing capacities are presented in **Figure 4-4**. The fractions of pipes in each of the three classifications for structural soil support capacity are shown in **Chart 4-5**.
Some areas of SWWD do not have identified soils. Those unmapped areas are mostly on the west side the District in the communities that developed earlier, such as St. Paul Park and Newport. For the unmapped soils, we assumed that those soils have limited structural support capacity and the pipes within those areas are scored as more likely to fail.

4.2.4 Frost Action Potential

Pipes placed in the ground are susceptible to damage due to soil movement (upward and lateral expansion) cause by frost. The NRCS publishes data classifying soils according to their potential to move due to frost (NRCS, 2016). Frost action occurs when moisture moves into the frost zone of the soil. The most important factors considered for the frost action potential of a soil are temperature, texture, density, saturated hydraulic conductivity, content of organic matter, and depth to the water table. Silty and highly structured, clayey soils that have a high water table in winter are most susceptible to frost action. Well drained, very gravelly, or sandy soils are least susceptible to frost action. The NRCS divides the potential for frost action into the following categories:

- Low
- Moderate
- High

The extents of soils in the SWWD with the potential to experience frost action are presented in F**igure 4-5**. The fractions of pipes within the SWWD in soils classified by the NCRS to have low, moderate, or high potential for frost action are shown in **Chart 4-6**. Some areas of SWWD do not have identified soils. Those unmapped areas are mostly on the west side the District in the communities that developed earlier, such as St. Paul Park and Newport. For the unmapped soils, we assumed that those soils have high potential for frost action and the pipes within those areas are scored as more likely to fail.

4.2.5 Ground Slope

Ground surface slope around storm sewer pipes can affect the likelihood of pipe failure; steeper slopes are more likely to experience loss and movement of material above and around the pipe due to erosion. Additionally, since the provided storm sewer data had many missing pipe elevations, the ground slope can be used as a surrogate for pipe slope (pipes are often installed at the same slope as the ground surface). Steeper pipes are more prone to failure due to the additional forces placed on the pipe from resulting higher stormwater velocities.
Barr used LiDAR (light detection and ranging) data from the state of Minnesota to estimate the local ground slope. Barr classified areas within the SWWD into the following categories based on ground surface slope:

- Mild (less than 3 horizontal: 1 vertical [3H:1V] slope)
- Somewhat steep (3H:1V to 2H:1V)
- Steep (greater than 2H:1V)
- High

Slopes greater than 3H:1V within the SWWD are shown in **Figure 4-6**. The majority of the pipes in the SWWD are placed on level grades (less than 3H:1V slope), as shown in **Chart 4-7**.

4.3 Consequences of Failure

Barr considered the characteristics contributing to the consequences of a failure separately from the attributes contributing to the likelihood of failure. We determined the consequences of pipe failure by assessing the maximum score of several “consequence scenarios” that take into account more than one characteristic related to the consequences of a pipe failure. For this risk analysis, we considered several consequence scenarios:

- Roadways or rail lines (from pipe crossings

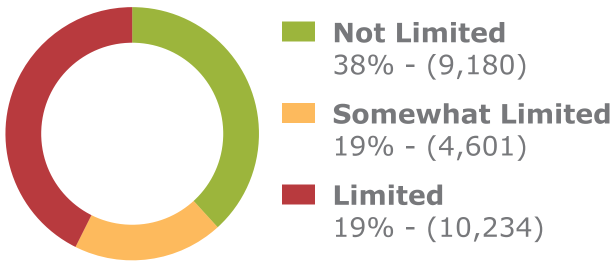


Chart 4-5: *Soil Structural Support Capacity for Pipes*

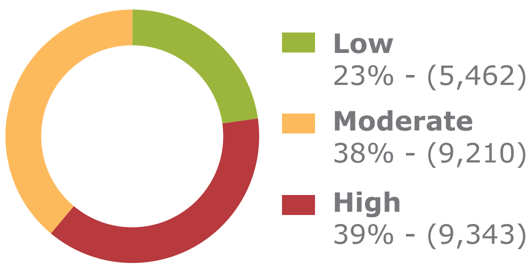


Chart 4-6: *Frost Action Potential for Pipes*

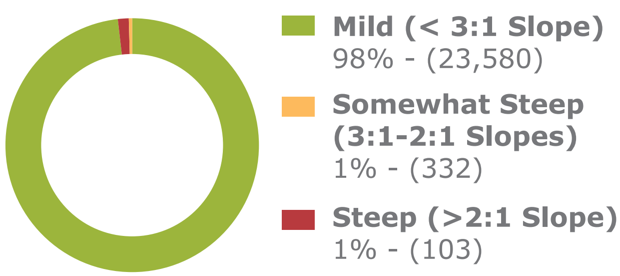


Chart 4-7: *Ground Slope for Pipes*

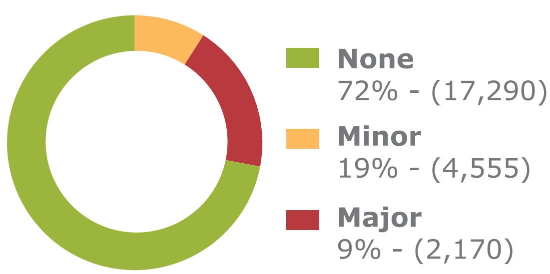


Chart 4-8: *Pipes Crossing Under Roadways and Rail Lines*

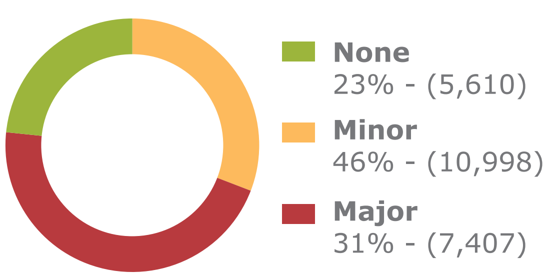


Chart 4-9: *Pipes Under Roadways and Rail Lines*

parallel to and under roadways and railways)
- Larger area from trunk storm sewer failure
- Structures
- Ground slope erosion and failure

These characteristics and how they affect the consequences of failure are described in the following sections.

Based on these characteristics, Barr developed a formula to calculate a qualitative consequences-of-failure value for each pipe or pipe segment in the SWWD.

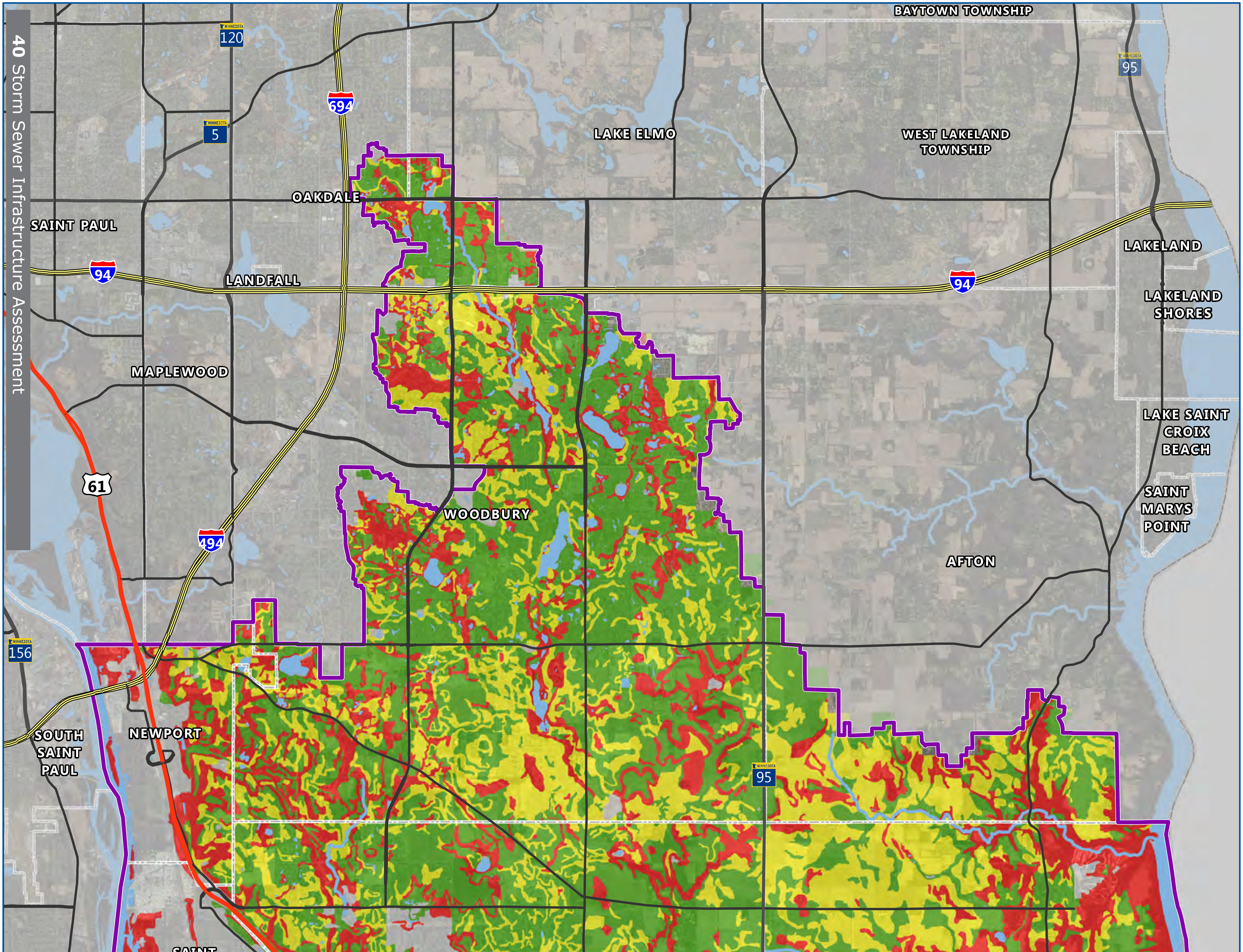
4.3.1 Impacts to Roadways or Rail Lines

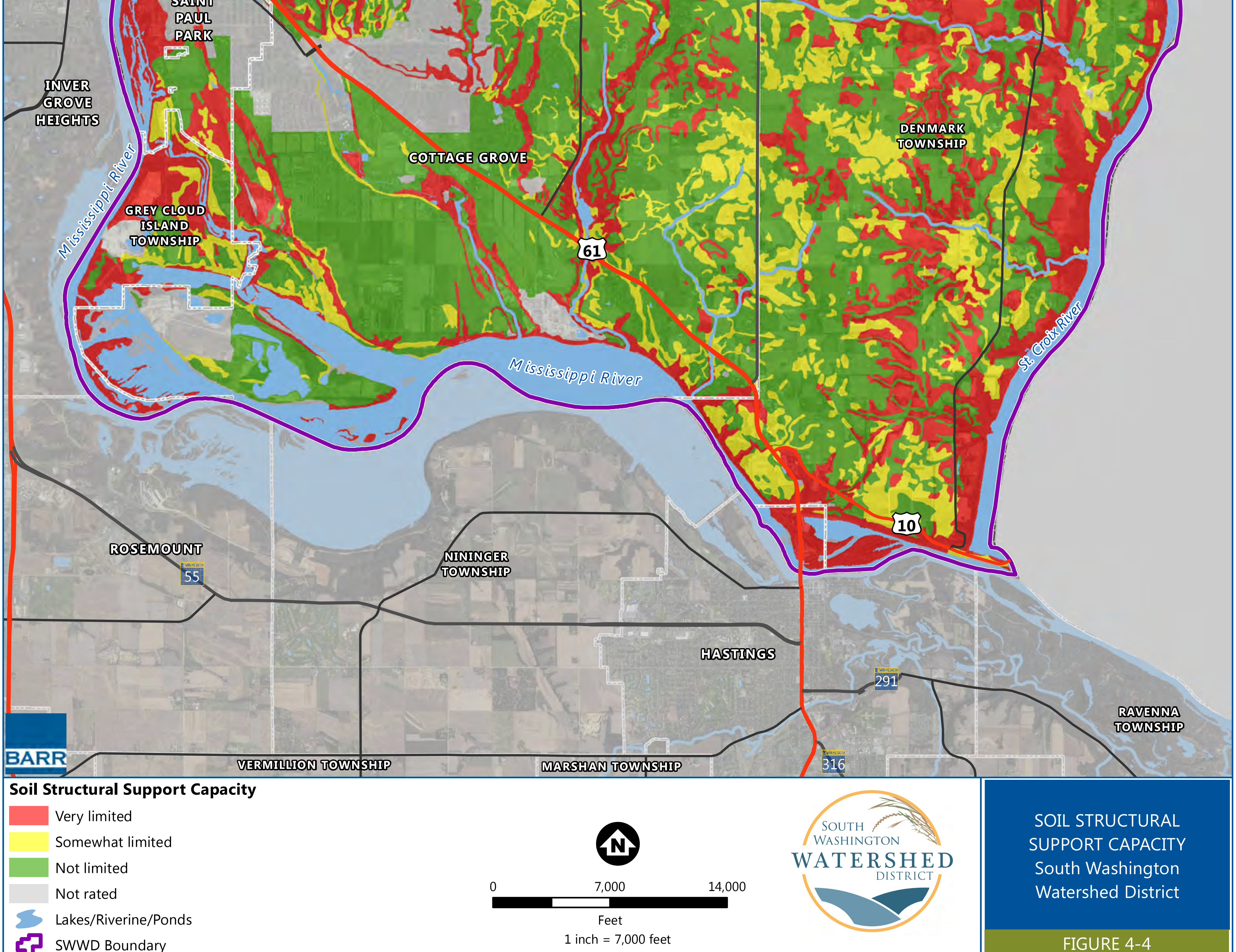
Many of the storm sewer pipes within the SWWD pass underneath roads and railroads. Failure of pipes crossing under roadways or railroads could cause water to back up behind the embankment, which could lead to overtopping of the roadway/railroad, erosion and embankment washout, or collapse. These potential impacts cause a threat to public safety and have the potential to be more significant on major traffic routes. Therefore, three categories were used to classify the pipes according to failure consequences **(Chart 4-8 and 4-9)**:

- None (does not intersect a road or rail line)
- Minor (intersects a road that is not a major route)
- Major (intersects a road that is an interstate highway, US highway, state trunk highway, county state-aid highway, municipal state-aid street, or any rail line)

Barr provided a higher score to pipes that crossed roadways and rail lines as opposed to pipes that are parallel with and under the roadways and rail lines. While both situations create risk to the transportation infrastructure in the District, pipes that are under the transportation line have a greater potential to create a localized sinkhole, while pipes that cross the transportation line have a greater likelihood of washing out the entire road or rail and interrupting service.

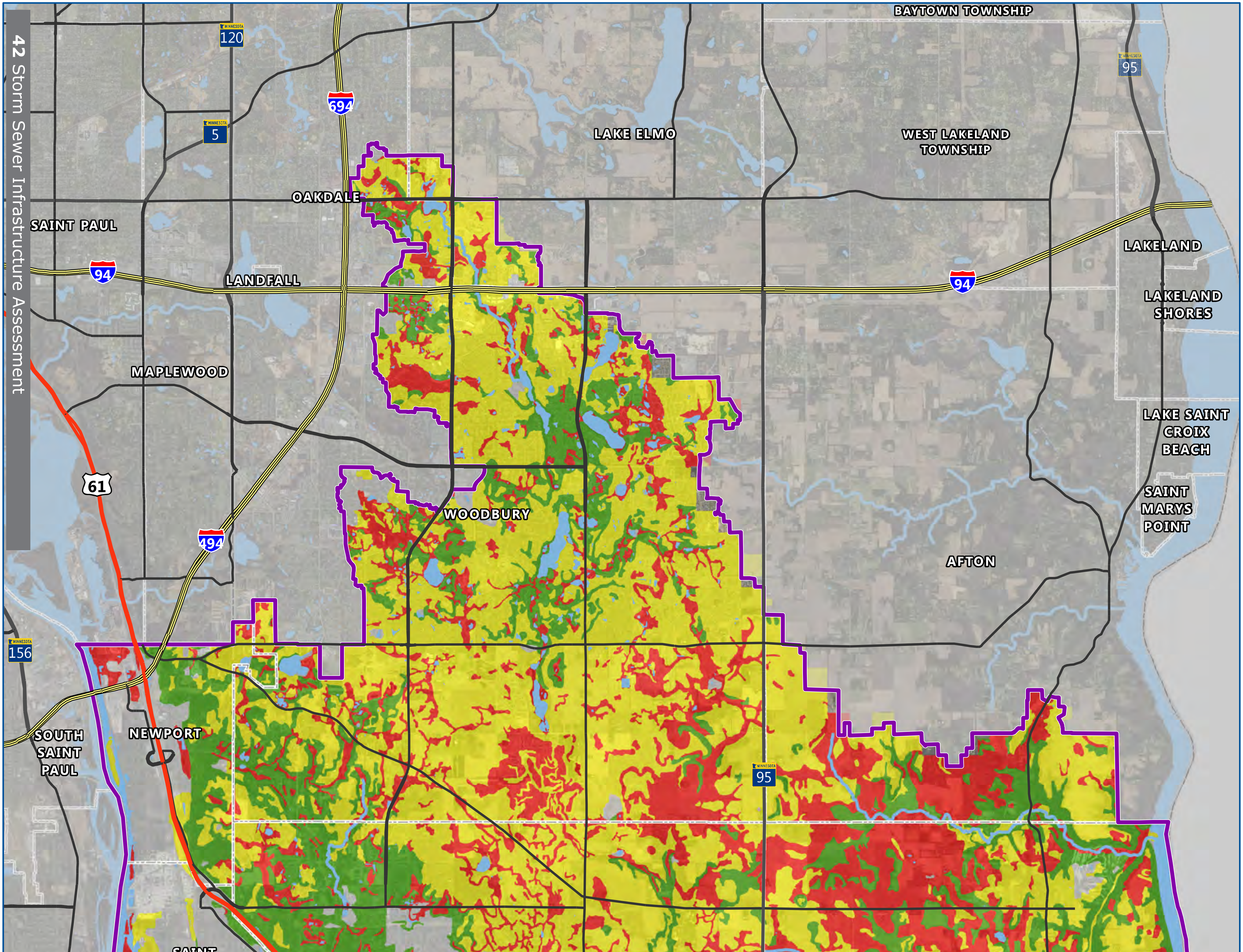
Barr Footer: ArcGIS 10.4.1, 2018-03-01 12:47 File: I:\Client\South_Washington_WD\Work_Orders\2017_Climate_Adaptation\Maps\Reports\Final_Report\Figure 4-4 - SWWD Soil Structural Support.mxd User: rcs2





SOIL STRUCTURAL SUPPORT CAPACITY
South Washington Watershed District

FIGURE 4-4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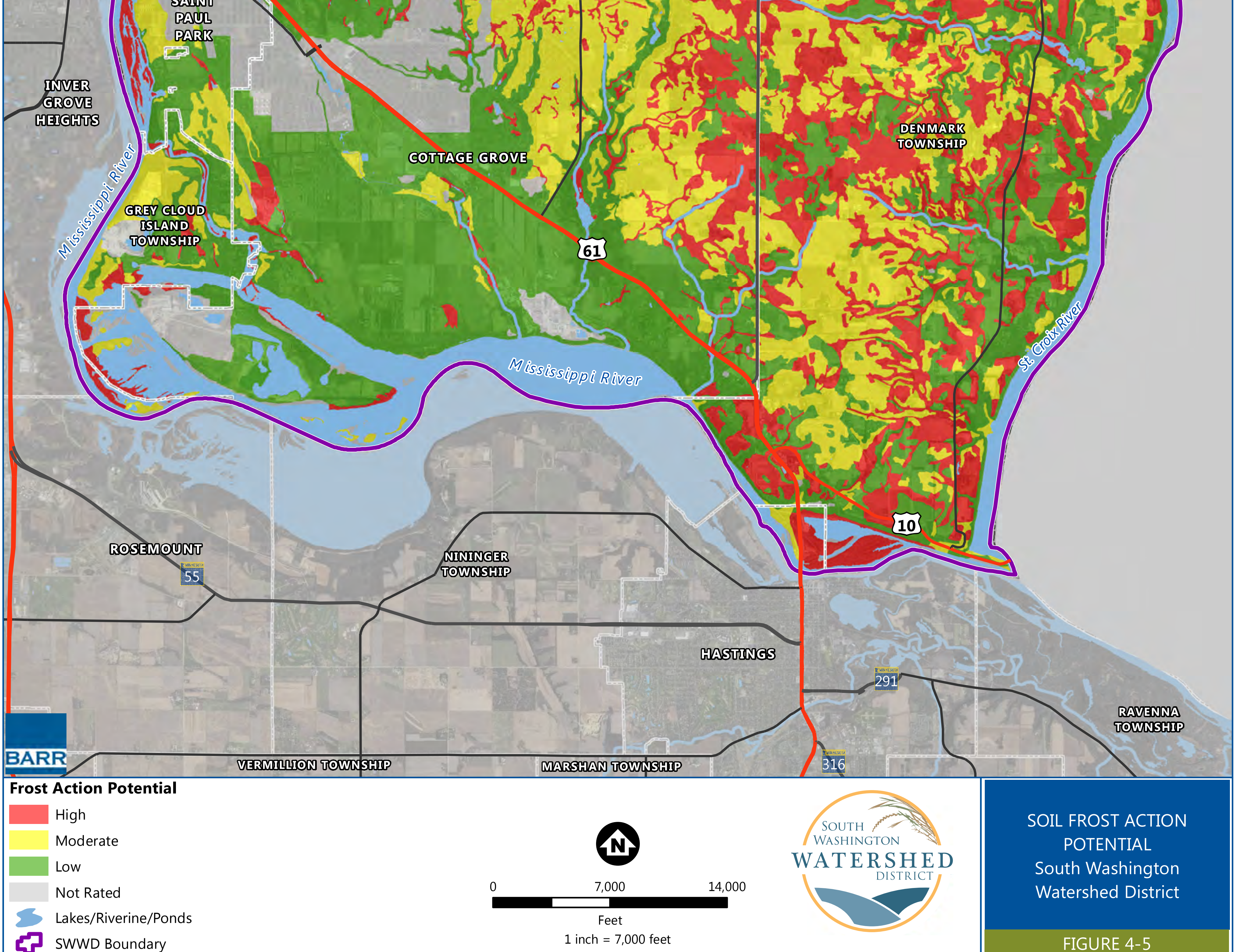
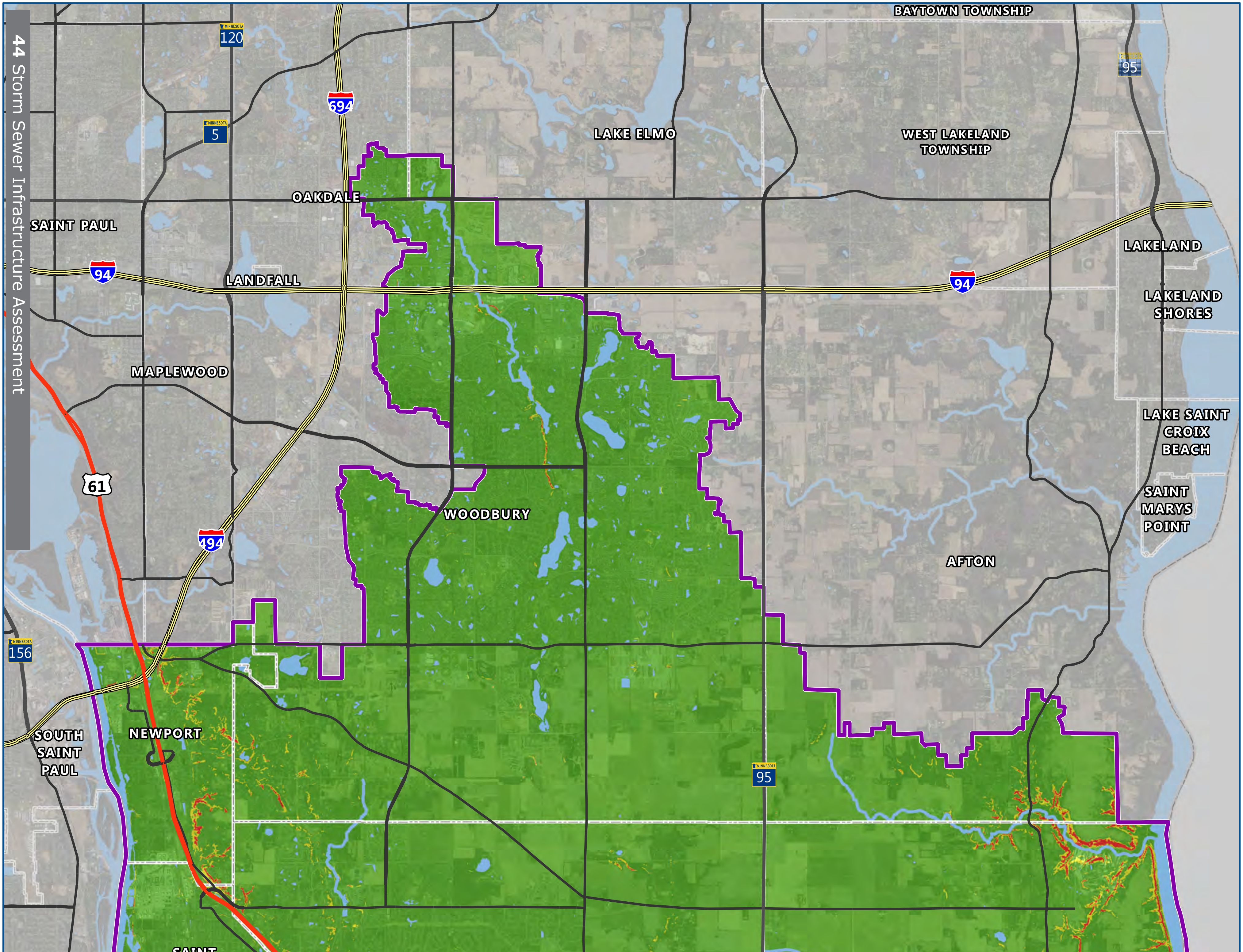


SOIL FROST ACTION POTENTIAL
South Washington Watershed District

FIGURE 4-5



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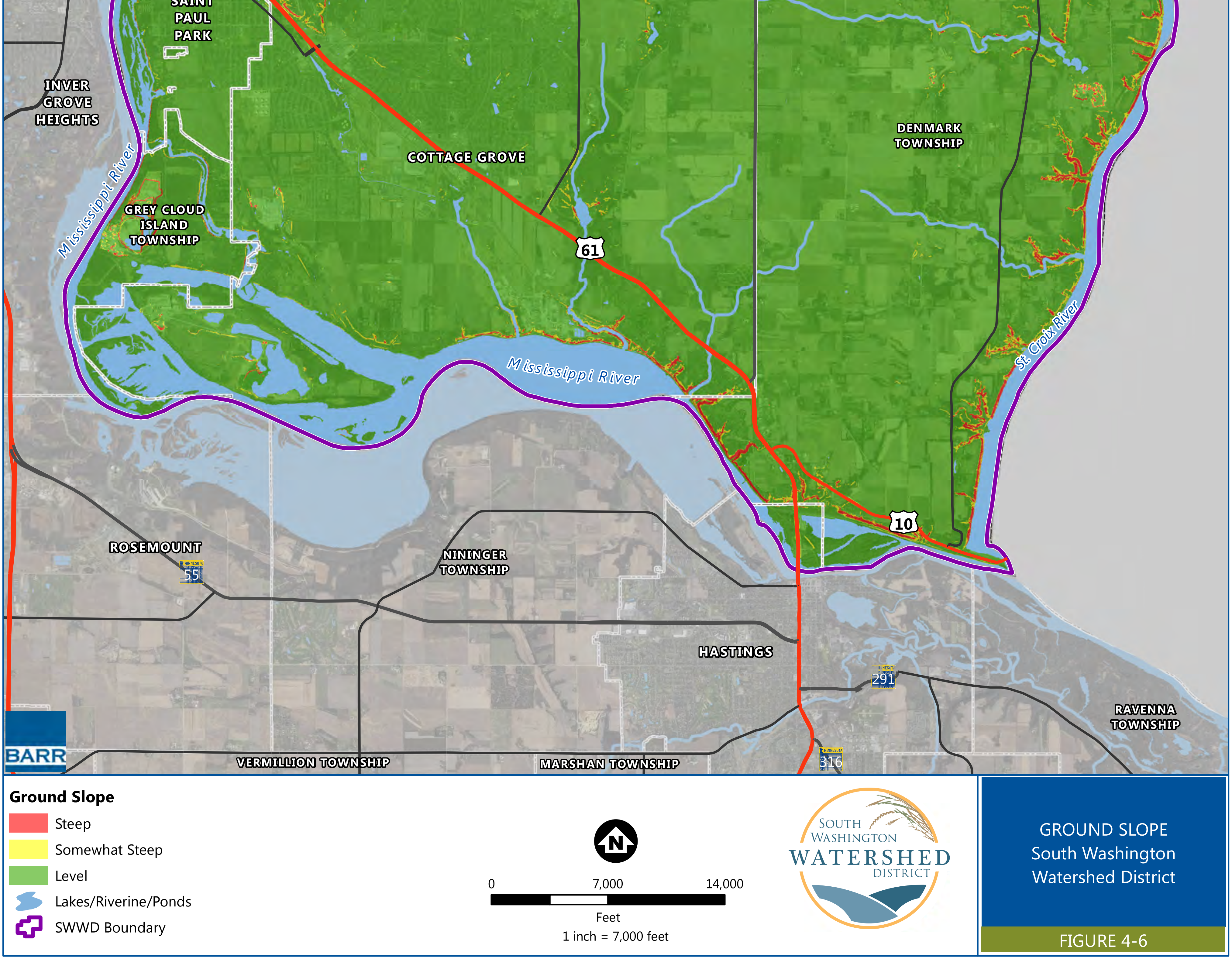
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1 inch = 7,000 feet
SOUTH WASHINGTON WATERSHED DISTRICT
GROUND SLOPE
South Washington Watershed District
FIGURE 4-6

4.3.2 Impacts to Trunk Storm Sewer

Trunk line storm sewer pipes drain water across watershed divides, draining water from one low area to another. A failure of a trunk line storm sewer pipe will likely have greater consequences because it would affect a larger upstream area than a similar-sized pipe that drains a much smaller unponded area. A failure of a trunk line storm sewer pipe can also potentially have a cascading effect. Barr classified storm sewer as trunk system if it drains a major flooding or ponding area (greater than 0.5 acre flooding or ponding) and categorized the pipes as either non-trunk or trunk.

The fraction of pipes within the SWWD that are trunk lines is shown in **Chart 4-10**.

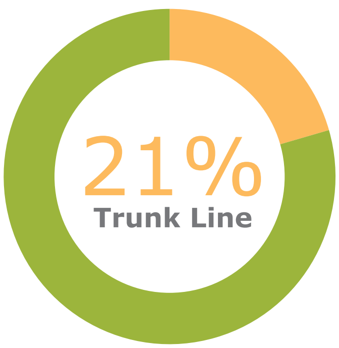


Chart 4-10: *Trunk Storm Sewer Lines*

4.3.3 Impacts to Structures

Failure of storm sewer infrastructure can cause pooling water upstream of the pipe failure and inundate structures (homes, businesses, commercial buildings, public facilities, etc.). For this portion of the study, Barr evaluated flooding of all structures using LiDAR-derived building footprints. These were intersected with potential flooding inundation extents provided by the Metropolitan Council using the emergency surface overflow elevation of each low-lying area.

We classified pipes in one of the following categories based on the number of structures impacted:

- No impact to structures
- Impact to 1 structure
- Impact to 2-5 structures
- Impact to 6-20 structures
- Impact to >20 structures

The fractions of pipes within the SWWD that could inundate the number of structures in these categories are shown in **Chart 4-11**.

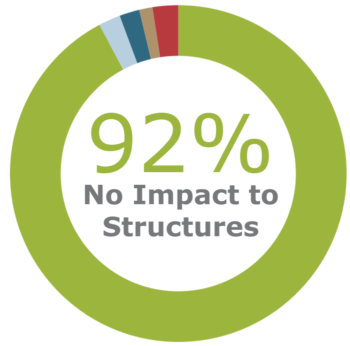


Chart 4-11: *Potential Structure Inundation*

4.3.4 Potential for Slope Failure

Steep ground slopes are more likely to experience mass slope failures and erosion when exposed to ponded or moving water. Therefore, in the event of a storm sewer failure, the consequences are greater in areas with steep ground slopes. Barr used LiDAR data from the state of Minnesota to estimate the local ground slope. Areas within the SWWD were classified in the following categories based on ground surface slope (same as **Section 4.3.5**):

- Mild (less than 3H:1V slope)
- Somewhat steep (3H:1V to 2H:1V)
- Steep (greater than 2H:1V)

Pipes were classified in one of these three categories based on the maximum slope along the pipe segment. Slopes greater than 3H:1V within the SWWD are shown in **Chart 4-6**. The majority of the pipes in the SWWD are placed on level grades (less than 3H:1V slope), as shown in **Chart 4-7**.

4.4 Combined Risk (Likelihood of Failure x Consequences of Failure)

The combined failure risk of a particular pipe is calculated by multiplying the “likelihood of failure” value by the “consequence of failure” value.

The distributions of “likelihood of failure,” “consequences of failure,” and combined risk scores are presented in **Charts 4-12 through 4-14**. Each figure also denotes what percentage of the pipes within the District fall within the highest score range (before the first major “breakpoint” in the data using a statistical method called Jenks natural breaks). For example, **Chart 4- 13** shows that after the first 6.9% of pipes, the consequence of failure score drops to a point where the scores largely flatten out (i.e., a large percentage of the pipes in the District have a similar magnitude for consequence of failure score). The likelihood of failure scores, consequence of failure scores, and combined risk scores are comparative only within their respective distributions. The scores do not reflect the absolute probability (i.e., an X-percent chance) of pipe failure or consequences. **Figures 4-7 through 4-9** show the geospatial distribution of all pipes and their respective score category of "likelihood of failure," "consequences of failure," and combined risk.

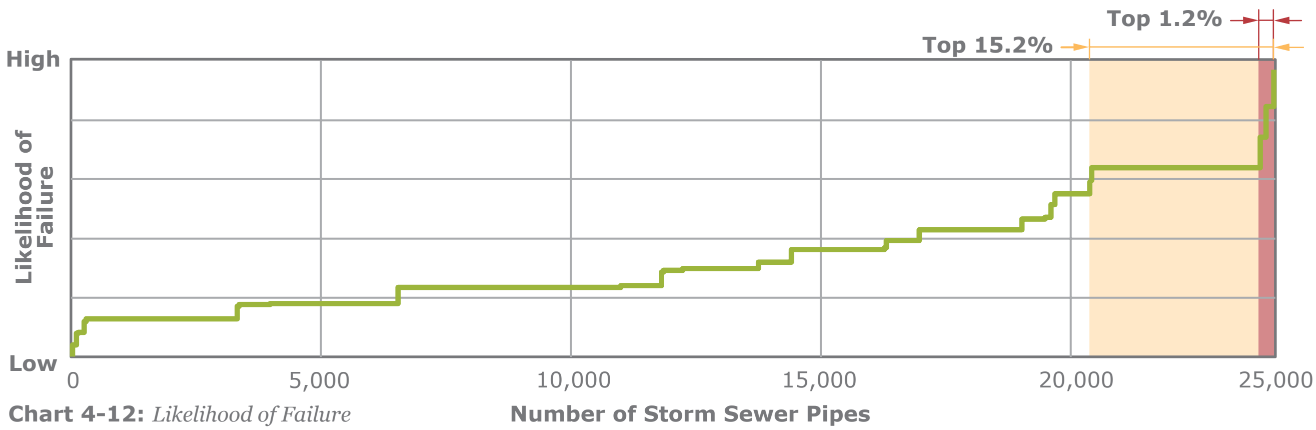


Chart 4-12: *Likelihood of Failure*

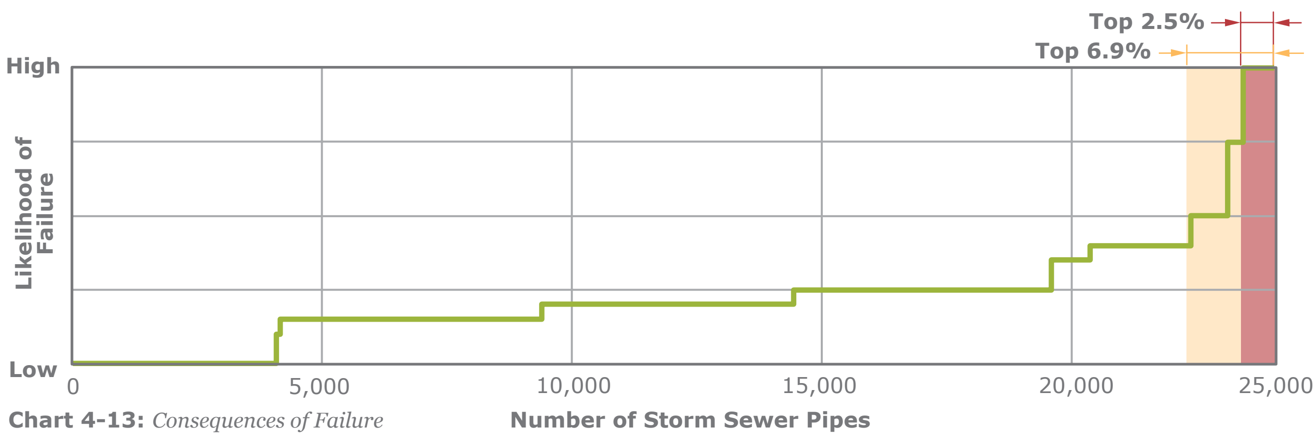


Chart 4-13: *Consequences of Failure*

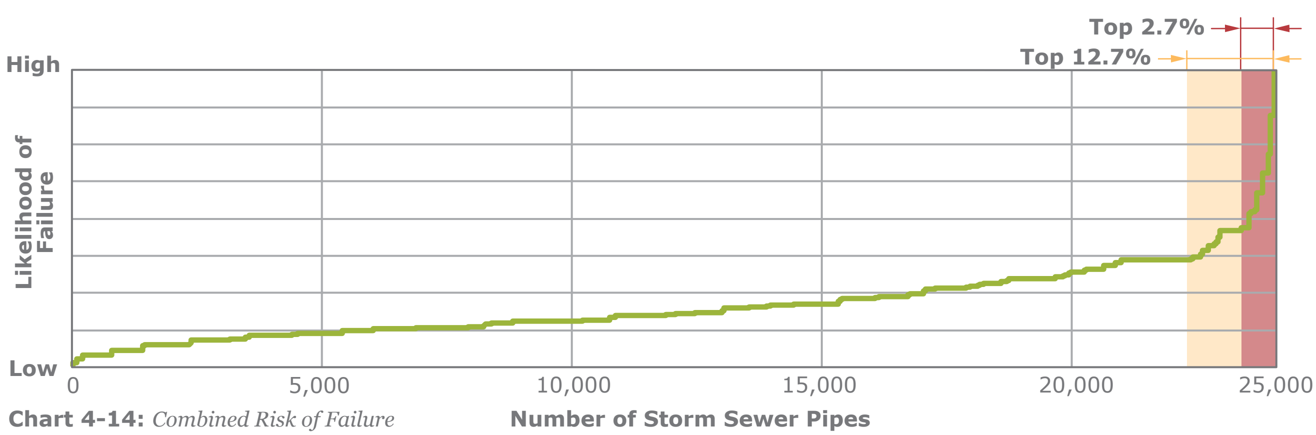
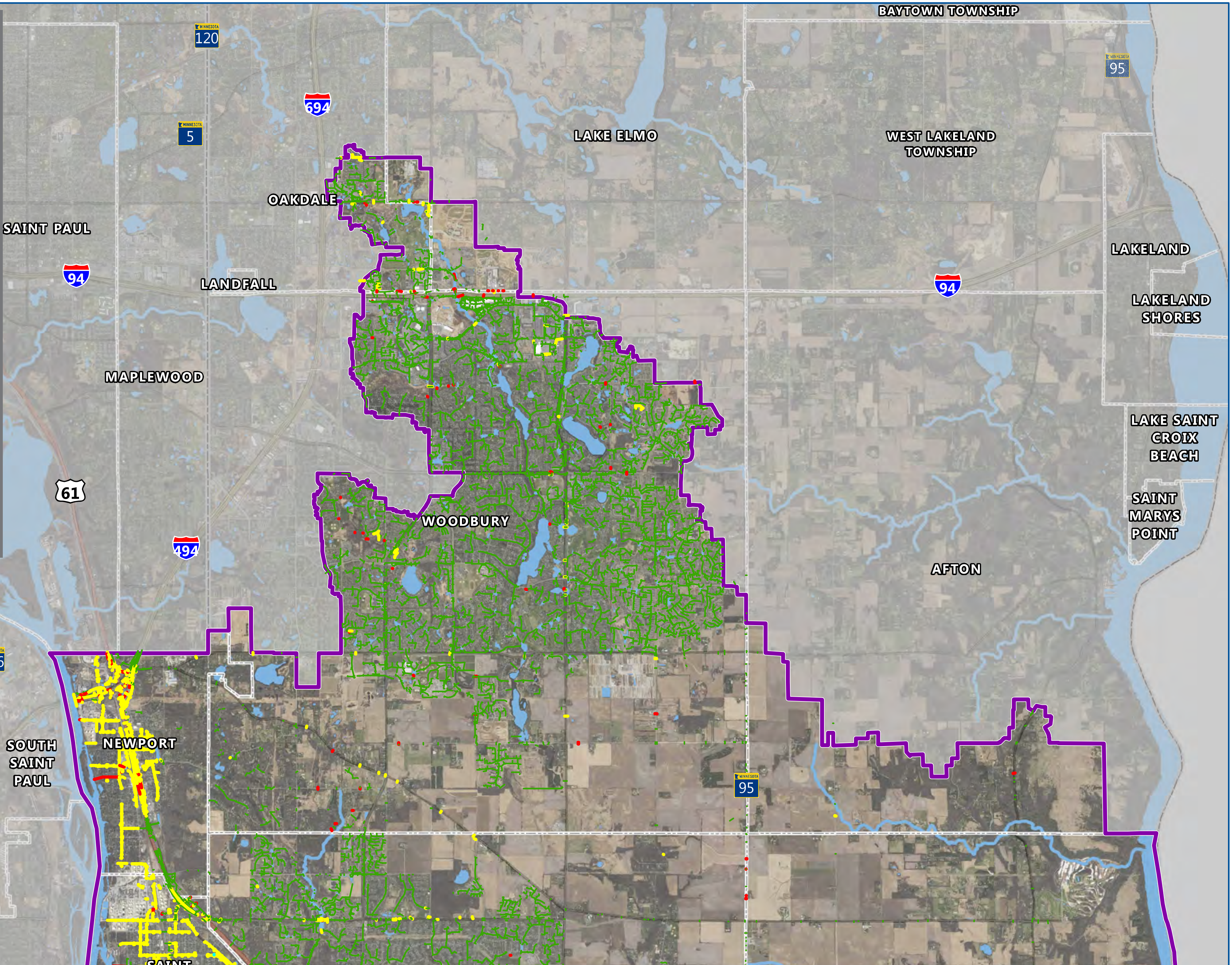


Chart 4-14: *Combined Risk of Failure*



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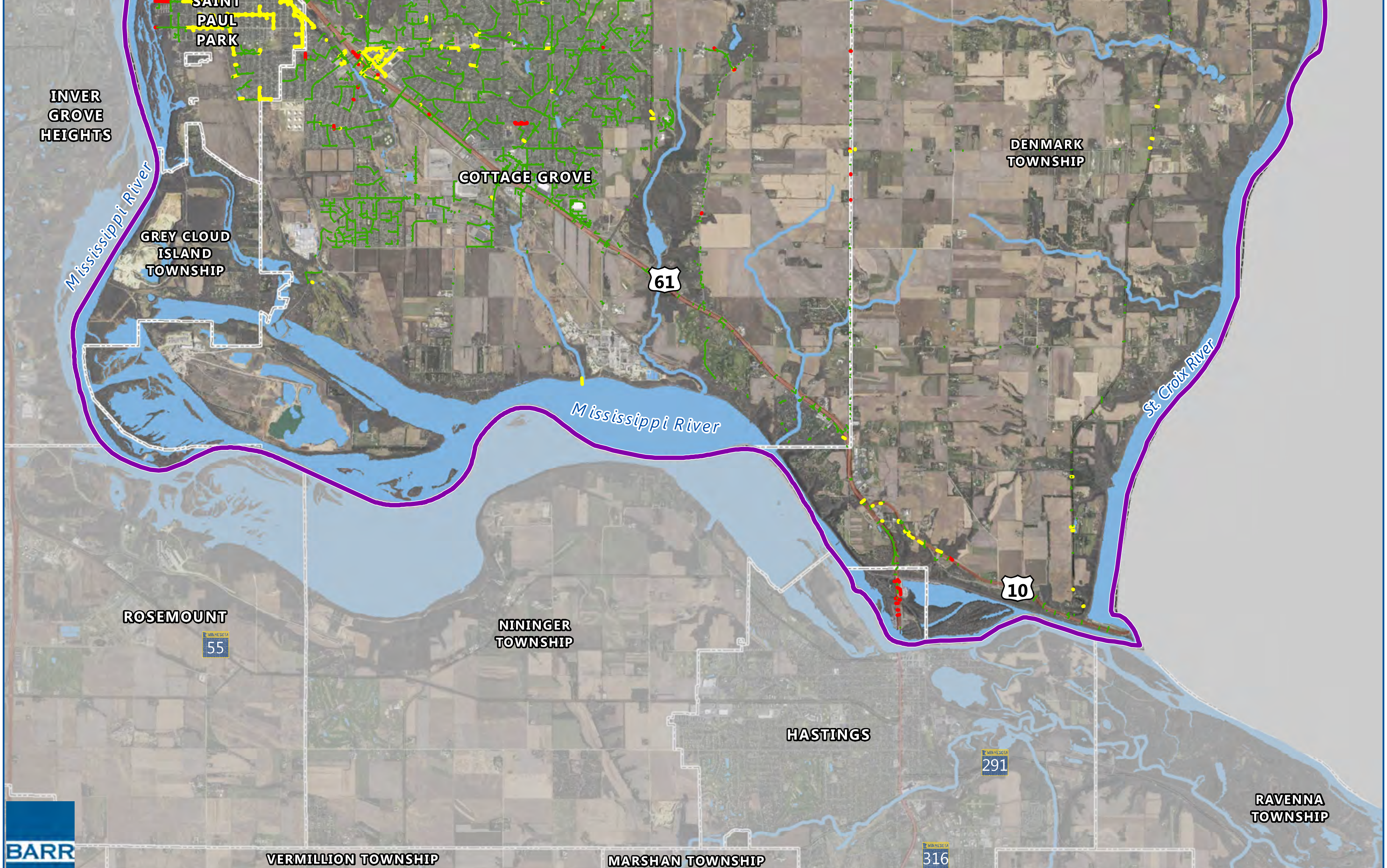

Storm Sewer Pipes Likelihood of Failure

- Top 1.2%
- Top 15.2%
- Other
- Lakes/Riverine/Ponds
- SWWD Boundary

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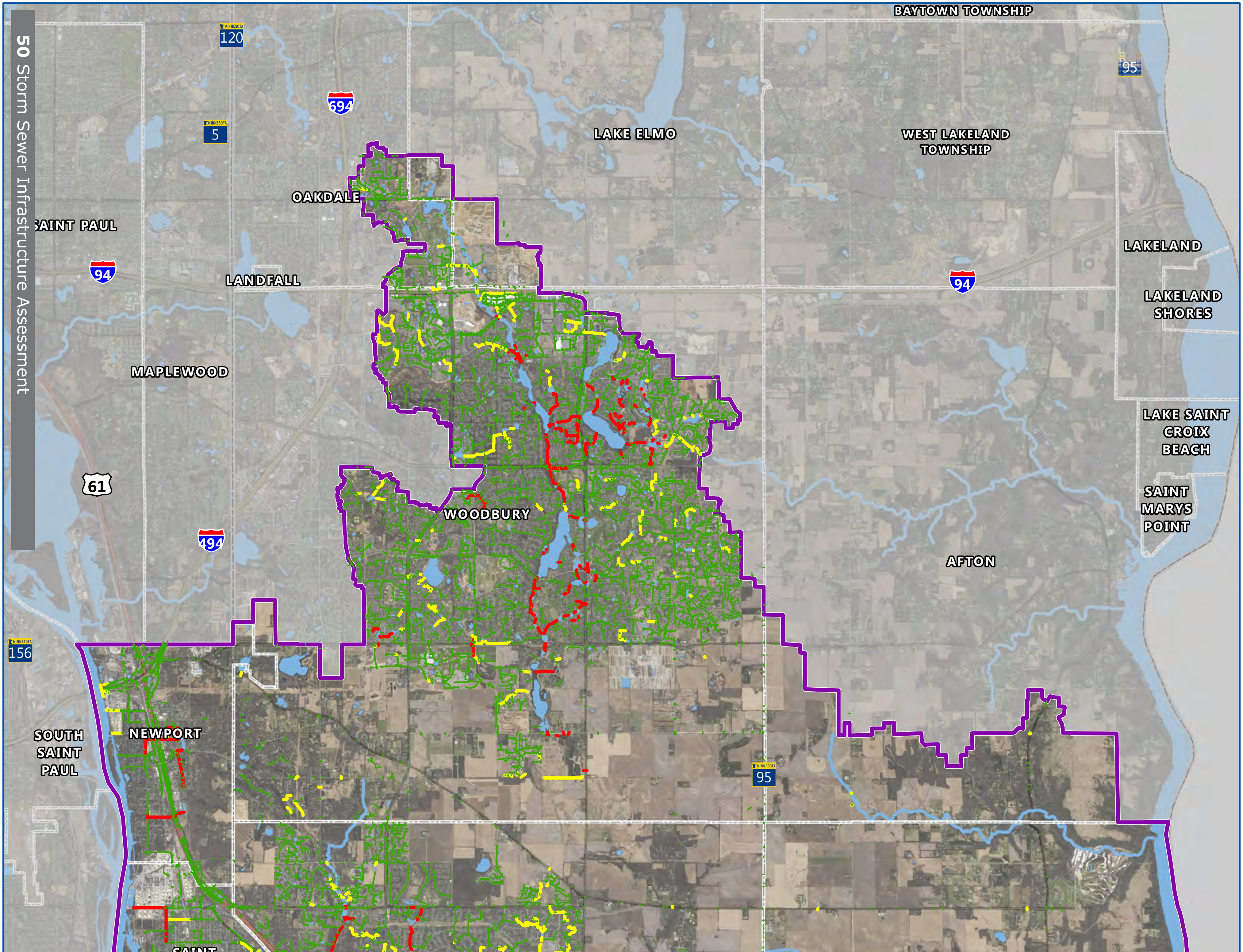
Feet
1 inch = 7,000 feet

STORM SEWER PIPES LIKELIHOOD OF FAILURE
South Washington Watershed District

FIGURE 4-7



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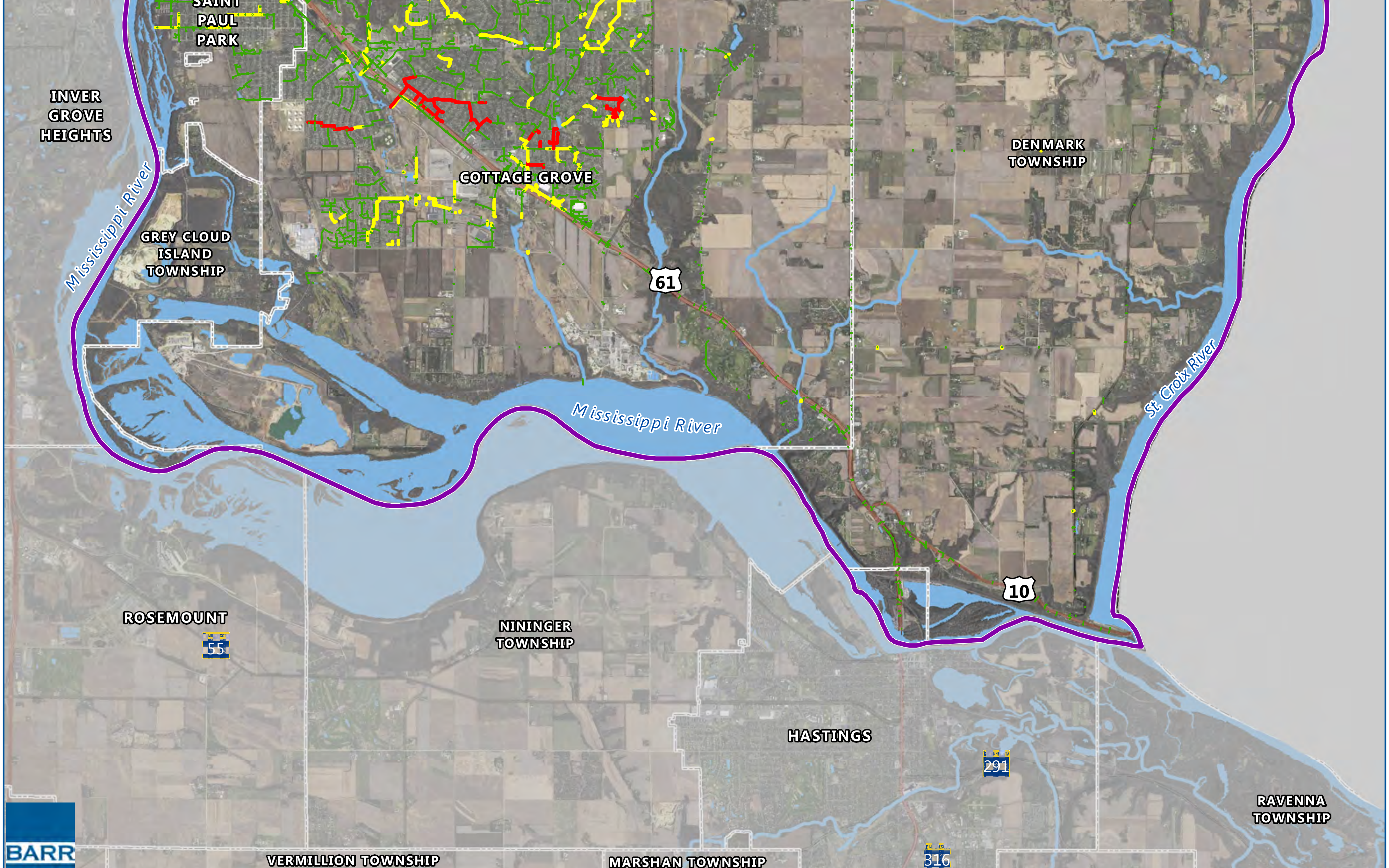


Storm Sewer Pipes Consequences of Failure

- Top 2.5%
- Top 6.9%
- Other
- Lakes/Riverine/Ponds
- SWWD Boundary

0 7,000 14,000

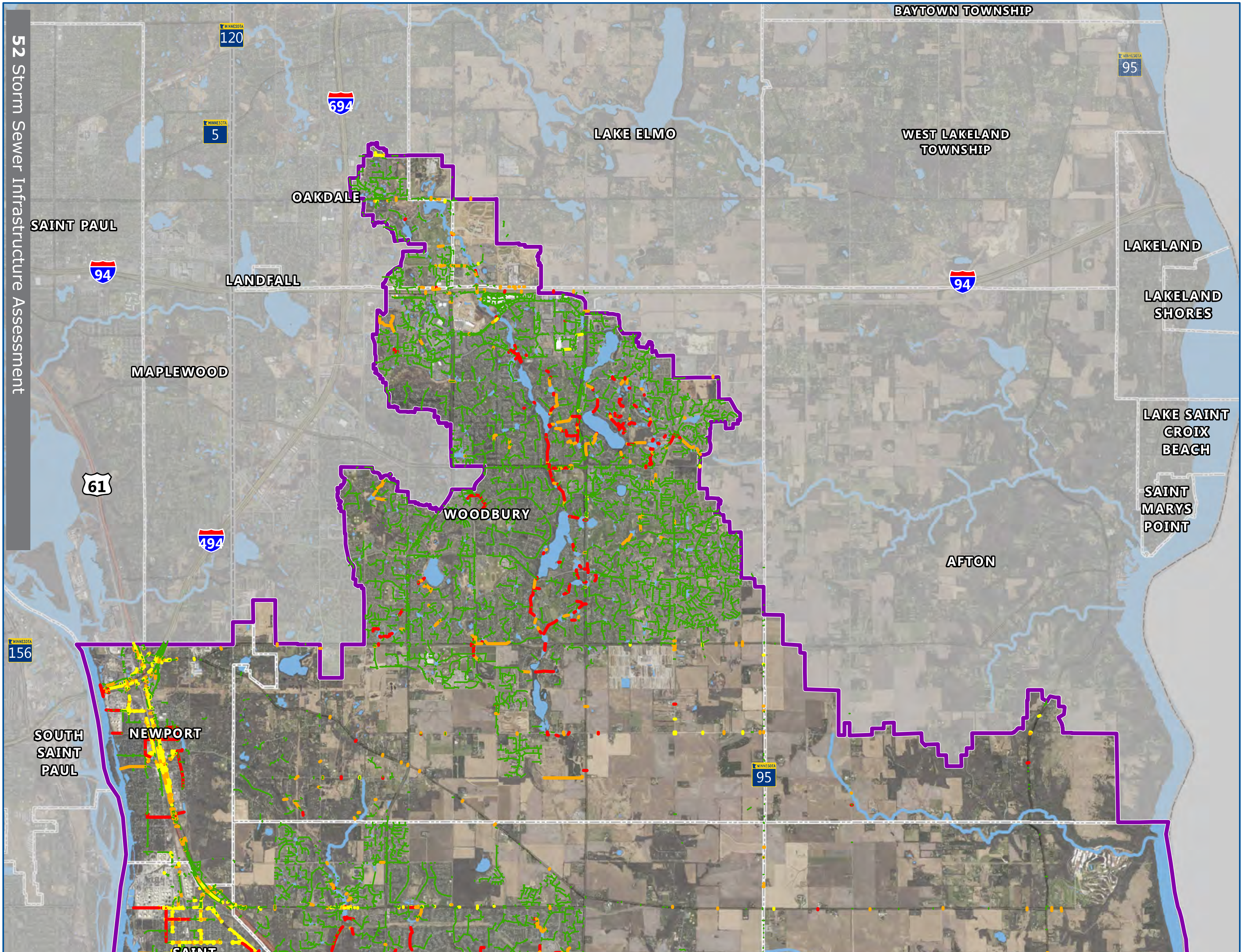
Feet

1 inch = 7,000 feet

SOUTH WASHINGTON WATERSHED DISTRICT

STORM SEWER PIPES CONSEQUENCES OF FAILURE
South Washington Watershed District

FIGURE 4-8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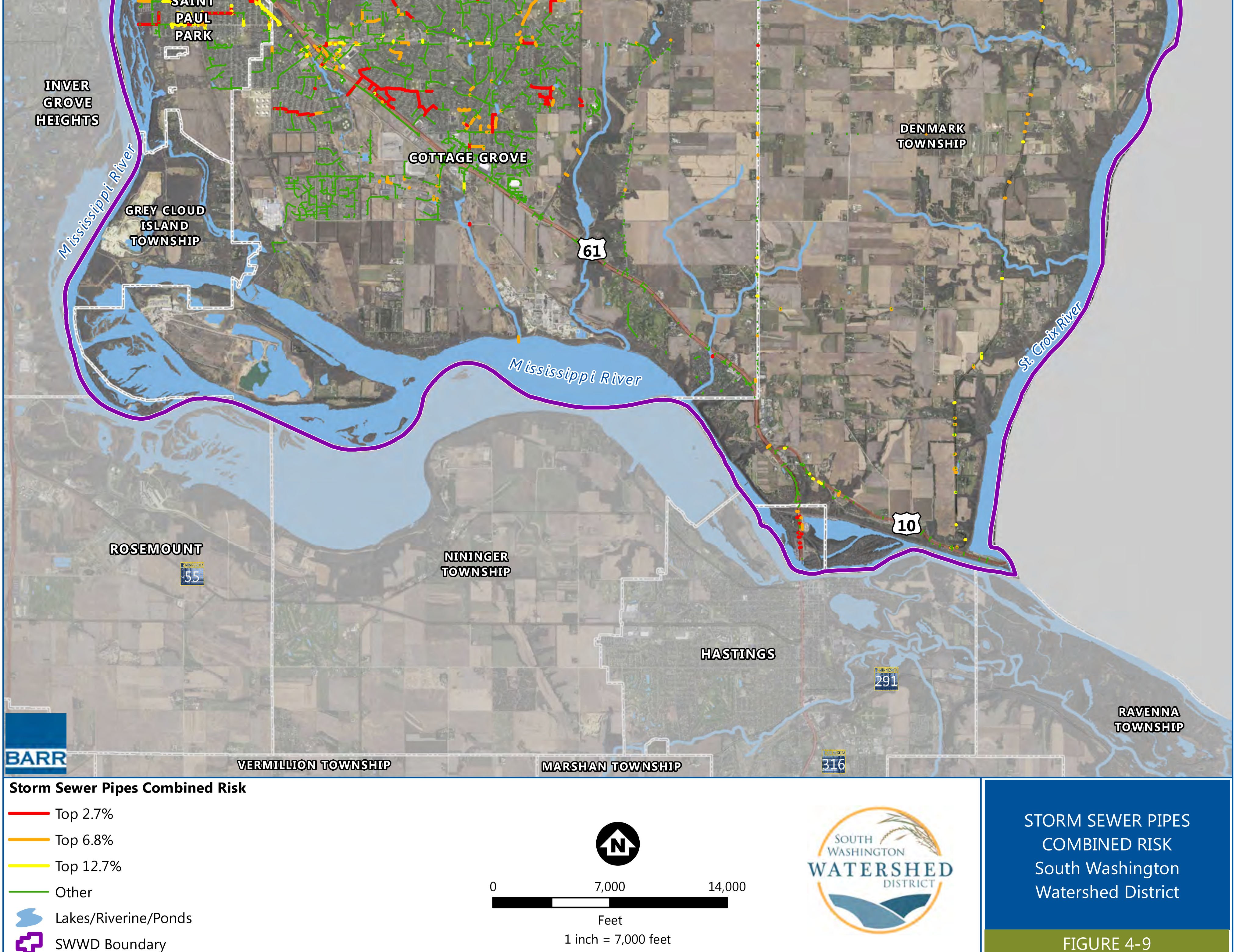

STORM SEWER PIPES COMBINED RISK
South Washington Watershed District

FIGURE 4-9

4.5 Recommendations

The GIS-based storm sewer risk analysis provides a relative estimate of the likelihood and consequences of pipe failure and assigns a combined risk score. This method is useful for comparative analysis, but does not provide an absolute risk for any pipe or predict future failure.

We recommend the following:

- The SWWD share the findings of this failure risk assessment with the owners of the pipes and stakeholders.
- The SWWD and other pipe owners perform pipe inspection, maintenance, and replacement using the results of this risk analysis along with other available data, prioritizing the pipes with the highest risk.
- Over the next 5 years, the SWWD and the other pipe owners continue to gather the missing pipe and soils attribute data and populate their GIS databases with gathered information, ultimately incorporating the additional information into this risk analysis. To provide a more complete analysis, we recommend the following pieces of information be collected:
    - Pipe age
    - Pipe material
    - Pipe inspection reports
    - Pipe inverts and slope
    - Record of pipe failures
    - District-wide flooding analysis and inundation mapping for precipitation events based on climate-change projections (larger than existing Atlas 14 100-year flooding)
    - Soils data for unmapped areas of the District (western portion) to determine pipe corrosion potential, soil structural support capacity, and frost action potential

5

Implementation

This SWWD climate-resilience plan identifies a range of specific strategies to address risks to groundwater, natural resources, and stormwater infrastructure. This plan is an outcome of the District's October 2016 Watershed Management Plan and the SWWD's collaboration with its member communities and stakeholders, who identified resources at-risk from climate change and high-level strategies to reduce climate risk (**Appendix A**).

The SWWD and its member communities, partners, and stakeholders are already implementing many of the climate-risk-reduction strategies identified in this report. Other strategies will require that existing programs be expanded or revised. Given the complexity of addressing climate risk and the District's limited role within the broader range of climate hazards, the District will need to work closely with its partners to implement the strategies identified in this report.

To promote climate resilience and adaptation, Barr recommends that the District take these steps in implementing the recommendations in this report:

- Adopt this plan as Guidance Document to the District's Watershed Management Plan.
- Share this report with the District's member communities and all stakeholders who participated in the September 2017 workshops.
- Collaborate with member communities, partners, and stakeholders to implement the groundwater and natural resources recommendations provided in **Tables 2-1**, **3-1**.
- Utilize existing District planning capacity to advance Emergency Response planning.
- Expand existing SWWD Cost Share Incentive Program to incentivize private efforts in turf reduction and tree preservation, and improvements in irrigation and de-icing operations.
- Work with storm sewer infrastructure owners to address the recommendations listed in **Section 4**. Specifically, expand and grow existing SWWD Coordinated Capital Improvement Program (CCIP) to incentivize infrastructure improvements that increase climate resiliency.

Our climate is changing, and District citizens and resources are experiencing the effects of that change. Addressing climate risk is fully within the SWWD's mission of managing "the water and related resources of the District," and the SWWD is fully committed to collaborating with its partners and stakeholders to develop holistic climate-risk-reduction solutions.

6

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Appendix

SOUTH WASHINGTON WATERSHED DISTRICT

CITY OF COTTAGE GROVE

CITIES OF NEWPORT & ST. PAUL PARK

WASHINGTON COUNTY

WASHINGTON COUNTY STAKEHOLDERS

CITY OF WOODBURY

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SOUTH WASHINGTON WATERSHED DISTRICT
ADDRESSING RISK THROUGH RESILIENCY

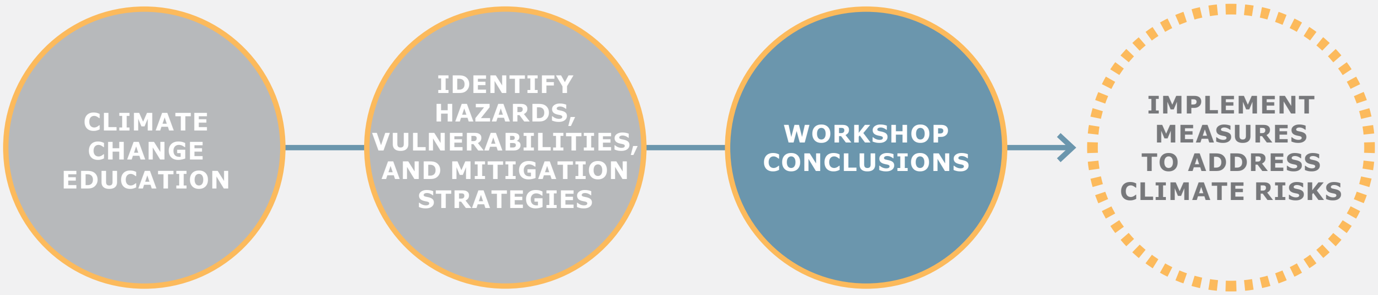
South Washington WATERSHED DISTRICT

PLANNING FOR MINNESOTA'S CHANGING CLIMATE

South Washington Watershed District (SWWD) hosted a series of workshops for their member communities and stakeholders to identify risks related to our changing climate and generated strategies to develop resilience. Whether resulting from larger and more intense rainfall events, rising nighttime temperatures, or warming winters, climate change and its associated hazards will lead to consequences that Minnesota and Washington County need to proactively address. Workshop attendees identified strengths and vulnerabilities as well as strategies to address risks related to climate change. SWWD will use the workshop outcomes to develop implementation measures for addressing climate risk in their capital improvement plans.

THE PROCESS

The resilience workshops helped participants identify climate hazards, community vulnerabilities, strengths, and strategies to mitigate risks to community related to climate change.



EVENT PARTICIPANTS

Over 60 people from around Washington County participated in the 2-day workshop series in September 2017. Participants included officials from the cities of Cottage Grove, Newport, Oakdale, St. Paul Park, and Woodbury as well as representatives from the SWWD and several adjacent watershed organizations, Washington County, state agencies, and the public.

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EXTREME RAINFALL

All parts of Minnesota are experiencing increasing frequency of extreme "mega" rainfall events, such as the 2012 Duluth rainstorm that caused massive flooding and infrastructure damage. The long-term trend in Minnesota is for greater annual precipitation, which is of particular concern for landlocked areas of Washington County.

WARMER WINTER

State climatologists have observed that the largest increase in temperatures is in the winter at night. The lack of extreme cold reduces some traditional winter recreation activities, requires changes in the management of our roads, and allows the survival of invasive species that couldn't previously flourish in Minnesota.

STRENGTHS, VULNERABILITIES,

Participants of the workshops focused on three primary sectors of their community and impacts from the hazards associated with a changing climate:

1. INFRASTRUCTURE
2. SOCIETAL
3. NATURAL RESOURCES

1 INFRASTRUCTURE

Protecting critical infrastructure, including Woodwinds Hospital, from mega rainfall events is a primary concern in SWWD. Concerns also include protecting sites along the rivers at risk from riverine flooding, particularly industrial sites.

WORKSHOP RECOMMENDATIONS

- **Develop emergency flood response plans:** Work with county and local partners to develop emergency flood response plans and communicate them to residents and stakeholders.
- **Build resilient stormwater infrastructure:** Work with local partners to inspect, repair, and increase the storage and conveyance capacities of SWWD's stormwater infrastructure to reduce flood risk.
- **Mitigate flood impacts:** Improve flood protection of properties and structures (e.g., flood-proofing).
- **Continue to promote reductions in impervious cover and increased infiltration:** Promote policies that reduce impervious cover, build soil health, increase tree canopy and interception, and encourage infiltration to reduce stormwater runoff and flooding.

WATERSHED DISTRICT'S

te Hazards

RISING TEMPERATURES

Washington County is experiencing pressures from increasing temperatures as well as increased heat from urban heat island effect, which can harm vulnerable populations such as the elderly as well as sensitive natural resources like trout streams.

EXTREME WIND

While the climate science is not clear on whether extreme wind will increase due to climate change, Washington County is already experiencing the impacts of extreme wind on infrastructure and urban tree canopy. Increasing urbanization of the county increases the exposure to this hazard.

AND MITIGATION STRATEGIES

2 SOCIETAL

Primary societal concerns for the people living and working in the SWWD include impacts to vulnerable populations such as the elderly or isolated and economically disadvantaged communities during emergencies. An ongoing concern is protecting groundwater sources and potable water supply. Also of concern are maintaining access to outdoor recreation with the dual challenges of a reduction in winter recreation and increased risk of mosquito- and tick-borne diseases.

WORKSHOP RECOMMENDATIONS

- **Communicate emergency plans to at-risk populations:** Work with local partners (e.g., communities and non-governmental organizations) to identify vulnerable populations, such as the elderly or isolated manufactured home parks, and communicate flood risk and emergency and evacuation plans.
- **Promote groundwater protection and reduce potable water usage:** Explore alternative sources of water supply, including stormwater reuse for irrigation. Work with partners to promote water conservation through reductions in turf grass and irrigation. Improve groundwater protection through education and adherence to the nitrogen management plan. Work with partners to develop a source water emergency plan to respond to groundwater contamination and ensure safe drinking water access.
- **Educate public about risk of vector borne diseases:** Work with local partners such as communities, schools, and parks organizations to educate the public about the increased risk of vector borne diseases and steps residents can take to mitigate that risk.

3 NATURAL RESOURCES

Threats to surface water quality from runoff pollution, including chlorides in Powers Lake and temperature impacts in Trout Brook, are primary concerns to natural resources from climate change. Concerns also include eroding ravines in the bluff lands along both major rivers and invasive species, both terrestrial and aquatic.

WORKSHOP RECOMMENDATIONS

- **Reduce chloride loading:** Work with local partners such as parking lot managers, communities, the county, and the Minnesota Department of Transportation to reduce chloride application.
- **Identify and stabilize eroding ravines:** In the bluff lands along the Mississippi and St. Croix Rivers, perform ravine inventories to identify and prioritize eroding ravines at risk from larger precipitation events.
- **Implement resilient plant palette:** Identify species of plants that are better suited for our changing climate and use in restorations and capital projects.
- **Proactively manage invasives:** Pilot innovative invasive species management techniques using biocontrols. Work with local partners on more aggressive management and removal of invasive species, focusing on new and emerging invasive species.

SWWD'S TOP CONCERNS AND PRIORITIES

PLANNING FOR A RESILIENT TOMORROW

SWWD is in the planning process to mitigate risks from and adapt to Minnesota's changing climate. SWWD is working closely with their member communities and stakeholders to identify and implement strategies to develop resilience in the face of increased risk from climate hazards including extreme rainfall, warmer winters, rising temperatures, and extreme wind. SWWD is making investments through the capital planning processes to implement projects to reduce community risk and develop resilience.

South Washington Watershed District

www.swwdmn.org

South Washington
Watershed District Office
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Woodbury, MN 55125
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SOUTH WASHINGTON WATERSHED DISTRICT
ADDRESSING RISK THROUGH RESILIENCY

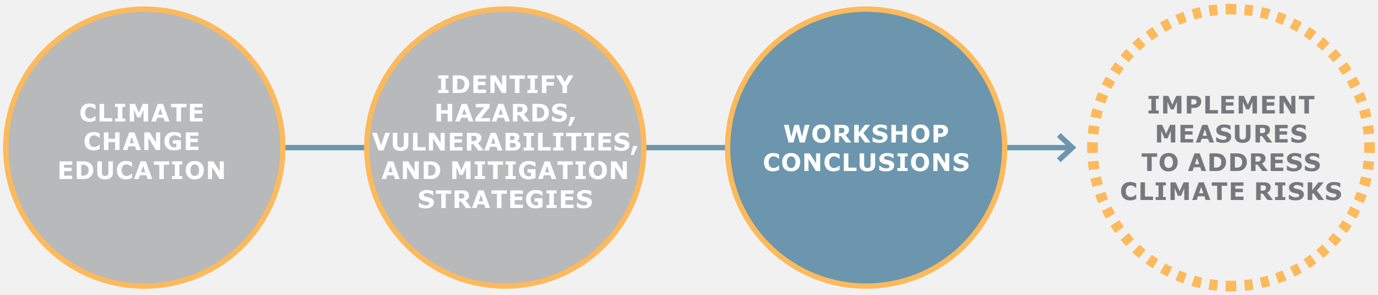
CITY OF COTTAGE GROVE

PLANNING FOR MINNESOTA'S CHANGING CLIMATE

The City of Cottage Grove participated in a series of workshops hosted by South Washington Watershed District (SWWD) to identify risks related to our changing climate and generated strategies to develop resilience. Whether resulting from larger and more intense rainfall events, rising nighttime temperatures, or warming winters, climate change and its associated hazards will lead to consequences that Minnesota and Cottage Grove need to proactively address. Workshop attendees identified strengths and vulnerabilities as well as strategies to address risks related to climate change. Cottage Grove will use the workshop outcomes to develop implementation measures for addressing climate risk in their capital improvement plans.

THE PROCESS

The resilience workshops helped participants identify climate hazards, community vulnerabilities, strengths, and strategies to mitigate risks to community related to climate change.



EVENT PARTICIPANTS

Over 60 people from around Washington County participated in the 2-day workshop series in September 2017. Participants included officials from the cities of Cottage Grove, Newport, Oakdale, St. Paul Park, and Woodbury as well as representatives from the SWWD and several adjacent watershed organizations, Washington County, state agencies, and the public.

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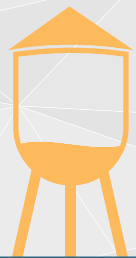
EXTREME RAINFALL

All parts of Minnesota are experiencing increasing frequency of extreme "mega" rainfall events, such as the 2012 Duluth rainstorm that caused massive flooding and infrastructure damage. The long-term trend in Minnesota is for greater annual precipitation, which is of particular concern for landlocked areas of Cottage Grove.

DROUGHT



Climatologists point out that within Minnesota's normal range of weather extremes is the drought of the dust bowl days in the 1930s. Although there is no recent trend for drought, Cottage Grove can expect drought to occur again. Long-term predictions of greater than ten years show an increased likelihood of drought.

STRENGTHS, VULNERABILITIES,

Participants of the workshops focused on three primary sectors of their community and impacts from the hazards associated with a changing climate:

1 INFRASTRUCTURE
2 SOCIETAL
3 NATURAL RESOURCES

1 INFRASTRUCTURE

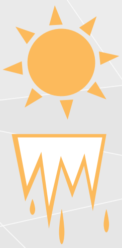
Protecting critical infrastructure, such as sanitary lift stations, pipelines, emergency response facilities, and major employers, from flooding and extreme events is a primary concern for Cottage Grove. Concerns also include icy and dangerous driving conditions on local roads, including Highway 61.

WORKSHOP RECOMMENDATIONS

- Coordinate emergency response plans: Work with local partners, including major employers (e.g., St. Paul Park Refinery, 3M), schools, railroads, and county, to review, coordinate, and communicate existing emergency response plans to identify gaps and redundancies in each entity's response plan.
- Provide backup power at critical locations: Because the facilities that are needed to provide resilience during flooding and other extreme events are vulnerable to power outages that accompany those events, upgrade aging technology and implement backup power at critical facilities, such as lift stations, senior housing, schools, fire stations, and city hall.
- Improve stormwater infrastructure to reduce flooding and icy roads: Develop 100-year flood mapping for the City to identify flood-prone infrastructure and buildings. Work with partners, such as Minnesota Department of Transportation, to improve storm sewer systems to reduce flooding, including localized flooding on Highway 61 that creates icy and dangerous driving conditions.

OTTAGE GROVE'S

te Hazards



WARMER WINTER

State climatologists have observed that the largest increase in temperatures is in the winter at night. The lack of extreme cold reduces some traditional winter recreation activities, requires changes in the management of our roads, and allows the survival of invasive species that couldn't previously flourish in Minnesota.

SEVERE WEATHER

While the climate science is not clear on whether severe weather will increase due to climate change, Cottage Grove is already experiencing the impacts of severe weather on infrastructure and urban tree canopy. Increasing urbanization of the county increases the exposure to this hazard.

AND MITIGATION STRATEGIES

2 SOCIETAL

Primary societal concerns for the people living and working in Cottage Grove include impacts to vulnerable populations such as the elderly or isolated and economically disadvantaged communities during emergencies. An ongoing concern is protecting groundwater sources and potable water supply.

WORKSHOP RECOMMENDATIONS

- **Communicate emergency plans to at-risk populations:** Work with local partners and non-governmental organizations such as churches and volunteer groups to communicate flood risk and emergency and evacuation plans to isolated communities, such as the elderly and residents of manufactured home parks. Leverage those local partners during an emergency.
- **Promote groundwater protection and reduce potable water usage:** To improve the resilience of the City's drinking water system, update the water conservation plan. Promote water conservation through education and adjustments to water rates to incentivize lower water usage.
- **Develop emergency response plans for pets:** Coordinate emergency action plans with local pet kennels and the Humane Society to see if those organizations could accommodate more pets during an emergency.

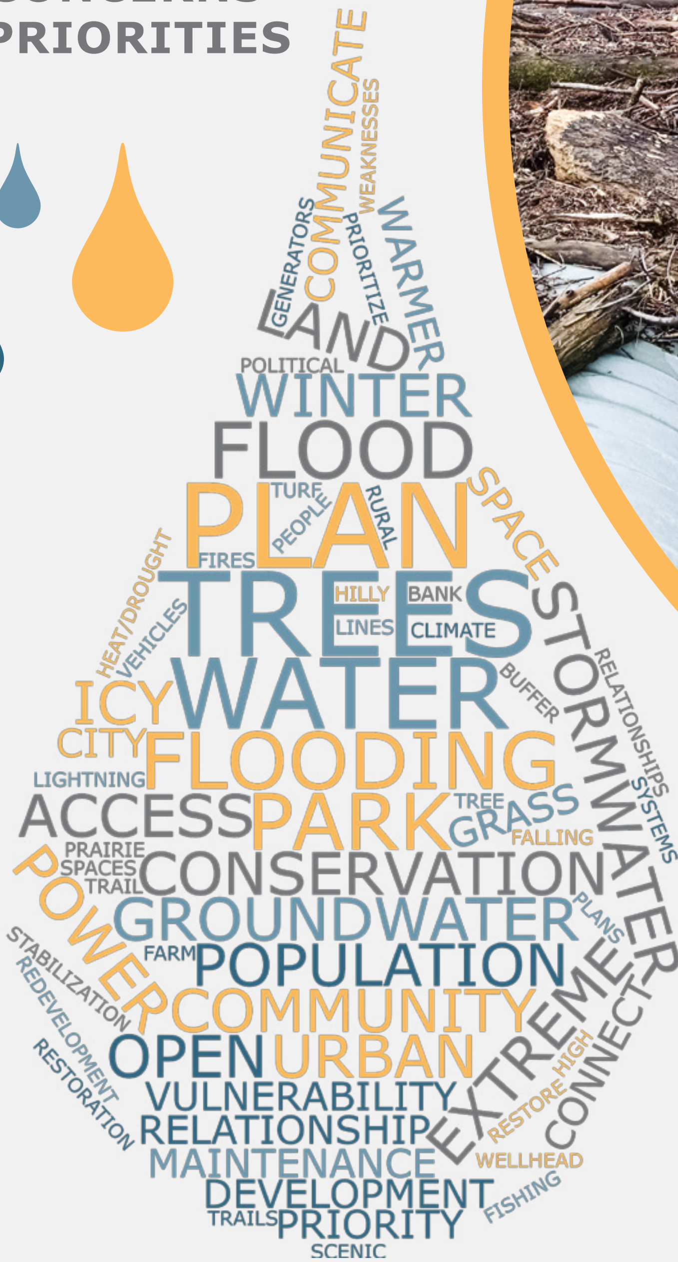
3 NATURAL RESOURCES

Threats to surface water quality from stormwater runoff pollution and a changing climate, including chlorides in wetlands, are primary concerns to natural resources in Cottage Grove. Concerns also include dangers to the health of the urban tree canopy.

WORKSHOP RECOMMENDATIONS

- **Continue to promote stormwater treatment and wetlands protection:** Promote policies that treat stormwater including reducing impervious cover, encouraging infiltration through rain gardens, managing erosion, and improving wetland buffers to protect wetlands and the Mississippi River.
- **Protect and expand the urban forest:** Continue the City's ash tree management program, expand tree planting programs, preserve existing trees, and select tree species for a changing climate.
- **Improve parks and open spaces:** Promote a balance of mowed turf and native grasses in parks, improve access to parks and education to increase community support for parks, and perform a natural resources inventory of open spaces. Partner with local organizations such as Shepherd Farm and the Minnesota Department of Natural Resources scientific research area to connect the community to natural resources.

COTTAGE GROVE'S TOP CONCERNS AND PRIORITIES



PLANNING FOR A RESILIENT TOMORROW

SWWD is in the planning process to mitigate risks from and adapt to Minnesota's changing climate. SWWD is working closely with their member communities, including the City of Cottage Grove, to identify and implement strategies to develop resilience in the face of increased risk from climate hazards including extreme rainfall, warmer winters, rising temperatures, and extreme wind. SWWD is making investments through the capital planning processes to implement projects to reduce community risk and develop resilience.

Cottage Grove

www.cottage-grove.org

South Washington WATERSHED DISTRICT

www.swwdmn.org

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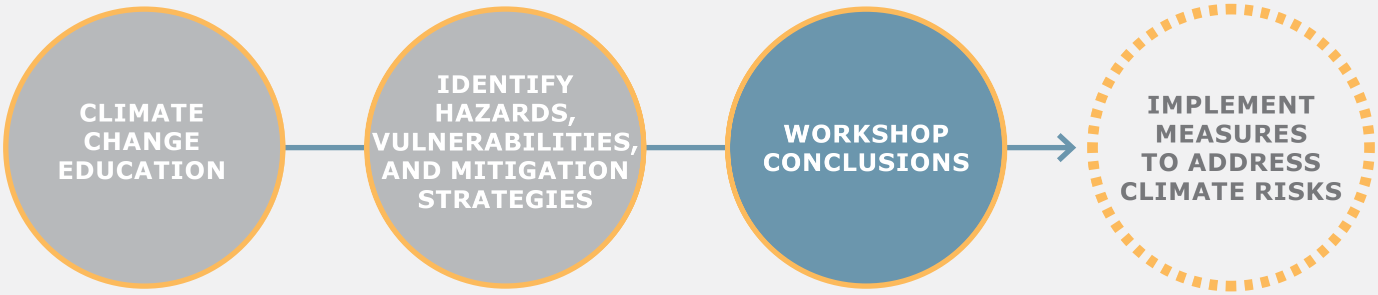
SOUTH WASHINGTON WATERSHED DISTRICT
ADDRESSING RISK THROUGH RESILIENCY
CITIES OF NEWPORT & ST. PAUL PARK

PLANNING FOR MINNESOTA'S CHANGING CLIMATE

The cities of Newport and St. Paul Park participated in a series of workshops hosted by South Washington Watershed District (SWWD) to identify risks related to our changing climate and generated strategies to develop resilience. Whether resulting from larger and more intense rainfall events, rising nighttime temperatures, or warming winters, climate change and its associated hazards will lead to consequences that Minnesota and cities within Washington County need to proactively address. Workshop attendees identified strengths and vulnerabilities as well as strategies to address risks related to climate change. The cities of Newport and St. Paul Park will use the workshop outcomes to develop implementation measures for addressing climate risk in their capital improvement plans.

THE PROCESS

The resilience workshops helped participants identify climate hazards, community vulnerabilities, strengths, and strategies to mitigate risks to community related to climate change.



EVENT PARTICIPANTS

Over 60 people from around Washington County participated in the 2-day workshop series in September 2017. Participants included officials from the cities of Cottage Grove, Newport, Oakdale, St. Paul Park, and Woodbury as well as representatives from the SWWD and several adjacent watershed organizations, Washington County, state agencies, and the public.

THE CITIES OF NEWPO

Top Climat

INCREASED RAINFALL

All parts of Minnesota are experiencing increasing frequency of extreme "mega" rainfall events, such as the 2012 Duluth rainstorm that caused massive flooding and infrastructure damage. The long-term trend in Minnesota is for greater annual precipitation, which is of particular concern for the river communities of of Newport and St. Paul Park.

WARMER WINTER

State climatologists have observed that the largest increase in temperatures is in the winter at night. The lack of extreme cold reduces some traditional winter recreation activities, requires changes in the management of our roads, and allows the survival of invasive species that couldn't previously flourish in Minnesota.

STRENGTHS, VULNERABILITIES,

Participants of the workshops focused on three primary sectors of their community and impacts from the hazards associated with a changing climate:

1 INFRASTRUCTURE
2 SOCIETAL
3 NATURAL RESOURCES

1 INFRASTRUCTURE

Protecting critical infrastructure, such as sanitary lift stations, electrical substations, and homes along the Mississippi River from flooding and extreme events is a primary concern for Newport and St. Paul Park. Concerns also include impacts from ice storms, such as downed power lines.

WORKSHOP RECOMMENDATIONS

- **Provide backup power at critical locations:** Because the facilities that are needed to provide resilience during flooding and other extreme events are vulnerable to power outages that accompany those events, upgrade aging technology and implement backup power at critical facilities, such as lift stations, senior housing, school, fire station, and city hall.
- **Protect homes and infrastructure along the Mississippi River:** Promote flood resilience through buy-outs of flood-prone structures and construction of a FEMA-certified levee.
- **Bury power lines:** To reduce the risk of power interruption during extreme events such as high winds and ice storms, bury power lines, particularly power supply to critical infrastructure.
- **Coordinate emergency response plans:** Work with local partners, including the St. Paul Park Refinery, schools, railroads, and County, to review, coordinate, and communicate existing emergency response plans.
- **Relocate city hall and police station:** Relocate city hall and the police station further away from the railroad in case of a spill or explosion on the railroad. Place new facility in a location with better access to both sides of Highway 61.

ORT & ST. PAUL PARK'S
te Hazards

DROUGHT

Climatologists point out that within Minnesota's normal range of weather extremes is the drought of the dust bowl days in the 1930s. Although there is no recent trend for drought, the cities of Newport and St. Paul Park can expect drought to occur again. Long-term predictions of greater than ten years show an increased likelihood of drought.

EXTREME WIND

While the climate science is not clear on whether extreme wind will increase due to climate change, the cities of Newport and St. Paul Park is already experiencing the impacts of extreme wind on infrastructure and urban tree canopy. Increasing urbanization of the county increases the exposure to this hazard.

AND MITIGATION STRATEGIES

2 SOCIETAL

Primary societal concerns for the people living and working in Newport and St. Paul Park include impacts to vulnerable populations such as the elderly or isolated and economically disadvantaged communities during emergencies. An ongoing concern is protecting groundwater sources and potable water supply.

WORKSHOP RECOMMENDATIONS

- **Communicate emergency plans to at-risk populations:** Work with local partners and non-governmental organizations such as the food shelf and civic groups (e.g., St. Paul Park Athletic Association, Lion's Club, Masons, VFW, Boy Scouts) to communicate flood risk and emergency and evacuation plans to isolated communities, such as the elderly, non-English speaking populations, and transient populations living in short-term housing along Highway 61. Leverage those local partners during an emergency.
- **Promote groundwater protection and reduce potable water usage:** To improve the resilience of the Cities' drinking water systems, update the water conservation plan. Promote water conservation through education and policies to limit irrigation.
- **Develop and promote transit options:** Develop public transit options and improve access to social services such as hospitals and clinics.

3 NATURAL RESOURCES

Threats to the Mississippi River and other natural resources from a changing climate, including chlorides and invasive species are primary concerns to natural resources in Newport and St. Paul Park. Concerns also include dangers to the health of the urban tree canopy.

WORKSHOP RECOMMENDATIONS

- **Connect communities to the Mississippi River:** Work closely with partners such as SWWD, Friends of the Mississippi River, the National Park Service, and the US Army Corps of Engineers to develop better access and awareness of the presence and value of the Mississippi River, which will promote protective actions of the river and develop civic pride as "river towns."
- **Protect and expand the urban forest:** Establish an urban forestry program, develop a tree succession plan for climate adaptation, and provide advice to homeowners on tree replacement on private property.
- **Reduce chloride loading:** Work with and educate local partners such as parking lot managers, SWWD, the County, and the Minnesota Department of Transportation to reduce chloride application.
- **Proactively manage invasives:** Work with local partners to identify emerging invasive species and provide education on the management and removal of invasive species. Pilot innovative invasives removal techniques such as using goats to remove buckthorn.

NEWPORT AND ST. PAUL PARK'S TOP CONCERNS AND PRIORITIES

PLANNING FOR A RESILIENT TOMORROW

SWWD is in the planning process to mitigate risks from and adapt to Minnesota's changing climate. SWWD is working closely with their member communities, including the cities of Newport and St. Paul Park, to identify and implement strategies to develop resilience in the face of increased risk from climate hazards including extreme rainfall, warmer winters, rising temperatures, and extreme wind. SWWD is making investments through the capital planning processes to implement projects to reduce community risk and develop resilience.

www.ci.newport.mn.us

www.stpaulpark.govoffice.com

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SOUTH WASHINGTON WATERSHED DISTRICT
ADDRESSING RISK THROUGH RESILIENCY

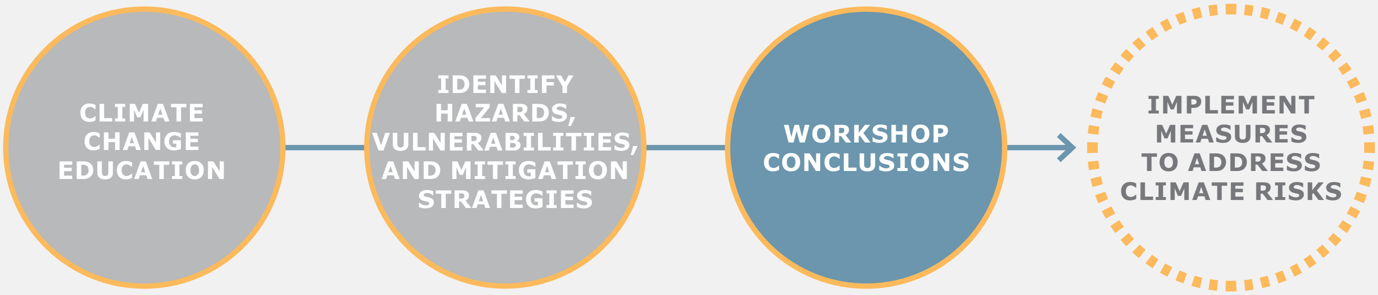
WASHINGTON COUNTY

PLANNING FOR MINNESOTA'S CHANGING CLIMATE

Washington County participated in a series of workshops hosted by South Washington Watershed District (SWWD) to identify risks related to our changing climate and generated strategies to develop resilience. Whether resulting from larger and more intense rainfall events, rising nighttime temperatures, or warming winters, climate change and its associated hazards will lead to consequences that Minnesota and Washington County need to proactively address. Workshop attendees identified strengths and vulnerabilities as well as strategies to address risks related to climate change. Washington County will use the workshop outcomes to develop implementation measures for addressing climate risk in their capital improvement plans.

THE PROCESS

The resilience workshops helped participants identify climate hazards, community vulnerabilities, strengths, and strategies to mitigate risks to community related to climate change.



EVENT PARTICIPANTS

Over 60 people from around Washington County participated in the 2-day workshop series in September 2017. Participants included officials from the cities of Cottage Grove, Newport, Oakdale, St. Paul Park, and Woodbury as well as representatives from the SWWD and several adjacent watershed organizations, Washington County, state agencies, and the public.

WASHINGTO

Top Climat

EXTREME WIND

While the climate science is not clear on whether extreme wind will increase due to climate change, Washington County is already experiencing the impacts of extreme wind on infrastructure and urban tree canopy. Increasing urbanization of the county increases the exposure to this hazard.

INCREASED RAINFALL

All parts of Minnesota are experiencing increasing frequency of extreme “mega” rainfall events, such as the 2012 Duluth rainstorm that caused massive flooding and infrastructure damage. The long-term trend in Minnesota is for greater annual precipitation, which is of particular concern for areas of Washington County within landlocked basins.

STRENGTHS, VULNERABILITIES,

Participants of the workshops focused on three primary sectors of their community and impacts from the hazards associated with a changing climate:

1 INFRASTRUCTURE
2 SOCIETAL
3 NATURAL RESOURCES

1 INFRASTRUCTURE

The challenges of coordinating with numerous local partners on climate adaptation planning and emergency response is a primary concern of Washington County. Concerns also include protecting critical infrastructure at risk from flooding and extreme events.

WORKSHOP RECOMMENDATIONS

- Coordinate climate adaptation and emergency response plans: Work with local partners throughout the county to develop climate adaptation plans and coordinate existing emergency response plans. Consider the need for continued climate adaptation planning with communities in the northern half of Washington County.
- Reduce flooding risk: Address known flooding areas and work with local partners including communities and watershed organizations to mitigate flooding risk to critical infrastructure and homes.
- Provide backup power at critical locations: Provide grants to communities to provide backup power at critical facilities such as fire stations and senior housing.
- Build storm shelters at county parks: Build storm shelters and emergency communications systems in county parks and facilities such as the Lake Elmo Park Reserve.
- Perform a climate vulnerability assessment: Conduct a system-wide assessment of all county assets to determine the risk posed by climate change.

ON COUNTY'S

te Hazards

WARMER WINTER

State climatologists have observed that the largest increase in temperatures is in the winter at night. The lack of extreme cold reduces some traditional winter recreation activities, requires changes in the management of our roads, and allows the survival of invasive species that couldn't previously flourish in Minnesota.

ICE STORMS

While the climate science is not clear on whether ice storms will increase due to climate change, Washington County is already experiencing the impacts of increased salt usage on its natural resources.

AND MITIGATION STRATEGIES

2 SOCIETAL

Primary societal concerns for the people living and working in Washington County include impacts to vulnerable populations such as the elderly or isolated and economically disadvantaged communities during emergencies. An ongoing concern is protecting groundwater sources and potable water supply.

WORKSHOP RECOMMENDATIONS

- **Identify at-risk populations and communicate emergency plans:** Work with local partners and non-governmental organizations like the YMCA and Family Means to identify at-risk populations, such as elderly, low-income, medically-fragile, disabled, non-English speakers, and children, and communicate emergency plans. Develop advanced warning systems targeted towards at-risk populations. Develop outreach materials in multiple languages.
- **Develop after action reports:** Study previous county emergencies to determine what went well and where improvements could be made in emergency planning and response. Incorporate these lessons learned into current emergency response planning.
- **Create a culture of preparedness using a health equity lens:** Provide targeted outreach to vulnerable populations to address existing health disparities and the disproportionate health impact climate change will have on at-risk communities.
- **Promote groundwater protection and reduce potable water usage:** To improve the resilience of the County's drinking water systems, develop a water conservation plan. Promote water conservation through education. Identify and develop plans to protect groundwater recharge areas.

3 NATURAL RESOURCES

Threats to surface water quality from runoff pollution, development, and a changing climate, including impacts to trout streams (e.g., Valley Creek), Mississippi and St. Croix Rivers, and wetlands are primary concerns to natural resources in Washington County. Concerns also include threats posed by invasive species.

WORKSHOP RECOMMENDATIONS

- **Continue to promote stormwater treatment and wetlands protection:** Collaborate with communities and promote policies that treat stormwater including reducing impervious cover, encouraging infiltration, and managing erosion to protect the County's streams, wetlands, lakes, and rivers.
- **Proactively manage invasives:** Work with local partners to identify emerging invasive species and provide education on the management and removal of invasive species. Implement boat launch inspections at vulnerable locations.
- **Reduce chloride pollution:** Work with local partners such as communities, watershed organizations, and the Minnesota Department of Transportation to reduce chloride application through policy and education.

WASHINGTON COUNTY'S TOP CONCERNS AND PRIORITIES

PLANNING FOR A RESILIENT TOMORROW

SWWD is in the planning process to mitigate risks from and adapt to Minnesota's changing climate. SWWD is working closely with their member communities, including Washington County, to identify and implement strategies to develop resilience in the face of increased risk from climate hazards including extreme rainfall, warmer winters, rising temperatures, and extreme wind. SWWD is making investments through the capital planning processes to implement projects to reduce community risk and develop resilience.

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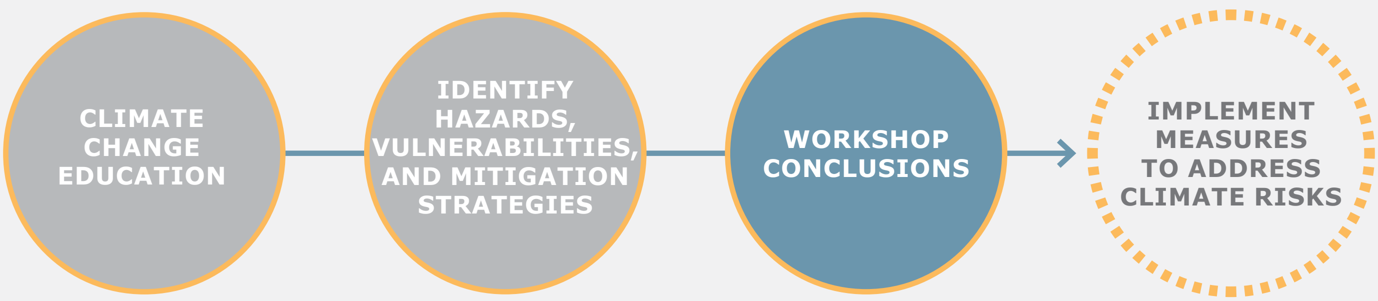
SOUTH WASHINGTON WATERSHED DISTRICT
ADDRESSING RISK THROUGH RESILIENCY
WASHINGTON COUNTY STAKEHOLDERS

PLANNING FOR MINNESOTA'S CHANGING CLIMATE

Washington County Stakeholders (Ramsey-Washington Metro Watershed District, Middle St. Croix Watershed Management Organization, Washington Conservation District, and the City of Oakdale) participated in a series of workshops hosted by South Washington Watershed District (SWWD) to identify risks related to our changing climate and generated strategies to develop resilience. Whether resulting from larger and more intense rainfall events, rising nighttime temperatures, or warming winters, climate change and its associated hazards will lead to consequences that Minnesota and Washington County need to proactively address. Workshop attendees identified strengths and vulnerabilities as well as strategies to address risks related to climate change. Washington County Stakeholders will use the workshop outcomes to develop implementation measures for addressing climate risk in their capital improvement plans.

THE PROCESS

The resilience workshops helped participants identify climate hazards, community vulnerabilities, strengths, and strategies to mitigate risks to community related to climate change.



EVENT PARTICIPANTS

Over 60 people from around Washington County participated in the 2-day workshop series in September 2017. Participants included officials from the cities of Cottage Grove, Newport, Oakdale, St. Paul Park, and Woodbury as well as representatives from the SWWD and several adjacent watershed organizations, Washington County, state agencies, and the public.

WASHINGTON COUN

Top Climat

INCREASED RAINFALL

All parts of Minnesota are experiencing increasing frequency of extreme "mega" rainfall events, such as the 2012 Duluth rainstorm that caused massive flooding and infrastructure damage. The long-term trend in Minnesota is for greater annual precipitation, which is of particular concern for landlocked areas of Washington County.

SEVERE WEATHER

While the climate science is not clear on whether severe weather will increase due to climate change, Washington County is already experiencing the impacts of severe weather on infrastructure and urban tree canopy. Increasing urbanization of the county increases the exposure to this hazard.

STRENGTHS, VULNERABILITIES,

Participants of the workshops focused on three primary sectors of their community and impacts from the hazards associated with a changing climate:

1 INFRASTRUCTURE
2 SOCIETAL
3 NATURAL RESOURCES

1 INFRASTRUCTURE

Protecting critical infrastructure, such as a wastewater treatment plant and a power plant, from flooding and extreme events is a primary concern for stakeholders in Washington County.

WORKSHOP RECOMMENDATIONS

- **Provide increased flood protection to critical infrastructure:** Work with local and regional partners to improve flood protection through structural and policy improvements at vulnerable locations, including the Met Council Wastewater Treatment Plant in Oak Park Heights, Xcel's power plant in Bayport, highways, and evacuation routes.
- **Identify impacts of and plan for increased precipitation:** Perform hydrologic and hydraulic studies of increased precipitation and extreme flooding on vulnerable water resources and facilities including Perro Creek, Carnelian Creek, Big Marine Lake outlet, Lake McKusick outlet, Tanners Lake, Oak Ridge Golf Course, and the cities of Willernie, Mahtomedi, and Pine Springs. Develop plans to address increased flooding prioritized by risk.
- **Coordinate climate adaptation and emergency response plans:** Work with local partners throughout the county to develop climate adaptation plans and coordinate existing emergency response plans. Continue climate adaptation planning with watershed organizations and communities in other portions of Washington County.

NTY STAKEHOLDERS'

te Hazards

EXTREME TEMPERATURES

Washington County is experiencing pressures from increasing temperatures as well as increased heat from urban heat island effect, which can harm vulnerable populations such as the elderly as well as sensitive natural resources like trout streams.

ICE STORMS

While the climate science is not clear on whether ice storms will increase due to climate change, Washington County is already experiencing the impacts of increased salt usage on its natural resources.

AND MITIGATION STRATEGIES

2 SOCIETAL

Primary societal concerns for the people living and working in Washington County include impacts to vulnerable populations such as the elderly or isolated and economically disadvantaged communities during emergencies. An ongoing concern is protecting groundwater sources and potable water supply.

WORKSHOP RECOMMENDATIONS

- **Communicate emergency plans to at-risk populations:** Work with local partners and non-governmental organizations to communicate flood risk and emergency and evacuation plans to isolated communities, such as the elderly, prison population, and residents of manufactured home parks. Update evacuation and long-term shelter areas.
- **Promote groundwater protection and reduce potable water usage:** To improve the resilience of the County's drinking water systems, develop a water conservation plan. Promote water conservation through education and policy. Study groundwater-surface water connections and recharge areas to protect groundwater quality.
- **Educate public about health risks of climate change:** Perform targeted outreach to vulnerable communities on health risks of climate change, including greater prevalence of allergens, pollen, and tick-borne diseases.

3 NATURAL RESOURCES

Threats to surface water quality from runoff pollution, development, and a changing climate are primary concerns to natural resources in Washington County. Concerns also include threats posed by invasive species.

WORKSHOP RECOMMENDATIONS

- **Continue to promote stormwater treatment:** Promote policies and implement projects that reduce impervious cover, encourage infiltration, mitigate temperature impacts, and reduce erosion to protect wetlands, trout streams, and lakes.
- **Proactively manage invasives:** Work with local partners to identify emerging terrestrial and aquatic invasive species and provide education on the management and removal of invasive species. Perform an inventory of invasive species in Washington County. Develop a monitoring and rapid response program.
- **Protect and expand the urban forest:** Monitor the health of the County's urban forest and select diverse tree species for a changing climate.
- **Perform inventories of and improve natural spaces:** Perform inventories of the natural resources of the county, including shorelines and wetlands and develop plans for restoration. Develop plans to create more open and natural spaces and create corridors to improve habitat and connectivity.

WASHINGTON COUNTY STAKEHOLDER'S TOP CONCERNS AND PRIORITIES

PLANNING FOR A RESILIENT TOMORROW

SWWD is in the planning process to mitigate risks from and adapt to Minnesota's changing climate. SWWD is working closely with their member communities, including Washington County Stakeholders, to identify and implement strategies to develop resilience in the face of increased risk from climate hazards including extreme rainfall, warmer winters, rising temperatures, and extreme wind. SWWD is making investments through the capital planning processes to implement projects to reduce community risk and develop resilience.

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SOUTH WASHINGTON WATERSHED DISTRICT
ADDRESSING RISK THROUGH RESILIENCY

CITY OF WOODBURY

Woodbury

South Washington WATERSHED DISTRICT

PLANNING FOR MINNESOTA'S CHANGING CLIMATE

The City of Woodbury participated in a series of workshops hosted by South Washington Watershed District (SWWD) to identify risks related to our changing climate and generated strategies to develop resilience. Whether resulting from larger and more intense rainfall events, rising nighttime temperatures, or warming winters, climate change and its associated hazards will lead to consequences that Minnesota and Woodbury need to proactively address. Workshop attendees identified strengths and vulnerabilities as well as strategies to address risks related to climate change. Woodbury will use the workshop outcomes to develop implementation measures for addressing climate risk in their capital improvement plans.

THE PROCESS

The resilience workshops helped participants identify climate hazards, community vulnerabilities, strengths, and strategies to mitigate risks to community related to climate change.

CLIMATE CHANGE EDUCATION → IDENTIFY HAZARDS, VULNERABILITIES, AND MITIGATION STRATEGIES → WORKSHOP CONCLUSIONS → IMPLEMENT MEASURES TO ADDRESS CLIMATE RISKS

EVENT PARTICIPANTS

Over 60 people from around Washington County participated in the 2-day workshop series in September 2017. Participants included officials from the cities of Cottage Grove, Newport, Oakdale, St. Paul Park, and Woodbury as well as representatives from the SWWD and several adjacent watershed organizations, Washington County, state agencies, and the public.

THE CITY OF

Top Climat

EXTREME TEMPERATURES

Woodbury is experiencing pressures from increasing temperatures as well as increased heat from urban heat island effect, which can harm vulnerable populations such as the elderly as well as sensitive natural resources like trout streams.

DROUGHT

Climatologists point out that within Minnesota's normal range of weather extremes is the drought of the dust bowl days in the 1930s. Although there is no recent trend for drought, Woodbury can expect drought to occur again. Long-term predictions of greater than ten years show an increased likelihood of drought.

STRENGTHS, VULNERABILITIES,

Participants of the workshops focused on three primary sectors of their community and impacts from the hazards associated with a changing climate:

1. INFRASTRUCTURE
2. SOCIETAL
3. NATURAL RESOURCES

1 INFRASTRUCTURE

Protecting critical infrastructure, such as sanitary and stormwater lift stations and community gathering spaces, from flooding and extreme events is a primary concern for Woodbury. Concerns also include providing energy resilience through renewable energy.

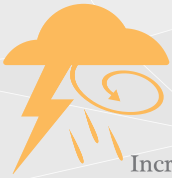
WORKSHOP RECOMMENDATIONS

- **Provide backup power at critical locations:** Because the facilities that are needed to provide resilience during flooding and other extreme events are vulnerable to power outages that accompany those events, upgrade aging technology and implement backup power at critical facilities, such as lift stations, hospitals, and evacuation centers.
- **Build resilience into power grid:** Implement solar power and explore other power sources to augment power supply and build in redundancy.
- **Reduce flooding risk:** Address known flooding areas, including creating an outlet to the Mississippi River from the CDP-85 Regional Infiltration Basin.

WOODBURY'S

te Hazards

SEVERE WEATHER



While the climate science is not clear on whether severe weather will increase due to climate change, Woodbury is already experiencing the impacts of severe weather on infrastructure and urban tree canopy. Increasing urbanization of the county increases the exposure to this hazard.

INCREASED RAINFALL

All parts of Minnesota are experiencing increasing frequency of extreme "mega" rainfall events, such as the 2012 Duluth rainstorm that caused massive flooding and infrastructure damage. The long-term trend in Minnesota is for greater annual precipitation, which is of particular concern for landlocked areas of Woodbury.

AND MITIGATION STRATEGIES

2 SOCIETAL

Primary societal concerns for the people living and working in Woodbury include impacts to vulnerable populations such as the elderly, non-English speaking populations, or isolated and economically disadvantaged communities during emergencies. An ongoing concern is protecting groundwater sources and potable water supply. Also of concern are providing transit options and building transit-oriented development.

WORKSHOP RECOMMENDATIONS

- **Communicate emergency plans to at-risk populations:** Work with local partners and non-governmental organizations (e.g., Christian Cupboard Emergency Food Shelf and Sowashco Cares) to communicate flood risk and emergency and evacuation plans to isolated communities, such as homeless youth, the elderly, and non-English speaking populations. Develop back-up plan to communicate with the public during power outages, using multiple languages.
- **Promote groundwater protection and reduce potable water usage:** To improve the resilience of the City's drinking water system, implement a water filtration system to remove contamination and explore alternative sources of water supply. Continue to promote water conservation through education and policies to reduce turf grass and irrigation.
- **Develop and promote transit options:** Develop an organized voice to advocate for public transit options and improve access to Metro Mobility. Promote development in existing transit corridors.

3 NATURAL RESOURCES

Threats to surface water quality from stormwater runoff pollution and a changing climate, including chlorides in wetlands and climate stresses to Tamarack Swamp, are primary concerns to natural resources in Woodbury. Concerns also include reduction in habitat and biodiversity from development of remaining natural spaces.

WORKSHOP RECOMMENDATIONS

- **Reduce chloride pollution:** Work with local partners such as parking lot managers, SWWD, the County, and the Minnesota Department of Transportation to reduce chloride application through policy and education.
- **Continue to promote stormwater treatment:** Promote policies that reduce impervious cover, build soil health, increase tree canopy and interception, and encourage stormwater reuse and infiltration to reduce stormwater runoff to protect wetlands and lakes.
- **Acquire key habitats and development management plans:** Secure portions of existing open space to stitch together green habitat corridors that are identified in the City's comprehensive plan to promote biodiversity. Develop management plans for key habitats, including the Tamarack Swamp.
- **Proactively manage invasives:** Work with local partners to identify emerging invasive species and provide education on the management and removal of invasive species.
- **Protect and expand the urban forest:** Monitor the health of the City's urban forest, expand tree planting programs, and select tree species for a changing climate.

WOODBURY'S TOP CONCERNS AND PRIORITIES

PLANNING FOR A RESILIENT TOMORROW

SWWD is in the planning process to mitigate risks from and adapt to Minnesota's changing climate. SWWD is working closely with their member communities, including the City of Woodbury, to identify and implement strategies to develop resilience in the face of increased risk from climate hazards including extreme rainfall, warmer winters, rising temperatures, and extreme wind. SWWD is making investments through the capital planning processes to implement projects to reduce community risk and develop resilience.

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