2022 Source Water Assessment

MOORHEAD PUBLIC SERVICE PUBLIC WATER SYSTEM

PWS ID # 1140008

2022 Source Water Assessment – Moorhead Public Service
Public Water Supply ID: 1140008

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I hereby certify that this plan, document or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Geologist under the laws of the State of Minnesota.

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Glossary

Agronomist – An expert in the science of soil management and crop production.

Appropriations – The total amount of water approved for use from an aquifer, stream, lake, or reservoir by the Minnesota Department of Natural Resources.

Aquatic consumption – A standard that is applied to a body of water by the Minnesota Pollution Control Agency that differentiates whether the water is safe for use via drinking, culinary, or food processing use, and whether or not fish caught in that waterbody can be consumed by people.

Aquatic life use – A standard that is applied to a body of water by the Minnesota Pollution Control Agency that describes whether the waterbody supports a healthy aquatic ecosystem or not.

Aquatic recreation use – A standard that is applied to a body of water by the Minnesota Pollution Control Agency that describes whether the waterbody supports or is impaired for recreational (i.e. swimming, boating, fishing, etc.) purposes.

Buffer – An area of equal width on either side of a stream.

Centerline – The center of a stream.

Concentrations – The abundance of an element or compound within a volume of water.

Contaminant – A chemical or pollutant, either natural or man-made, that degrades water quality.

Cyanobacteria – A type of microorganism that obtains its energy through photosynthesis. Also known as Blue-Green Algae, they produce toxins that can be harmful if pets and humans come in contact with them.

Cyanotoxins – A toxin that is produced by cyanobacteria.

Delineated area – A watershed area that has been outlined as contributing to a downstream waterbody that serves as a public water supply source.. The ERA, SMA, and DWSMA are all delineated areas.

Dilution – The action in which a chemical, biological, or contaminant concentration is reduced in water by increasing the amount of water present.

Disinfectant – Any oxidant, including but not limited to chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

Disinfection byproduct (DBP) – A chemical that is formed from a reaction between a disinfectant and organic matter that is present in water.

Fecal coliform – A type of bacteria that is found in animals and humans and is transmitted to the natural environment.

Geography – Physical features of a described land area.

Gradient – The degree of slope of a surface, either of the land or water table.

Hydrologic Unit Code (HUC) – A code assigned by the U.S. Geological Survey (USGS) for each watershed. HUCs are nested values, with larger watershed basins having fewer digits and sub-basins of that watershed having more digits that are derived from the larger basin codes. For example the Red River basin has an assigned HUC4 of 0902, while a subwatershed of the Red River, like the Otter Tail River watershed, has a HUC8 value of 09020103.

Infrastructure – The physical structures and facilities that are needed for a public water supply's operation.

Inorganic chemical – Metals, salts, or other compounds that typically do not contain carbon.

Intake – A pipe located in a waterbody from which a public water supplier pumps their raw water for treatment.

Lakeshed – An area surrounding a lake that contributes water via runoff, groundwater, or stream flow.

Lime Sludge – A semi-solid material that is a byproduct of using lime during a water treatment process.

Microorganism – An organism that can only be seen with the use of a microscope.

Mitigate – Decrease in severity.

Organic chemical – A compound that contains carbon.

Perennial stream – A reoccurring or year round stream flow.

Photosynthesis – The process by which a plant uses sunlight in combination with carbon dioxide and water to create food for itself.

Radionuclides – An element that decays radioactively, emitting radiation as a result.

Toxin – Poison from plant or animal origin.

Watershed – An area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel.

Abbreviations

Cfs – cubic feet per second

DBPs – Disinfection By-Products

DNR – Department of Natural Resources

DWSMA-SW – Drinking Water Source Management Area – Surface Water

EPA – U.S. Environmental Protection Agency

ERA – Emergency Response Area

HAB – Harmful Algal Bloom

HUC – Hydrologic Unit Code

KML – Keyhole Markup Language

LiDAR – Light Detection and Ranging

MCL – Maximum Contaminant Level

MDA – Minnesota Department of Agriculture

MDH – Minnesota Department of Health

MPS – Moorhead Public Service

mg/L – milligrams per liter

MN – Minnesota

MGY – millions of gallons per year

MNDWIS – Minnesota Drinking Water Information System

MnGEO – Minnesota Geospatial Information Office

MPARS – Minnesota Permitting and Reporting System

MPCA – Minnesota Pollution Control Agency

MPN/100 mL – Most probable number of organisms per 100 milliliters of solution

NHD – National Hydrography Dataset

NRCS – Natural Resource Conservation Services

NTU – Nephelometric Turbidity Units

NWI – National Wetland Inventory

PCBs – Polychlorinated Biphenyls

PCSI – Potential Contaminant Source Inventory

ppb – parts per billion

ppm – parts per million

PWS – Public Water Supplier

PWSs – Public Water Suppliers

SDWA – Safe Drinking Water Act

SMA – Spill Management Area

SWA – Source Water Assessment

SWAs – Source Water Assessments

SWCD – Soil and Water Conservation District

SWIPP – Surface Water Intake Protection Plan

TTHM – total trihalomethanes

ug/L – micrograms per liter

USGS – United State Geological Survey

Introduction to the Source Water Assessment

Background

The 1996 amendments to the federal Safe Drinking Water Act (SDWA) required the Minnesota Department of Health (MDH) to complete source water assessments (SWAs) for public water systems (PWS). The first source water assessment (SWA) for Moorhead was completed in February 2003.

Since the first SWAs were completed, much has changed in the processes used to develop source water protection plans, as well as with the data and tools to support these efforts. For example, we now have more data available and use a more sophisticated method to characterize water quality. Also, the water resource management framework in Minnesota has changed substantially, most notably with a shift towards watershed-based comprehensive local water planning.

MDH has dedicated resources to update the Moorhead SWA and to work with the PWS, Moorhead Public Service (MPS) to create a Surface Water Intake Protection Plan (SWIPP). These documents will be used to drive implementation of activities to protect the surface water-derived source water for the city of Moorhead for the next ten years. After the 10 years have elapsed MDH will reassess the PWS source water assessment area. This updated SWA will then guide the amended SWIPP.

Contributors to the SWA

MDH, in partnership with Moorhead Public Service, assembled a team of staff from Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, Minnesota Board of Water and Soil Resources, Minnesota Department of Agriculture, Clay County, the Buffalo-Red River Watershed District, the city of Fargo, North Dakota, a state government representatives, and the city of Moorhead to develop and review this SWA.

Purpose of the SWA

The information from this updated and enhanced assessment can be used to expand upon activities to prevent or mitigate contamination of Moorhead's surface water-derived source of drinking water. The SWA provides information regarding the drinking water sources for public water systems. A SWA includes information on the following: identification of the resource used as a drinking water source, its physical setting, public water system intake and treatment, contaminants of concern, and known threats.

Source Water Characteristics

Moorhead obtains water primarily from the Red River (Figure 1), with some additional water from two nearby groundwater aquifers. The contributing area encompasses five different eight-digit

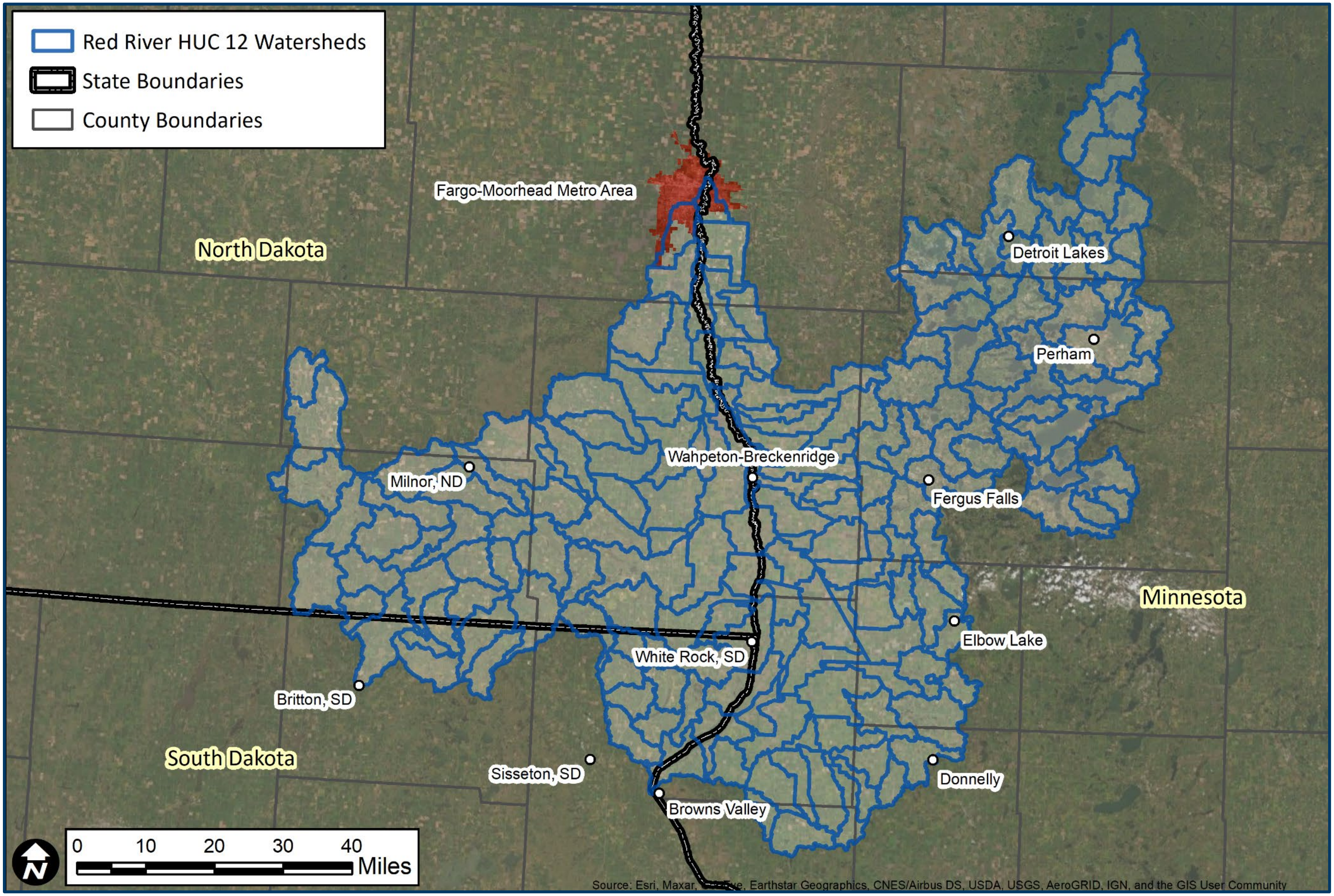

Figure 1 – Red River watershed upstream from the Fargo-Moorhead metro area.

Hydrologic Unit Code (HUC8) watersheds which flow to Moorhead from the south and drains 4,261,453 acres. The contributing watershed is within South Dakota, North Dakota, and Minnesota.

The Red River basin has been heavily altered hydrologically by ditching and drainage, particularly those watersheds in closest proximity to Moorhead. The 2017 Upper Red River of the North Watershed Restoration and Protection Strategy (WRAPS) Report estimates that the majority of the streams in that HUC8 watershed have been highly altered to support farmland drainage. It should be noted, however, that much of the Red River headwaters is of similar condition. As a result of this alteration, from a water chemistry and biological perspective, most of the watersheds upstream from Fargo-Moorhead are considered to be in poor condition, as documented in their respective WRAPS reports. The exception is the Otter Tail River, which has generally undergone less conversion to agriculture than the Bois de Sioux and Mustinka Rivers, as documented in the WRAPS report (MPCA, 2021). While this does not directly impact drinking water, it is well known that there is a link between watershed health and drinking water quality. WRAPS reports for the Bois de Sioux (MPCA, 2020) and Mustinka (MPCA, 2013) Rivers also show similar altered hydrology and land use stressors in those watersheds, highlighting that the issues present in close proximity to Moorhead are also present throughout the Red River Basin upstream from the Fargo-Moorhead area.

Source Watershed Statistics for Moorhead Public Service

Minnesota Watershed Area: 2,407,900 acres	Upstream Stream Length: 5,994 miles
North Dakota Watershed Area: 1,497,143 acres	Upstream Lake Area: 240,839 acres
South Dakota Watershed Area: 356,410 acres	Upstream Wetland Area: 342,491 acres[1]
Total Watershed Area: 4,261,453 acres	

[1]Wetland information is based on US Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) data

Infrastructure Characteristics

The following list describes the key infrastructure components and permit capacity to provide safe and reliable water for residents and businesses in the city of Moorhead.

The city operates and blends two drinking water systems: the surface water intake on the Red River, and a groundwater system consisting of three wellfields, with two wells finished in the North Buffalo Aquifer wellfield, three wells finished in the South Buffalo Aquifer wellfield, and two wells finished in the Moorhead Aquifer wellfield.

Models created for the Buffalo Aquifer Management Plan (MPS, 2017) show that with reduced consumption and conservation by MPS, the city’s wellfields are capable of providing 100% of the water needed by the city for a period of several years. However, there is concern that continuous use of the three existing wellfields may lead to depleted water levels in portions of the Moorhead and Buffalo aquifers, and result in decreased productivity of Moorhead’s wells, particularly during drought conditions when recharge is expected to be non-existent. Model simulations of drought conditions indicate that water levels in the aquifer were lowered in all simulations, and aquifer

Public Water System Characteristics

Intake Location:	Red River, downstream of the 1-94 crossing.
Treatment Facility:	One treatment facility approximately 2.5 miles northeast of the Red River intake.
Treatment Methods:	Softening; particulate removal via coagulation, flocculation and sedimentation; disinfection via ozonation; granular activated carbon biofiltration; secondary disinfection via chloramination.
Production:	Max daily production of (up to) 10 million gallons, average daily production of 4.3 million gallons (Minnesota Drinking Water Information System (MNDWIS)).
Storage Capacity:	8.65 million gallons tank and tower storage.
Backup Water Sources:	Groundwater, with seven wells finished in glacially-derived sand and gravel. These wells, finished in the North and South Buffalo and Moorhead aquifers, can provide full backup for a limited period of time.
DNR Appropriations Permit:	Combined from all sources: 6,968 millions of gallons per year (MGY) permitted. Actual use and permit numbers for sources listed in Table 1.

conditions in some scenarios approached or violated safe yield threshold guidelines established by the DNR (2022). Modeled water level declines were less when a third wellfield was simulated to the Buffalo Aquifer, which supports the need for an additional wellfield source for MPS.

Additional information on MPS's groundwater resource and its protection is available in MPS's current Wellhead Protection Plan Parts 1 and 2 (Oswald and Hume, 2012, and Moorhead Public Service Wellhead Protection Team, 2013, respectively).

Table 1 shows the water volumes pumped from the MPS's wells and surface water intake, as reported for the past five years to the DNR Minnesota Permitting and Reporting System (MPARS).

Table 1 – Annual Volume of Water Discharged from Water Supply Wells

Intake or Well Name (Unique Number)	MPARS No.	2017	2018	2019	2020	2021
Red River Intake	1977-1852	1,089.7	1,012.3	979.4	1,112.3	**1,154.7**
Well #6 (241492)	1987-1243	35.2	**136.4**	90.7	104.5	88.3
Well #6B (437645)	1987-1243	**71.2**	18.8	43.1	1.9	2.6
Well #8 (222049)	1947-0014	66.4	90.7	94.8	101.8	**177.7**
Well #9 (222050)	1947-0014	247.6	**145.5**	116.8	98.1	41.1
Well #10 (222051)	1947-0014	2.6	**36.1**	0.0	10.0	15.1
Well #11 (511085)	1977-1850	49.8	28.5	**74.4**	12.2	9.1
Well #12 (511086)	1977-1850	42.4	**91.8**	82.7	32.9	80.5
System Total		**1,605.0**	1,560.1	1,482.0	1,473.6	1,569.1

▪Expressed as millions of gallons. Bolding indicates the greatest annual pumping volume reported in the five year span for that well, intake or whole system.

Total water use by MPS has remained relatively stable during this period, and in fact both peak and average use have remained relatively stable since 2000, despite an increase in population served (Pritchard, personal comm., 2022).

Figure 2 shows actual average and peak daily water demand for Moorhead, compared with projections of per capita average and peak daily use. Actual use from 2000 to 2021, while fluctuating, has shown a nearly flat trend, while earlier estimates derived from MPS' Water Distribution System Modeling and Capital Improvements Study, prepared by Ulteig Engineers, Inc. in 2006, forecast steadily increasing water demand (WAter Distribution System Modeling and Capital Improvements Study, Ulteig Engineers, Inc., 2006). MPS has utilized the Fargo-Moorhead Metropolitan Council of Governments (MCOG) population growth projections to update forecasts on steadily increasing population and potential demand increases. The flat trend in the observed data is due to conservation measures implemented by MPS through the use of conservation rate structures, conservation outreach efforts, and more efficient in-home plumbing fixtures and appliances.

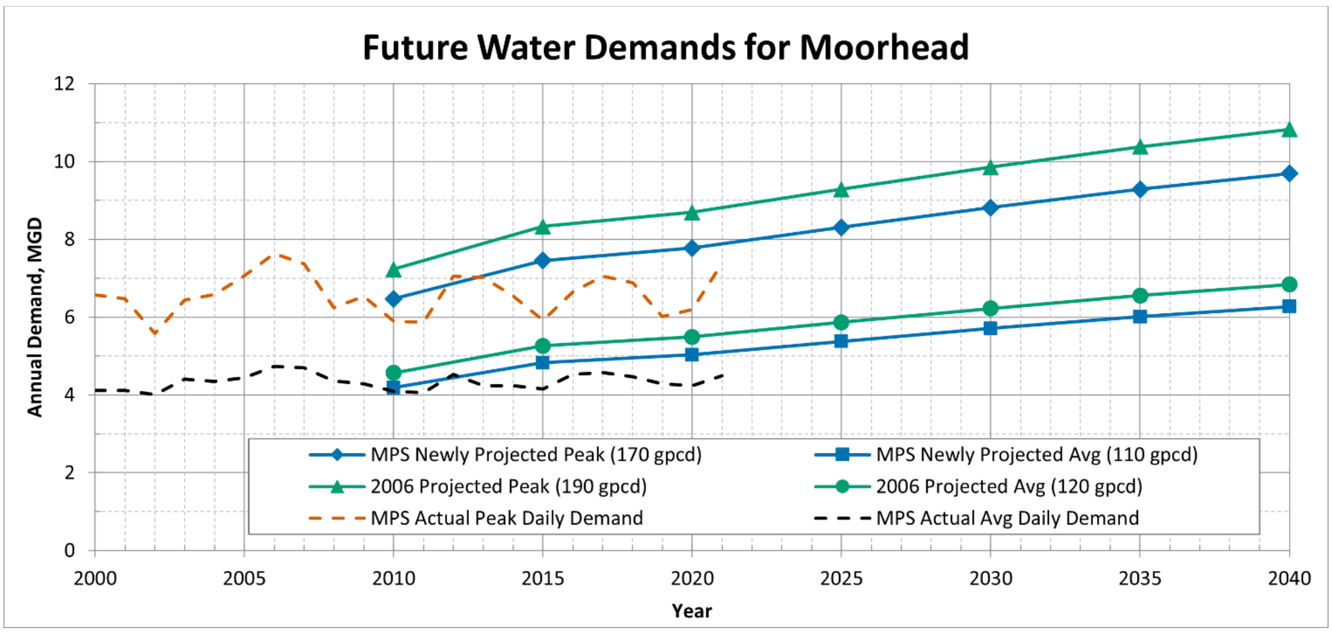

Figure 2 – Peak and average water use trends observed from 2000 through 2021 compared to projected demand through 2040.

Source Water Protection Areas

Four nested protection areas are presented in the SWA. Three of these areas are shown in Figure 3, while the fourth is shown in Figure 4.

Emergency Response Area

The Emergency Response Area (ERA) is designed to help MPS and the city address potential contaminant sources and contaminant releases that present an immediate health concern to water

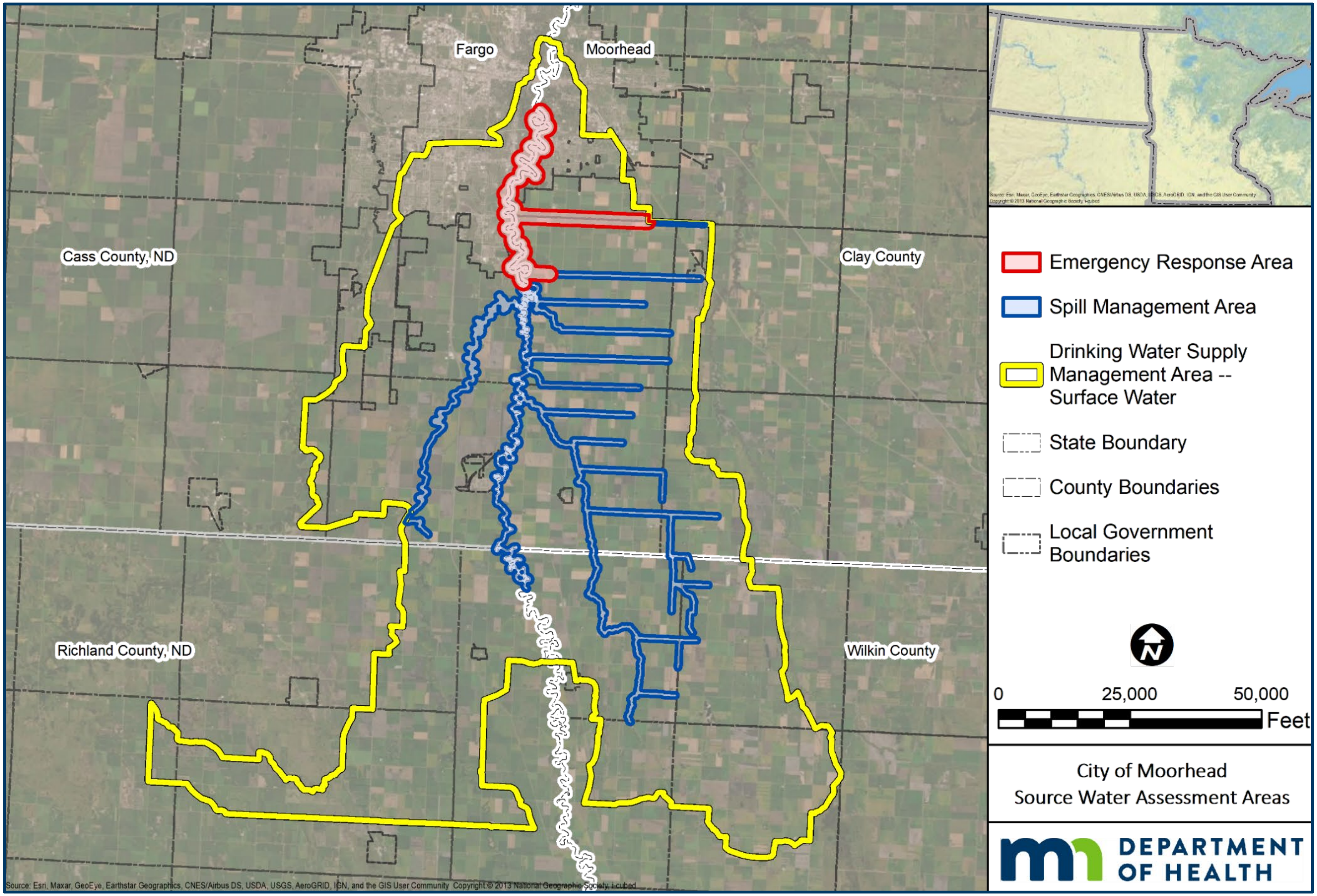

Figure 3 – Moorhead's Drinking Water Supply Management Area, Spill Management Area, and Emergency Response Area

users. The ERA highlights possible point source contamination issues that could impact the water supply. The ERA geographic area is defined by the amount of notification time MPS needs to close the surface intake, plus some additional time to accommodate unanticipated delays in notification and shut down. The width of each reach's ERA is a quarter mile on either side of the stream reach.

The Moorhead ERA includes reaches within an eight hour time of travel distance upstream along the Red River, Rose Coulee (ND) and several public ditches on the Minnesota side of the river (Figure 3). The time of travel distances were calculated using the 90th percentile value of channel velocity data from USGS gages. For a few public ditches (County Ditches 9 and 32 in Clay County, MN, and Rose Coulee in Fargo), the time of travel along the Red River to the intake was subtracted from eight hours, and the remaining distance was applied to those ditches.

Historical aerial photos from the U.S. Geological Survey (USGS) and the Minnesota Geospatial Information Office (MnGEO) dating back several decades show that a number of surface water features in the region, including the Red and Wild Rice Rivers, Wolverton Creek, and the public ditches in the watershed, have changed substantially since the NHD dataset was last amended. This is due to the natural river meandering and ditch reconstruction that have altered channel geometries. To correct for this and ensure that river time of travel distances were as accurate as possible, aerial photographs from as recently as 2017 were used to adjust GIS line segments to reflect current channel courses.

The land use in the ERA is mostly agricultural and developed.

Spill Management Area

The Spill Management Area (SMA) is designed to focus source water protection activities on potential contaminant sources within 500 feet of either 1) the centerline of a public stream, or 2) the shoreline of a lake contributing flow to a PWS's source waterbody. Like the ERA, the SMA is designed to highlight point source contamination issues of immediate concern that could impact the water supply but at longer times of travel.

The Moorhead SMA has been delineated for all perennial public stream tributaries, ditches and lakes within either a 24-hour time of travel or 25 river miles upstream of the intake outside of the ERA, whichever is greater and most supported by flow data, where available (Figure 3). All SMA stream reaches were delineated with buffers of 500 feet width from the centerline of the stream, as per MDH Guidance (2022). There are no lakes within the SMA distance, but if there were they would also be delineated with 500 foot buffers from the shoreline. The final SMA includes reaches of the following streams:

- Red River
- Wild Rice River (ND)
- Wolverton Creek
- Clay County Ditches 9, 11, 22, 32, 33, 36, 40, 53, and 60
- Judicial Ditch 1 (Clay/Wilkin county border)

The land use in the SMA is mostly agricultural, with some developed lands, wetlands, and open water.

Drinking Water Supply Management Area – Surface Water

The Drinking Water Supply Management Area – Surface Water (DWSMA-SW) is designed to protect water users from long-term health effects related to low levels of contamination that originate from diffuse, widespread sources. These contaminant sources, known as non-point contaminants, can pose a high-level threat when the combined concentration of the contaminant from across the watershed is substantially high. The DWSMA-SW also incorporates areas where future land use development may influence the source water quality. These future development issues are addressed below.

The DWSMA-SW was delineated using HUC 12 watershed boundary data from the U.S. Natural Resources Conservation Service (NRCS), and refined by using the Minnesota Department of Natural Resources (DNR) surface water auto-catchment dataset to remove river catchments that were downstream from the confluence. For Moorhead, the DWSMA-SW encompasses portions of two HUC 12 watersheds upstream from or within the city.

The resulting DWSMA-SW includes the watersheds listed in Table 2. The streams within the DWSMA-SW drain from land represented by agricultural, forested, wetland, and developed uses. Historical aerial photos from the USGS and MnGEO dating back several decades show that the current dataset of streams that are considered perennial is accurate.

Table 2 – Watersheds included in the Moorhead DWSMA-SW

HUC 12 Watershed Name	HUC 12 Code	State(s)	Watershed (acres)
City of Fargo-Red River*	090201040504	MN, ND	12,714
City of Hickson-Red River	090201040403	MN, ND	25,887
County Ditch No 22	090201040301	MN	12,330
County Ditch No 40-Red River	090201040501	MN, ND	27,495
Judicial Ditch No 1	090201040303	MN	19,615
Lower Wolverton Creek	090201040304	MN	22,171
Outlet Wild Rice River	090201051006	ND	23,908
South Pleasant Cemetery	090201051004	ND	33,306
Town of Walcott	090201051005	ND	21,361
Upper Wolverton Creek	090201040302	MN	11,911

*Trimmed from full HUC 12 using DNR catchment calculations. Not a full HUC 12 watershed.

Source Water Assessment Area

The Source Water Assessment Area (SWAA) includes the entire Red River watershed upstream from MPS's intake in both Minnesota and North Dakota. The small portion of the upstream Red River Basin that is in South Dakota has not been included. The final SWAA is shown in Figure 4.

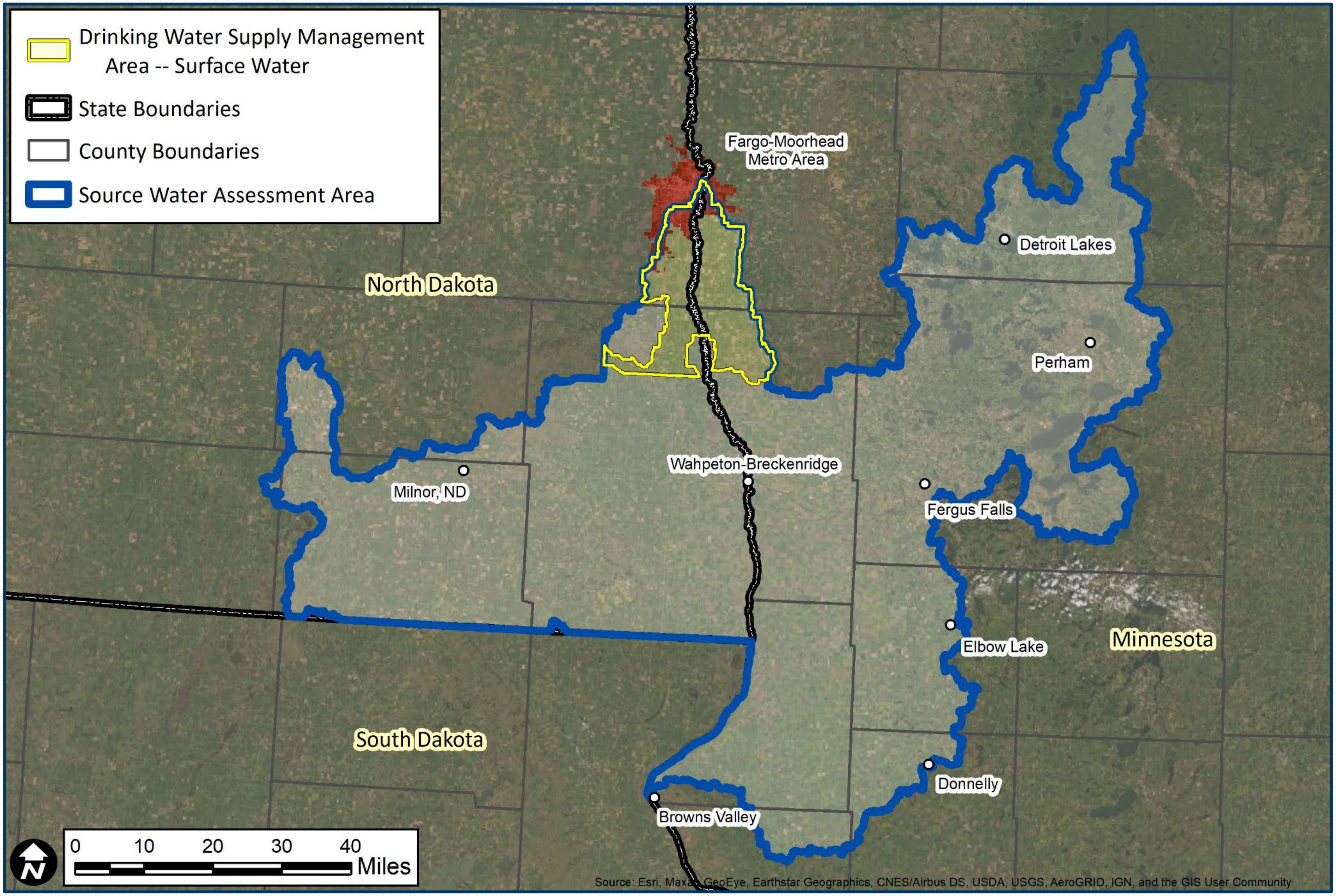

Figure 4 – Moorhead's Source Water Assessment Area.

SWA Area Statistics for Moorhead

Emergency Response Area: 5,381 acres

Spill Management Area: 13,247 acres

Drinking Water Supply Management Area – Surface Water: 210,699 acres

Source Water Assessment Area: 3,905,043 acres

Contaminants of Concern

The federal Safe Drinking Water Act (SDWA) regulates primary contaminants, which are listed on the Environmental Protection Agency (EPA) website at National Primary Drinking Water Regulations (https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations). They are divided into categories of microorganisms, organic chemicals, inorganic chemicals, radionuclides, disinfectants, and disinfection byproducts.

Water quality indicators are used to determine watershed health. Maintaining source water quality over time ensures that treatment processes remain effective and efficient for consumers. While there may not be drinking water standards or limits for some indicators like total organic carbon or total suspended solids, they can lead to creation of disinfection byproducts (DBPs) within drinking water treatment and distribution systems. DBPs are not usually found in source water, and can be avoided by requiring PWSs that use conventional treatment to remove a significant percentage of total organic carbon prior to chlorination.

In addition to the contaminants regulated by the SDWA, some emerging contaminants are also of concern. Emerging contaminants are chemicals about which we are gaining new understanding and awareness regarding their public health or environmental impacts. These emerging contaminants do not yet have SDWA regulated maximum contaminant levels (MCLs), but may have health-based guidance values developed by the U.S. Environmental Protection Agency (EPA) or MDH.

Table 3 summarizes important water quality detection data for MPS. The detections are either concentrations of raw source water sampled from the Red River (i.e. turbidity, total organic carbon, E. coli) or from post-treatment entry or distribution point samples (i.e. organic compounds, nitrate, disinfection by-products and harmful algal bloom toxins).

Table 3 highlights the:

- Drinking water quality information for Moorhead,
- Violations and significant detections of contamination in the raw (untreated) or finished (treated) water, and
- Potential or probable sources of contamination, if the samples are likely from the source water.

Table 3 – Drinking Water Quality Results for Moorhead Public Service

Water Quality Parameters and Measurement Units	Violations	Detections and water quality concerns	Data Source	Potential Source(s) and comments
Regulated Volatile Organic Compounds, Synthetic Organic Compounds[1,2]	None	One detect of synthetic compound in 2016; Some past (prior to 2009) detections of herbicides, gasoline compounds	MDH-MNDWIS	Entry-point data likely related to source water concentrations
Nitrate (as Nitrogen) mg/L or ppm[1,2]	None	Treated water maximum of 3.6 mg/L (2004) listed in MNDWIS; only one intake measurement (0.46 mg/L in 2014) reported	MDH-MNDWIS, MPS	Seasonal cycling may occur in raw intake water
Turbidity (NTU)[1]	None	Source results regularly above 40 NTU during spring and summer through LT2 Source Monitoring Survey 2016 - 2018	MDH-MNDWIS	Source water turbidity is usually due to erosion in watershed
Total Organic Carbon (mg/L)[1,2]	None	Intake water usually < 10 mg/L; Treated water usually < 5 mg/l	MDH-MNDWIS, MPS	Can lead to increased production of disinfection by-products
Disinfection By-Products Haloacetic Acids (ug/L)[2]	None	Average total concentration 4 ug/L	MDH-MNDWIS	By-products of disinfection
Disinfection By-Products Total trihalomethanes (TTHM, ug/L)[2]	None	Average total concentration 1 ug/L	MDH-MNDWIS	By-products of disinfection
Disinfection By-Products Bromate (mg/L)[2]	None	Maximum entry point concentration 2011-2021 0.012 mg/L	MDH-MNDWIS	By-product of disinfection via ozone
E. coli (MPN/100 mL)[2]	None	No treated water detects	MDH-MNDWIS	Sewers, septic systems, sewage lagoons, manure from farm animals, as well as fecal waste from birds, wildlife, and other natural sources
Harmful Algal Bloom Toxins[1,2]	N/A	No detects reported	MDH-MNDWIS, MPS	Indicates presence of potentially harmful algae in water column

- [1]Raw Water
- [2]Treated Water
- N/A: Not applicable (No MCL exists)

The Minnesota Pollution Control Agency (MPCA) has established that a number of streams in the DWSMA are impaired for aquatic recreation, consumption and life uses. Table 4 describes the reaches that are impaired and what those impairments are. Many of the impairments have total maximum daily load (TMDL) reports for those reaches. Aquatic recreation use, aquatic life use, and aquatic consumption use definitions can be found at Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List (PDF) (https://www.pca.state.mn.us/sites/default/files/wq-iw1-04k.pdf). Water use classes are summarized at Water quality standards (https://www.pca.state.mn.us/water/water-quality-standards).

While these impairments do not directly pertain to drinking water, they do further underscore the water quality issues observed in the watershed. It should be noted that while the city's drinking water treatment system protects against turbidity, fecal coliform, and E. coli bacteria, there are some contaminants that, while not a problem historically may not be addressed by current treatment practices should they be found at levels of concern. These include substances such as nitrate and per- and polyfluoroalkyl substances (PFAS). These contaminants are particularly difficult to treat, so prevention is key. Preventing further impairments and mitigating existing impairments within the watershed would have long-term benefits for Moorhead's drinking water.

The water quality in the Red River has been impacted by human activities. Observed impacts in the Red River that may or already have impacted drinking water quality include:

- Erosion in the watershed is leading to high turbidity in the Red River, which can affect treatment.
- Red River water is increasing in total dissolved solids over time, which has the potential to affect corrosivity of water in treatment and distribution systems.
- Pesticides should remain a monitoring priority due to the dominance of agriculture in the Red River Valley.

Table 4 – Stream Chemistry Impairments within Moorhead's DWSMA

Lake or Stream Name	Reach Description	AUID	Use Classes	Impaired Parameters	Parameters with TMDLs	In ERA or SMA
Red River	Wild Rice River (ND) to Buffalo River	09020104-544	1C, 2Bdg, 3C	E. coli[1], Mercury-Fish[2], Turbidity[3]	--	ERA
Red River	Otter Tail River to Wild Rice River (ND)	09020104-543	1C, 2Bdg, 3C	E. coli[1], Mercury-Fish[2], Turbidity[3], Arsenic[4]	--	SMA
Wolverton Creek	Railroad bridge to Red River	09020104-550	2Bg, 3C	E. coli[1], Fish bioassessments[3], Total Suspended Solids[3]	E. coli[1]	SMA
Wolverton Creek	Unnamed creek to railroad bridge	09020104-549	2Bg, 3C	Dissolved Oxygen[3], E. coli[1]	E. coli[1]	SMA

- 1 Aquatic Recreation Use
- 2 Aquatic Consumption Use
- 3 Aquatic Life Use
- 4 Naturally Found contaminant

Erosion and high turbidity

Water quality conditions are considered by the MPCA to be generally poor in the mainstem of the Red River near Moorhead due to a combination of cultivated land use prevalence, altered and straightened watercourses and ditching, intensive drainage, and a lack of vegetated buffers around wetlands and streams (MPCA, 2017). The Red River is considered impaired for turbidity due to high concentrations of suspended sediment, and has been listed as impaired since 1996. The MPCA is currently developing TMDL studies for the Red River turbidity impairments with completion expected in 2022. Wolverton Creek has been listed as impaired due to high concentrations of suspended sediment since 2020 and a TMDL study will be required.

The source of this sediment is likely stream bank and field erosion via overland runoff. The watersheds upstream from Moorhead, with the exception of most of the Otter Tail River, have been highly altered by ditching, and these modifications have caused increased erosion as watercourses attempt to correct this channelization through natural hydrologic processes.

Suspended sediment serves as a transport mechanism for organic carbon, E coli and coliform bacteria, as organic carbon and bacteria adhere to sediment surfaces that are then taken up by MPS's drinking water intake. MPS's treatment system has been built to address pathogens coming into the intake, but periodic or sudden increases in suspended sediment have the potential to overwhelm filtration and disinfection processes, which in turn can lead to microbial detections in entry point or distribution system samples. To date, MPS has not had any microbial detections in entry point samples due to this potential issue.

Additionally, short-term increases in organic carbon at the intake can also potentially increase disinfection by-product formation, as chlorine injected at the treatment plant combines with organic compounds in solution. These disinfection by-products are known or suspected carcinogens and are subject to SDWA regulation. As of the date of this report, MPS has not had any violations of the disinfection byproduct rule.

Work has been ongoing by watershed districts in the DWSMA to improve turbidity in the Red River. This work is very important for resource impacts, but could also have unintended consequences if nutrient loads are not also reduced. For instance, harmful algae blooms (HABs) can take advantage of more light entering the water column when turbidity decreases (Benayache, 2019). If a cleaned up and less turbid Red River still contains excess nutrients, HABs may become more common.

Increasing dissolved solids

Dissolved solids have been increasing in the Red River as determined by their relationship with specific conductivity. Specific conductivity is a function of the concentration of dissolved salts present as charged ions in solution, so the higher the specific conductivity of a solution the more salt that water contains. Note that dissolved solids refer to all ions in solution, including both inorganic major ions and organic molecules.

MPS has observed that specific conductivity within the Red River has increased over time, and local USGS gage data from 2007 on supports that assertion. Figure 5 shows river discharge and the overall average trend in specific conductivity data from the USGS on the Red River at Fargo (Site 05054000) for the entire period of record for specific conductivity. The data suggest an overall increase, and although there may be evidence to suggest that the increase is tied to increased discharge in the river at Fargo-Moorhead for some portions of the period of record, the trend here appears to be only partially dependent on overall discharge. Specific conductivity from 2016 onward in particular shows some independence from discharge.

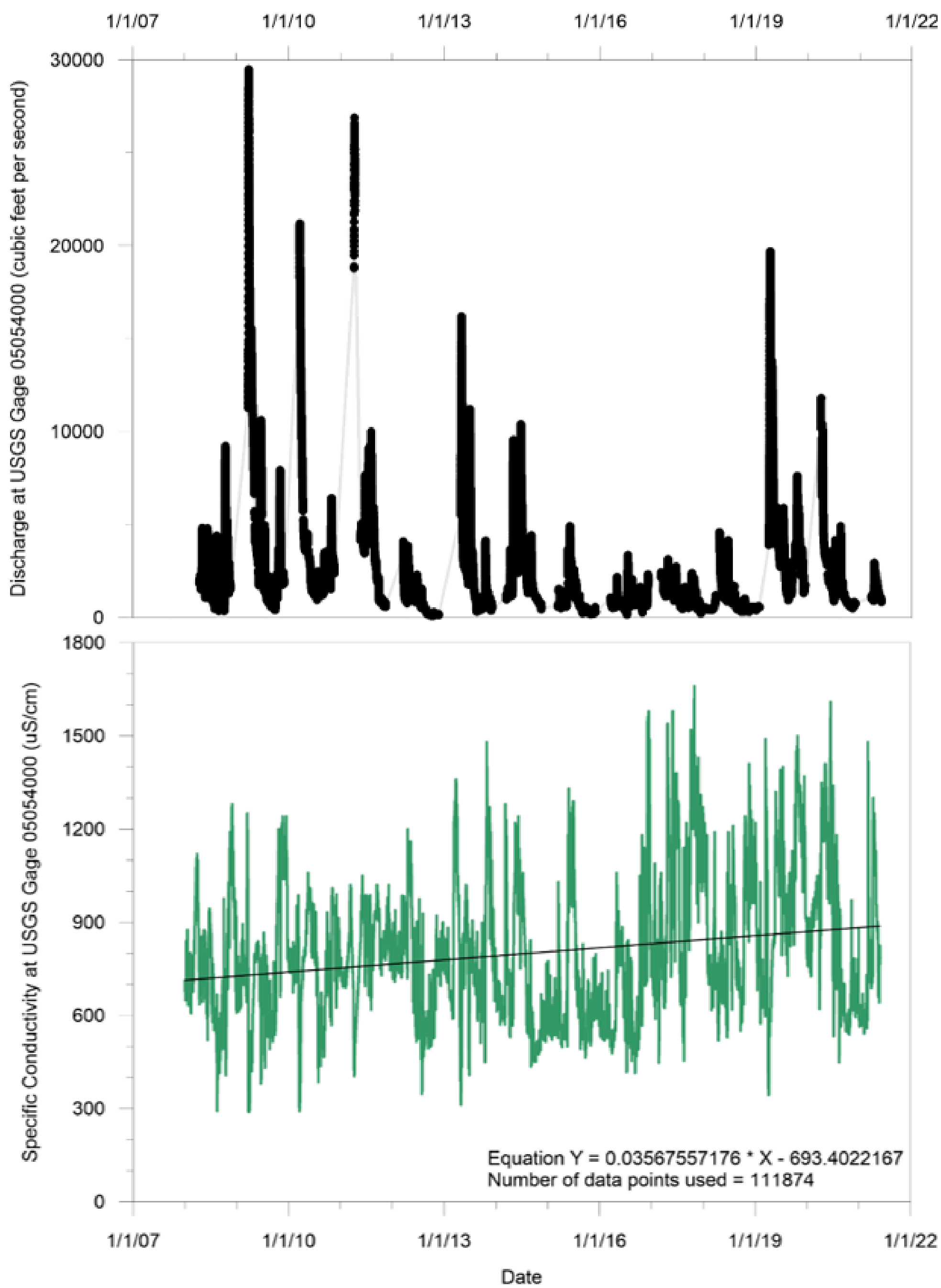

Figure 5 – Discharge (top) and specific conductivity (bottom) from the Red River at Fargo-Moorhead USGS gage (Site 05054000) from October 2007 to present.

Monitoring data collected by the MPCA also supports the MPS' observations. Figure 6 shows specific conductivity measurements from different locations along the Red River within the SMA, ERA, and just downstream from the MPS intake. The measurements and sample data collected at those points, as shown in the bottom of Figure 6, clearly show an increasing trend since the late 1960s. The red trendline indicates average specific conductivity for those points through time, and further emphasizes the trend. The rate of increase averages approximately 50 uS/cm per decade.

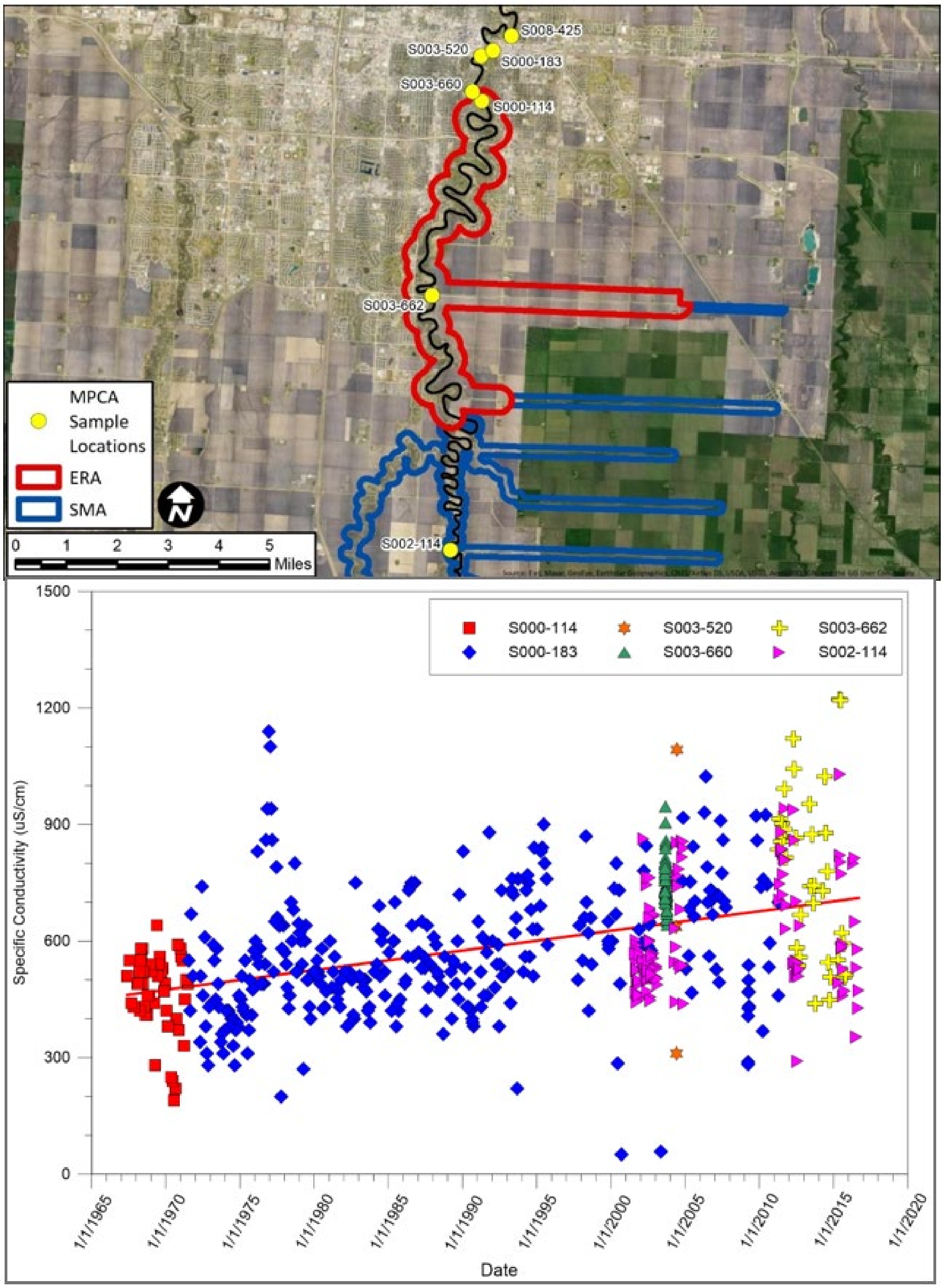

Figure 6 – Locations along the Red River with specific conductivity measurement histories (top). Specific conductivity measurements and the long-term trend is shown on the bottom.

Statistical analysis of sample data from the MPCA suggests an increase in sulfate relative to both chloride and nitrate in solution since the late 1960s (Figure 7). Overall, all three anions have been increasing in concentration over time, which suggests that the Red River is receiving

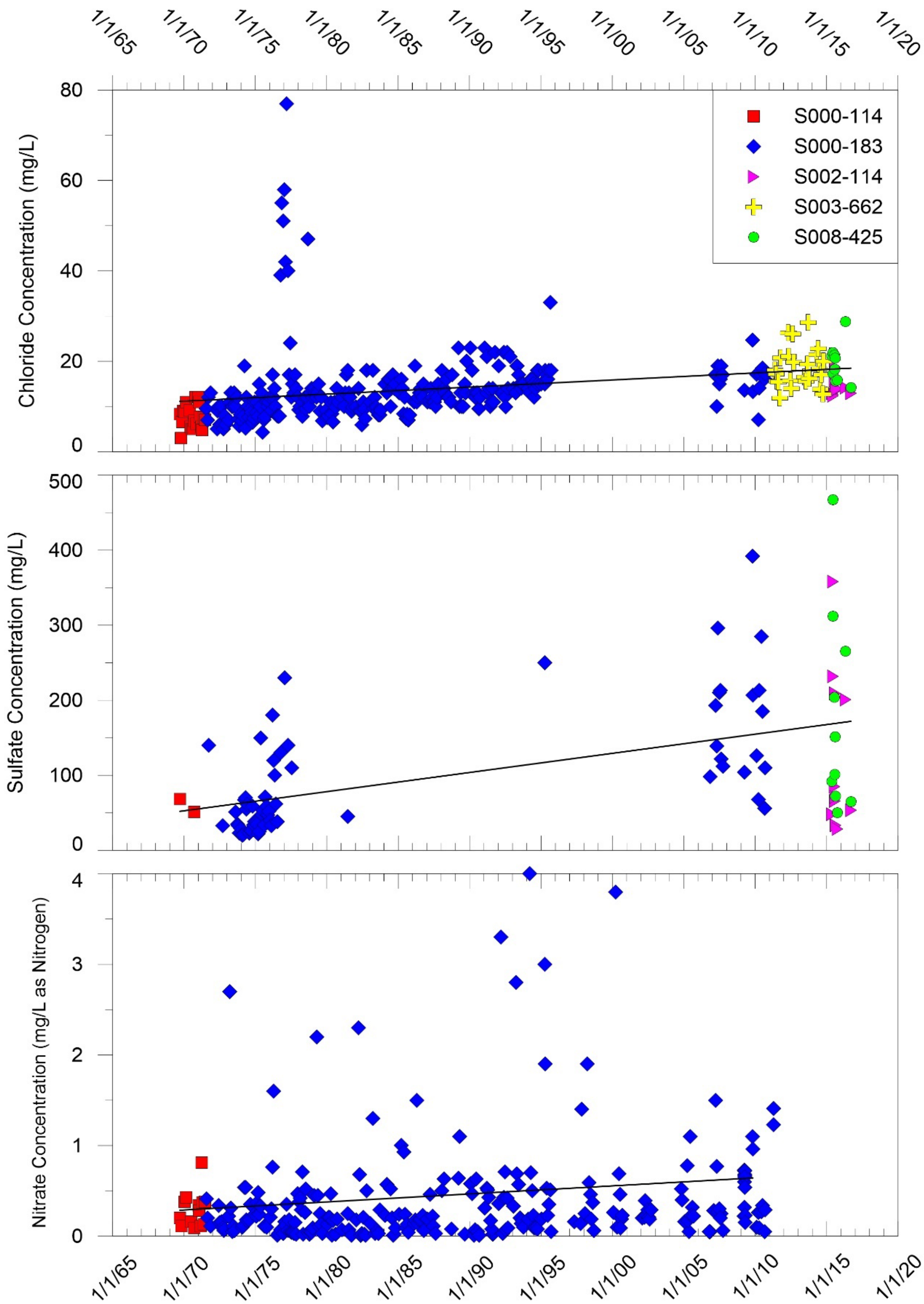

Figure 7 – Chloride, sulfate, and nitrate concentration trends in the Upper Red River since 1969.

water that is more concentrated in major ions. Overall, concentration increases per decade are 1.6 mg/L for chloride, 25 mg/L for sulfate, and 0.09 mg/L for nitrate. Sulfate concentration has regularly been measured above the secondary MCL of 250 mg/L. This concentration can create aesthetic concerns for MPS and force continued reliance on groundwater dilution to ensure consumer confidence in their drinking water.

The source of increasing salinity in the Red River requires further study. Increasing salinity in the Red River could be due to increased groundwater discharge from upwelling from upstream Cretaceous bedrock aquifers, which, in parts of the Red River Valley, tend to contain harder water than glacial aquifer units in Minnesota (USGS, 1976). It may also originate from agricultural practices such as increased drain tile installation or fertilizer use upstream. Regardless, constraining the sources of salinity to the Red River would likely be useful, not just for drinking water but also for river ecosystem functions as conditions and land uses change upstream from Moorhead.

A recent event illustrates the water quality issues involved for MPS (Pritchard pers. comm., 2021). Flow in the Red River through the summer months of 2021 was predominantly coming from tributaries north of the Bois du Sioux River. Beginning the 26th of October, the U.S. Army Corps of Engineers began discharging water from White Rock Dam near Wheaton, MN. Discharge was less than 30 cubic feet per second (cfs) for the first three days until discharge was increased to more than 600 cfs on the 29th and more than 1000 cfs on the 30th. Figure 9 shows daily discharge volumes from White Rock Dam juxtaposed against total and non-carbonate hardness during that same period.

Red River water was comparatively soft before the Bois du Sioux River flows reached Moorhead (Figure 8). As of the 29th—three days before the released water reached Moorhead—the total hardness of river water at MPS's intake was 356 mg/L, with non-carbonate hardness measuring at 133 mg/L. Hardness began trending upward within two days, peaking at 1,280 mg/L on November 4th, with non-carbonate hardness making up most of the hardness at 960 mg/L.

This major change in hardness prompted MPS to begin blending with groundwater to maintain consistent water quality, as shown at the top of Figure 8. The initial blend, started on November 1st, was 75% surface water / 25% groundwater, however by November 3rd MPS had to increase the amount of groundwater used to around 50%.

Source water blending due to hardness does have some financial ramifications for MPS, with daily costs roughly doubling from early October to mid-November (Table 5). Average daily chemical treatment costs for softer Red River water were around $2,300 per day or $615 per million gallons of water treated. When MPS began blending at 50% surface/50% groundwater daily costs rose to more than $4,600 per day or $1,200 per million gallons. These increased costs were due to increased lime and soda ash needed for softening the mixed waters.

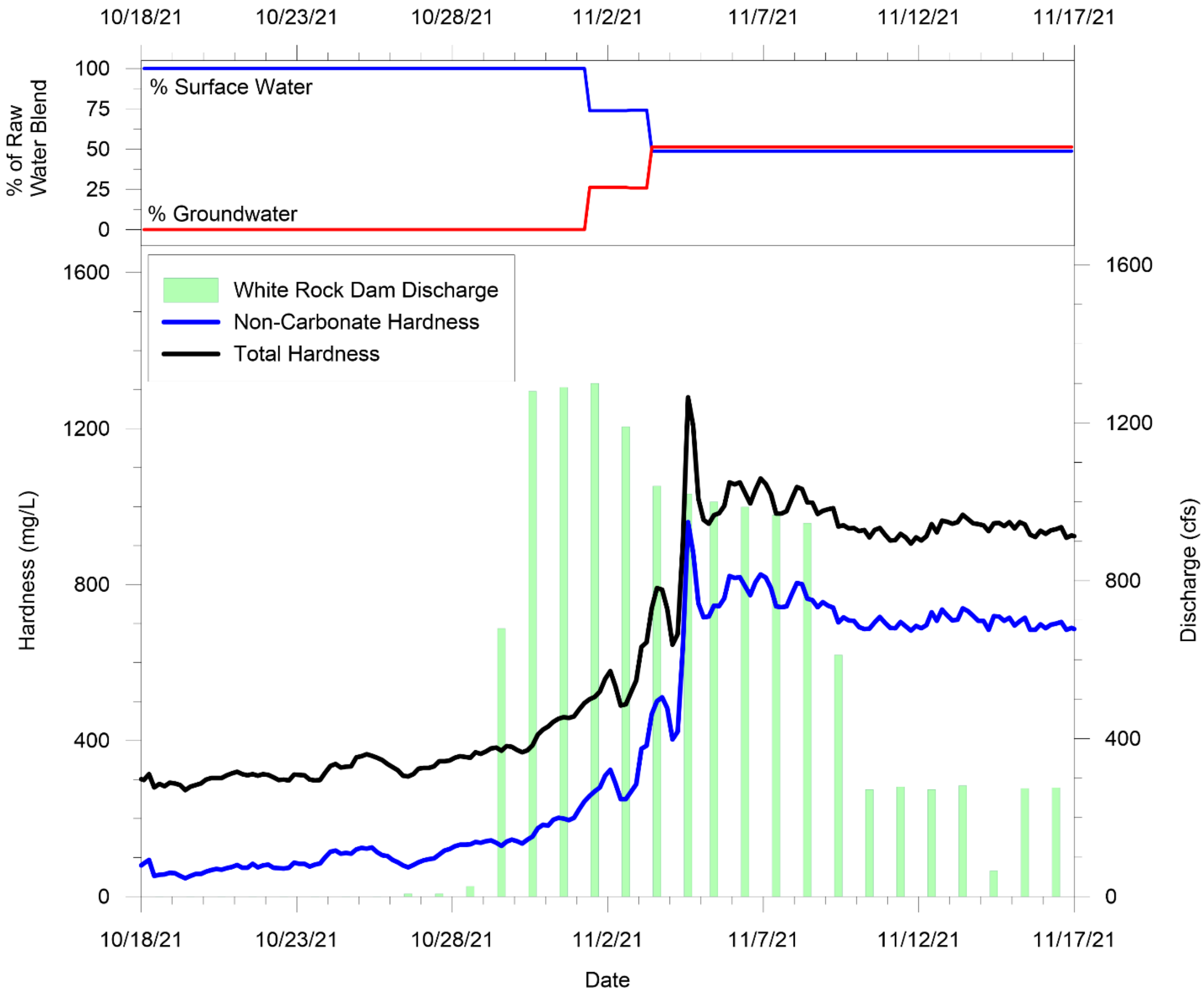

Figure 8 – White Rock Dam release impact on hardness measured at the MPS intake (bottom) and source water blending response from MPS as a result of water quality changes (top).

Table 5 – Average Daily Cost Comparison of River Water Treatment Versus Groundwater Blending Event (October through November 2021)

	% River	Lime	Soda Ash	Liquid Ferric	Fluoride	Carbon Dioxide	Sodium Hexa	Total Daily Cost[1]
Before Blending	100%	$1,018.93	$568.06	$435.43	$33.64	$87.87	$24.00	$2,293.71
Blending Nov 1 - 2	78%	$1,310.70	$1,303.70	$429.12	$36.47	$145.28	$0.00	$3,342.30
Blending Nov 3 - 16	48%	$1,561.28	$2,303.88	$495.67	$34.96	$108.03	$29.14	$4,645.58
% Change (Before vs. Nov 3 - 16)		153%	406%	114%	104%	123%	121%	203%

▪1 Total daily cost includes chemicals (chlorine, ammonia, anionic polymer, lox, and calcium thio) not shown in this table that did not increase in cost with blending.

Events like this have happened in the past, under different climatic circumstances, and with some differences in costs. Spring through fall of 2021 brought a sustained drought throughout much of Minnesota and the Dakotas, and the large increase in hardness with White Rock Dam flows may have been made more extreme by this drought. However, MPS has had to dilute White Rock Dam-influenced flows in the Red River before and will likely need to do so in the future. The Bois du Sioux River in general, whether upstream or downstream from White Rock Dam, is heavily impacted by agriculture, with 86% of land usage devoted to agriculture, and is heavily hydrologically modified, and therefore downstream flow chemistry has been degraded relative to the Otter Tail River and other tributaries (MPCA, 2020). The combined impacts from heavy alteration to support agriculture and climate change may increase TDS issues in the Red River in the future. The Climate Change Impacts section discusses how climate change may contribute to water quality concerns.

Pesticides and Nutrients

No pesticides have recently been detected within the HUC12 watersheds within the DWSMA-SW. Also, no pesticides have been found during routine entry point sampling conducted during the past 20 years by MPS. However there have been detects of chlorpyrifos and some other pesticides in the greater Red River Valley in reaches downstream from Fargo-Moorhead. As such, and due to the dominance of crop cultivation as a land use in the watershed, as well as the altered hydrology present that can shorten travel times from fields to adjacent waterbodies, pesticides and nutrients remain a concern in Moorhead's surface water. Monitoring for these chemicals in source water should be considered a priority.

Potential Contaminant Source Inventory

MDH, MPS, and the city of Moorhead conducted a Potential Contaminant Source Inventory (PCSI) to evaluate the different types of contaminants found in the watershed that threaten the quality of the city's source water. These identified potential sources can have a direct or indirect threat to public health and the drinking water quality. The PCSI is organized by threats and potential risks closest to the intake (i.e ERA), potential contaminants along contributing water bodies (i.e. SMA), and land use management within the DWSMA-SW. The data in the tables was collected from various state and local databases and discussed in detail with the city and SWCD.

An interactive map was created for the PCSI and a Keyhole Markup Language (i.e. KML) file version of the map will be provided to MPS and the city for spatial reference. MDH can provide an archived map and its attributes for these locations to other partners on request.

The following source summaries document the different types of contaminant sources within the ERA and SMA. Certain types of contaminants are indicated as being high priority due to the fact that they can have a significant impact on surface water quality. Each identified contaminant source went through a detailed analysis; MDH can provide the criteria for these analyses on request.

Point Source Contaminants in the ERA and SMA

The following summary documents the point sources identified in the ERA and SMA:

Point Sources in the ERA and SMA	
Aboveground Tanks:	1 facility (high priority)
Feedlots:	3 (high priority)
Industrial Stormwater:	1 (high priority)
Municipal or Privately-Owned Stormwater Outlets	60 (high priority)
Wastewater, Municipal Collection System:	2 (high priority)
Wastewater, Municipal NPDES/SDS Permit:	2 (high priority)
Construction Stormwater Permit:	10
Underground Pipeline:	2 SMA

There is one aboveground tank site in the SMA. Cenex Land O Lakes has on-site storage of one diesel fuel tank holding 560 gallons of fuel. No aboveground tanks are known to exist in the ERA or SMA in North Dakota, however at the time of this publication, centralized authority of aboveground storage tanks was being negotiated, so information was not available.

There are three known, registered feedlots in the SMA in Minnesota: the Scott Smith Main Farm, Paul Rehder Farm, and Steve Walker. No feedlots are known to exist in the ERA or SMA in North Dakota. Contaminants associated with feedlots include soil runoff, bacteria, fertilizer, etc. Proper manure management is crucial to operating a compliant feedlot and minimizing water quality impacts.

Stormwater outlets can be a quick avenue for contaminants to be carried to a waterbody. There is one industrial stormwater permit that is open and active. The Knife River Materials – Moorhead facility is within the ERA.

There is a total of 60 stormwater outlets that drain into the Red River in the ERA and SMA. There are 59 municipal stormwater outlets that are within the ERA, with the majority (57) owned exclusively by one of the two cities. Two outlets are owned by the Bluestem Amphitheater. One additional outlet is in the SMA, and is owned by the city of Oxbow.

There is one municipal wastewater NPDES/SDS permit within the SMA. The permit sets limits on discharges from the cities of Sabin and Comstock. Additionally, the cities of Moorhead and Fargo both have municipal wastewater collection systems operating within the ERA and SMA; both cities discharge into the Red River downstream from the Fargo-Moorhead area.

The 10 construction stormwater permits in Minnesota are considered open and active. The runoff from these sites can contaminate the city's source water if not handled appropriately. A simple on-site visit to these locations can determine if the construction areas are a potential contamination source. No construction stormwater permits were found on the North Dakota side of either the ERA or SMA.

There are two underground pipelines that cross under the Red River in the ERA. The Nustar Pipeline Operating Partnership and Magellan Pipeline Company own and operate these pipelines. The pipelines contain a type of liquid that is considered to be "non-highly-volatile". Both pipelines cross underneath the Red River less than one mile south of the I-94 bridge crossing.

Non-Point Source Contaminants in the ERA and SMA

The following summary documents the non-point sources identified in the ERA and SMA:

Non-Point Sources in the ERA and SMA	
Railroads:	8: 1 ERA, 7 SMA (high priority)
Roads/Bridges Over Surface Water:	88: 11 ERA, 77 SMA (high priority)
Streets/Roads Near Surface Water:	194 (high priority)
Golf Course:	2
Holding Ponds:	1 SMA
Open Green Spaces (Baseball Fields, Parks, Cemeteries etc.):	18

There are 88 roads or bridges that cross over a stream or ditch in the ERA and SMA, with 11 crossings in the ERA and 77 crossings within the SMA. There are an additional 197 city streets and rural roads in both North Dakota and Minnesota that are near a tributary waterbody, which can also effect source water. The time of travel and dilution factor are much higher on roads outside of the ERA. In addition, there are eight railroad bridges that span streams and ditches in the ERA and SMA.

As mentioned above, large green spaces can be a source of nutrient runoff and contamination. There are two golf courses (Rose Creek and Fargo Country Club, both in North Dakota) in the ERA. Of the Open Green Space sites, there are three cemeteries (Evergreen Memorial Cemetery in Moorhead, Sunset Memorial Gardens and Riverside Cemetery in Fargo) that are in the ERA. The balance of the Open Green Space sites are parks, with 11 on the North Dakota side, and four in Minnesota.

There is a holding pond complex associated with the city of Sabin's Sewage Treatment Facility located in the SMA. This pond complex does have an outlet that funnels to County Ditch #32, and is located approximately 180 feet from the bank of the ditch. The city of Comstock also has a wastewater treatment facility holding pond complex that is adjacent to the SMA. Because the complex is not within the SMA, it is not included in the holding ponds number shown above.

Drinking Water Supply Management Area – Surface Water

Point source contaminants are not considered for management within the DWSMA-SW by definition, except where those contaminant locations are also within the ERA and SMA. Non-point source management through analysis of land use, existence of drain tile, and nutrient and pesticide sourcing within the DWSMA-SW is addressed below.

Land Use

Land use plays an important role in water quality and directing implementation activities in the ERA, SMA and DWSMA-SW. The following section describes land uses documented in the 2019 National Land Cover Database (USGS, 2021), and land use-associated impacts to surface water quality and drinking water.

Land use overall is quite diverse, ranging from a large metropolitan area with outlying small towns, to a thriving rural farming community. Although the source water area contains a well-developed metropolitan area, the majority of the land use in the region is agricultural. Agricultural in the region is largely cultivated for crops or used as hay/pasture lands.

Most of the DWSMA-SW is located in Cass County, North Dakota, or Clay County, Minnesota. Both counties have well-developed land use plans in place to oversee growth. The cities in the Fargo-Moorhead Metropolitan area have well developed land use plans and planning departments managing these issues in their respective city limits.

Residential development is concentrated in the urban centers. Moorhead, MN, Dilworth, MN, and Fargo and West Fargo, ND, are the largest cities in the area. These cities manage storm water through local ordinance and state statutes. Typically, storm water is managed by impounding and discharging storm water runoff to the river through a well-developed storm water conveyance system. Several smaller cities are located up stream of the city of Moorhead drinking water intake. It appears that there are varying levels of storm water management in these areas.

Commercial and industrial land uses make up a relatively small portion of unincorporated areas upstream. Rural commercial uses are generally located along the larger county roads, and state and interstate highways. Typically, rural businesses are targeted towards serving the agricultural community. The larger cities have a well-developed industrial and commercial sector, and many of these facilities have industrial storm water permits. Fargo has a comprehensive storm water management ordinance and follows the State of North Dakota requirements. Moorhead is governed as a Minnesota MS4 storm water system and has a comprehensive storm water management program. In both cases discharges from commercial/industrial uses are rigorously managed.

Public park use is limited in scope in the SMA but is quite common in the ERA. Many of these facilities are open spaces with little generation of storm water runoff due to the relative lack of impervious surfaces, allowing for increased infiltration of storm flows. Park authority use of fertilizers and pesticides should be managed to protect drinking water downstream.

Flood prevention has driven a great deal of land use change in the past few decades. The Red River flows north through Fargo and Moorhead. Winter snow melts commonly cause the Red River to overflow its banks. Large scale flooding of the Metro area is not uncommon and can have large impacts on the Moorhead water intake during events. Controlling flooding and bypassing the Moorhead intake will mitigate water quality issues caused by spring flooding. The Climate Change section below discusses the measures that are being taken to address Red River flooding.

Emergency Response Area

Forty-five percent of the ERA overlaps with the city of Moorhead, and the cities of Fargo and Briarwood in North Dakota. This developed area is concentrated in the portion of the ERA that is immediately upstream of and surrounding the intake. The ERA contains the Red River streams and County Ditches 9 and 32. These waterways stretch a total of 19.8 miles throughout a mix of cultivated crops, development, and wetlands. The ERA contains almost as much developed area (40.3%) as cultivated crops (43.0%).

Spill Management Area

The SMA encompasses 14 streams and ditches, as specified in the Delineated Watershed Areas section. These reaches flow through 132 miles of cultivated crops (8,966 acres or 67.7% of SMA area) and wetlands (2,470 acres or 18.7% of SMA area), with minor portions of developed area (1,057 acres or 8.0% of the SMA) and open water (662 acres or 5.0% of the SMA).

Drinking Water Supply Management Area – Surface Water

The DWSMA-SW is Moorhead’s largest delineated protection area at 21,458 acres. Over 83% of land use is cultivated crops. The second largest land use component is development (12.3%) and is comprised of impervious surfaces such as roads, buildings, and other infrastructure.

Given the large percentage of cultivated crops, and the predominance of altered drainage via drain tile and ditching in the watershed, this area would benefit from improved drainage management and management of fertilizer and cover crop use to help reduce the sediment and nutrient loading effects.

The following table describes land uses within the ERA, SMA, DWSMA-SW, and the headwaters of the Red River Watershed.

Table 6 – Land Uses within Delineated Protection and Watershed Areas

Type of Area (unit size)	Emergency Response Area	Spill Management Area	Drinking Water Source Management Area – Surface Water	Entire Red River watershed upstream from Fargo-Moorhead
Area (acres)	5,391	13,234	210,458[3]	4,256,679[4]
Lake area in acres (# of lakes)	3.4 (One Lake)	8.3 (9 Lakes, Ponds, and Reservoirs)	156.9 (64 Lakes, Ponds, and Reservoirs)	245,179 (10,657 Lakes, Ponds, and Reservoirs)
Stream length in miles (# of stream segments[2])	23.7 (33 Stream segments)	118.1 (210 Stream segments[1])	372.4 (422 Stream segments[1])	5,978 (9,517 Stream segments)
Barren Land (acres)	0 (0%)	4 (<1%)	16 (<1%)	5,498 (<1%)
Cultivated Crops (acres)	**2,319 (43.0%)**	**8,966 (67.7%)**	**175,104 (83.2%)**	**2,721,995 (64.0%)**
Development (acres)	**2,172 (40.3%)**	**1,057 (8.0%)**	**25,971 (12.3%)**	245,183 (5.8%)
Forest (acres)	8 (<1%)	46 (<1%)	798 (<1%)	**300,910 (7.1%)**
Hay/Pasture (acres)	0 (0%)	12 (<1%)	152 (<1%)	244,839 (5.8%)
Herbaceuous (acres)	0 (0%)	18 (<1%)	528 (<1%)	106,814 (2.5%)
Open Water (acres)	321 (6.0%)	662 (5.0%)	1,553 (<1%)	270,970 (6.4%)
Shrub land (acres)	0 (0%)	0 (0%)	2 (<1%)	4,682 (<1%)
Wetlands (acres)	**570 (10.6%)**	**2,470 (18.7%)**	**6,332 (3.0%)**	**358,358 (8.4%)**

[1]Streams were determined by historical photo analysis showing perennial flow
[2]Streams are based on the National Hydrography Dataset (NHD) flowlines
[3]Area is a combined acreage of the ERA, SMA, and DWSMA-SW
[4]Area includes the ERA, SMA, and DWSMA-SW, as well as land in Minnesota, North Dakota, and South Dakota

Buffer Law Compliance

The Minnesota buffer law was established in November 2017 for all public waters and November 2018 for public ditches. The law provides flexibility to all landowners to comply with the law by using practices that are outlined in the Natural Resources Conservation Service Field Office Technical Guide. Both counties that contain the ERA and SMA, Clay and Wilkin, are at 95-100% compliance. Buffered waterbodies that are in compliance are low priority for Source Water Assessment and planning purposes.

Public waters and ditches that are within the DWSMA-SW and are not in compliance should be considered high priority for bringing into compliance. Protecting waters that contribute to the drinking water supply should be addressed first to ensure sediment concentration in the Red River improves. Implementation activities will require collaboration and communication with

Clay or Wilkin Counties. Compliance with the buffer law is beneficial for managing surface water runoff near waterbodies, but with drain tile in the DWSMA-SW, the management of land use and fertilizer practices needs to be addressed as well.

Climate Change Impacts

Historically, the flatness of the Red River Basin has contributed to frequent flooding in the Fargo-Moorhead area. The Red River Basin is at the bottom of the glacial Lake Agassiz Basin. The basin is characterized by slopes of around one foot per mile in the DWSMA-SW, particularly in the reaches between Wahpeton-Breckenridge and Fargo-Moorhead (Red River Watershed Management Board, 2004). This very shallow slope, combined with heavy clay and swelling clay-rich soils, creates an environment where the flooding Red River overspills its banks easily to form massive, shallow ponds on the valley surface (Schwert, 2003).

Flooding in the basin is also complicated by late-winter to early-spring snow melt dynamics. The Red River flows north, making ice dams of the river during sudden melting periods common. These ice dams have been to blame for many of the largest flood events, including the 1997 flood, which is the flood of record for most of the major towns and cities in the U.S. portion of the basin. In Fargo-Moorhead, only the 2009 flood was larger, and it, too, was caused by the same spring melt runoff issues that affected the metro area in 1997 (U.S. Army Corps of Engineers, 2011).

Additionally, annual precipitation totals have increased over time, and are expected to continue to increase as climate change progresses through the 21st century (Minnesota Department of Natural Resources, 2021). Figure 10 features data collected from the Minnesota Climate Explorer tool, which shows the annual precipitation trend for the Upper Red River watershed, and the annual mean climate projections of precipitation for the middle and late 21st century. The ranges shown represent an average of the most commonly used climate model calculations, which in turn use the most plausible IPCC greenhouse gas emissions scenarios, including a mid-century reduction best case scenario in blue (RCP 4.5, where greenhouse gas emissions begin to drop by 2045), and a worst-case scenario where emissions continue at current levels in red (RCP 8.5, where emissions continue to increase throughout the 21st century). The projections averages (means of all downscale model runs, represented by the longer line at the middle of the shaded ranges) of the two time points (mid- and late-century) highlight the range in uncertainty of all IPCC evaluated models.

The projected precipitation ranges are quite large, but illustrate what climate scientists have hypothesized about how climate change is expected to affect annual precipitation trends in the Red River valley. Average annual precipitation is expected to increase by about two inches by mid-century, and if CO_2 emissions continue at current rates, average annual precipitation is expected to increase by an additional two inches by the year 2100. The plotted ranges shown indicate that annual precipitation amounts could be far greater or far less, as precipitation events are also projected to become more extreme as well.

Another factor in model trends is that increasing temperatures in the watershed could actually mean that the region experiences more droughts, even with increased precipitation. Model means for the two scenarios indicate average annual temperature increases of six to 10 degrees

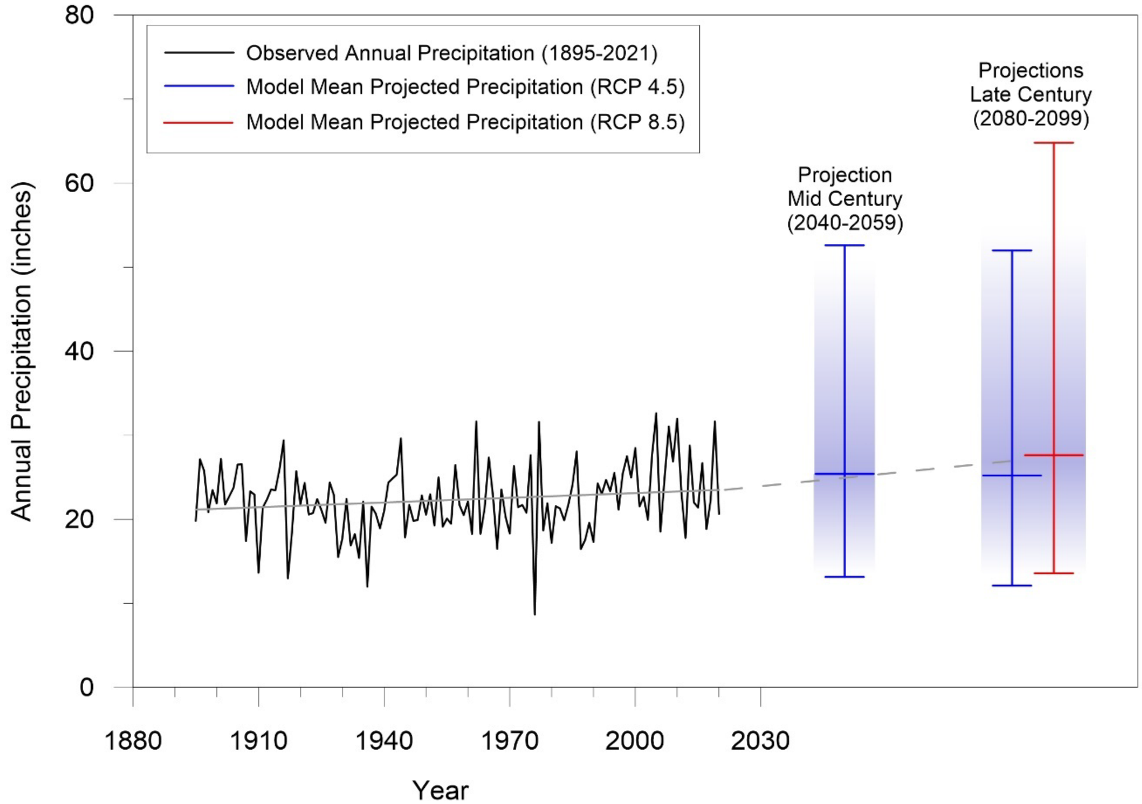

Figure 9 – Observed annual precipitation trend and average modeled climate change projections for the mid and late 21st century based on models simulating the RCP 4.5 reduced CO_2 emissions scenario and the "worst-case" continued CO_2 emissions scenario.

Fahrenheit for RCP 4.5 and RCP 8.5, respectively. These higher temperatures will drive increased evaporation rates and could lead to less flow available in the Red River for surface water supplies.

Flooding due to climate change is projected to be a continuing problem in the Red River Valley in the coming century. As discussed in more detail in the 2020 Minnesota State Water Plan (BWSR, 2020), climate model projections suggest that the Red River in particular will see more heavy spring rainfall events, with late summer becoming drier than current patterns. As shown in the Long Term Flood Solutions report (Red River Basin Commission, 2011), heavy or exceptional flooding events are expected to become more frequent. While snowmelt ice dams are the more common causes of major flood events on the Red River, large scale severe rainfall events have caused several recent flood events of note, including the 2007 flood, as well as the 2014 event as shown in USGS flood crest data. All told, 22 of the years since 1900 have seen 10-year or greater flood events. Of those events, 10 have occurred in the past 25 years.

Flooding and drought are both quite disruptive to Moorhead's water supply planning. MPS typically relies more heavily on groundwater during flood periods, and flood events in the future could lead to faster depletion of the area's aquifers. If flood periods become more frequent then groundwater dewatering is likely to become an even larger concern. The same groundwater depletion is likely during increased drought scenarios.

The city of Fargo and state of North Dakota are currently building the Fargo-Moorhead flood diversion project (Metro Flood Diversion Authority, 2021). This project will, during flood events, hold back excess flows upstream along the Red River while diverting those excess flows through a man-made channel west of the Fargo metro area. The diverted flow will rejoin the Red River north of the metro area. The project has already partially constructed dam structures south of the Fargo-Moorhead area, and recent project updates have outlined plans for diversion channel construction through West Fargo. As of the time of this report, the project is expected to be finished in 2027.

Drought planning has also been conducted by the city of Fargo and state of North Dakota. Planning for the Red River Valley Water Supply Project (2021) is in progress to divert flow from the Missouri River to Fargo during periods of low flow in the Red River. This project is still in early planning stages with limited construction completed, and is not likely to be fully completed before Moorhead's next SWA amendment is slated to occur. MPS is not currently an end user in the project, so it is not known how Moorhead would potentially benefit from these Missouri River flows.

Summary of High-Priority Issues

Moorhead's surface source water has been impacted by watershed-wide, erosion-driven high turbidity, as well as increasing total dissolved solids (TDS) in solution. These high TDS or turbidity periods force the MPS to use more of its limited groundwater resources. Pesticides have not yet been observed in Moorhead's entry point samples, however continued monitoring for pesticides upstream from the intake will be crucial for ensuring safe drinking water. Additionally, the Red River is expected to continue to frequently flood due to increasing precipitation due to climate change, which could also force MPS to increasingly rely on groundwater to meet the needs of water users. The issues below are the highest priority for action within the delineated Source Water Assessment areas for the city of Moorhead.

Emergency Response Area and Spill Management Area: MPS and the city should ensure that their emergency management plan is updated to address any potential contamination events. The most prevalent issue that could impact the city's drinking water is municipal stormwater from both Fargo and Moorhead. Other management priorities include two pipelines that cross the Red River, as well as construction stormwater permits, industrial stormwater, and one feedlot on the Minnesota site of the river.

Also present in the ERA and SMA are roads adjacent to and bridges over the river and tributaries, which could impact river water quality during spills or via stormwater flushing. Railroad crossings and boat landings are also potential spill sources in the ERA and SMA. These infrastructure locations can quickly contaminate the source water and should be a focus in an emergency spill management plan.

Drinking Water Supply Management Area – Surface Water: The DWSMA-SW is primarily dominated by agriculture, with some area devoted to urban land uses. The long-term health of the watershed can be improved by focusing on best management practices for erosion prevention, land use, fertilizer, and runoff, all of which can have negative impacts on water quality.

Recommended Actions

The SWA is a tool for the PWS and local partners. The PWS and local partners should consider implementing the activities below to protect the source water and its surrounding watershed. The activities should also be included in Moorhead's Surface Water Intake Protection Plan when it is developed.

Monitoring Source Water

Continued monitoring of source water quality is needed to determine the best implementation approaches to address the current and potentially worsening water quality in the contributing watershed. Reaches within the ERA and SMA should be the main focus for implementation of measures that address point source contamination. As was mentioned in the "Contaminants of Concern" section, a number of reaches in the DWSMA are impaired for aquatic recreation, aquatic life, and aquatic consumption uses.

Monitoring of total dissolved solids and/or major ion chemistry trends should also be a priority. Some analytes are already regularly above secondary drinking water limits, and so present aesthetic concerns for MPS. Conclusively tracing the high sulfate source and determining if there are any efforts that could mitigate the issue would help ensure that MPS is able to rely more exclusively on their surface water intake.

A dye-trace study, coupled with watershed flow modeling of the Upper Red River HUC8 watershed, would help refine the delineation of the SWA areas identified in this document. The larger contributing streams and perennial ditches that lack flow gage data should be a major focus of the study, although all of the larger gaged streams should also be studied. Creating a valid model requires large amounts of flow data. Once established, the model can be used to determine potential impacts from contaminant sources throughout the watershed. A model could also help to better outline nutrient, pesticide, and sediment erosion budgeting in the watershed.

Emergency Preparedness

Emergency spill prevention and response preparedness is a vital aspect of protecting the source water. The annual PWS emergency plan is necessary and should be updated to include the SWA and coordinated with the MPCA Emergency Response unit, first responders, city planners, and local government staff. Existing coordination of emergency response with current city, county , and state government partners in North Dakota should continue as well.

Potential Contaminant Source Management

Point and non-point source contamination is a high priority for protecting source waters and public health. The point source locations of highest concern are listed in the Potential Contaminant Source Inventory section. For contaminants in Minnesota, each one of the PCSI points is associated with an agency (MPCA, MDA, etc.), local authority, or contaminant source owner. These entities should work together to set up an approach to mitigate the contaminant issue. For contaminants in North Dakota, collaboration with the city of Fargo, Cass County, and the State of North Dakota should be considered.

Contaminant Conveyances and Potential Releases

Stormwater in the ERA is a major concern for MPS. Any direct runoff and stormwater conveyance structures that are closest to MPS's intake are of greatest concern. Understanding the directional flow and contributing surfaces to the stormwater system is key to understanding how to mitigate any potential contamination. Additionally, investigation should be completed to determine if fueling stations near the ERA and SWA have stormwater conveyances that could rapidly move a large fuel spill to the river. This information should be added to emergency response plans so that first responders can block flow to these input points or capture materials at their source. The stormwater conveyances may also need to be included in future SWA delineations, based upon any stormwater system modeling data that may be available at that future time.

Non-Point Source Pollution and Land Management

Non-point source nutrients and pesticides are a concern for the city's drinking water even though they have not yet been detected at Moorhead's intake. Of greater concern for water quality is sediment transport in the Red River, which is the product of ditching and hydrologic alteration throughout the watershed. These issues can be addressed through cooperation with watershed authorities, local producers, and agronomists. Education of these groups about pesticide and sediment loss from agricultural fields should be key components of the plan.

Alternative Water Supply

Alternative and emergency water sources are an important factors in source water protection planning. Planning for additional wellfields has been documented in the Buffalo Aquifer Management Plan (MPS, 2017) and through recent conversations with the DNR (2022). MPS also continues to stay up to date on the progress of the Red River Valley Water Supply Project in an effort to verify costs of membership and end user inclusion, and compare feasibility to expansion of groundwater pumping capacity along the length of the Buffalo Aquifer as described in MPS's Buffalo Aquifer Management Plan. Planning for new wellfields, and potentially using new pumping strategies to minimize aquifer impacts, should continue to be conducted with collaboration with the DNR.

The "Public Water System Characteristics" summary above states that MPS has water storage capacity of between one and two days. The existing set of Buffalo and Moorhead aquifer wells are able to provide a full-volume back-up for the intake during normal conditions, but exclusive use of the two aquifers for years or decades is likely to reduce water levels in the aquifers, particularly during drought conditions when aquifer recharge has been diminished. Exploring and possibly establishing additional back-up capacity should be considered to ensure that Moorhead's water supply is more resilient during times that the Red River is flooded, at low flow, or is of poor quality.

Additionally, aquifer storage and recovery (ASR), wherein surface water is infiltrated through overlying sediments into one or more of the city's aquifers for future use, could be a solution to decreasing yields from groundwater, provided water quality or aquifer properties are not degraded by the infiltration process. At this time MPS is not planning for any ASR projects, however a follow-up study to the ASR feasibility analysis conducted by the University of Minnesota Water Resources Center (2021) could be useful.

Source Water Protection Planning

MDH can assist MPS and the city in developing a Surface Water Intake Protection Plan (SWIPP) that will lay out strategies for protecting and improving source water quality. MPS and the city of Moorhead can receive assistance from the MDH Surface Water Planner and Hydrologist to complete the planning document. Upon completion of the SWIPP, MPS and the city of Moorhead will be eligible for MDH plan implementation grants to fund documented plan activities. The SWIPP will also guide the MPS and local planning partners by documenting other potential complementary watershed-level activities to protect drinking water on a larger scale than can be accomplished by MPS alone.

The DWSMA-SW stretches into Clay and Wilkin Counties in Minnesota, and both contribute to the source water for the city of Moorhead. Water planning and implementation in the area has been ongoing (Clay County, 2017, and Buffalo – Red River Watershed District, 2020). The Buffalo-Red River Watershed District recently began implementing their Comprehensive Watershed Management Plan (2020) for the Upper Red River downstream from the Orwell Dam, and drinking water was featured in that document. The implementation strategies developed in the future SWIPP can be used to inform drinking water-focused activities in the various other One Watershed, One Plan areas within the DWSMA when they are written, and can also be adopted in other future planning documents.

The DWSMA-SW also reaches into Cass and Richland Counties in North Dakota. Water resource planning operates differently on both the state and county level in North Dakota, and water resource plans at the local level do not address CWA or SDWA issues within planning areas or downstream from those areas.

This SWA is designed to provide guidance for planning purposes for the next 10 years. After the 10 years have elapsed MDH will reassess all aspects of the SWA. This updated SWA will then guide the amended SWIPP.

References

Benayache, Naila-Yasmine, Tri Nguyen-Quang, Kateryna Hushchyna, Kayla McLellan, Fatima-Zohra Afri-Mehennaoui, and Noureddine Bouaïcha (2019), *An Overview of Cyanobacteria Harmful Algal Bloom (CyanoHAB) Issues in Freshwater Ecosystems*." In Limnology-Some New Aspects of Inland Water Ecology. IntechOpen.

Buffalo – Red River Watershed District. (2020), *Buffalo-Red River Watershed Comprehensive Watershed Management Plan*. http://www.brrwd.org/pdf/1W1P_2018/1W1P_Final_Plan_Docs/BRRW_CWMP_Final_10-28-20.pdf

Clay County, Minnesota. (2017), "Local Water Management Plan, 2017 – 2026". https://claycountymn.gov/DocumentCenter/View/5492/Clay-County-LWMP-2017-2026-?bidId=

Edwards, M., & Triantafyllidou, S. (2007), *Chloride-to-sulfate mass ratio and lead leaching to water*. Journal American Water Works Association, 99(7), pp. 96–109.

Lindholm, G. F., and Norvitch, R. F. (1976), *Ground water in Minnesota,* United States Geological Survey Open File Report 1976-354, St. Paul, Minn., 100 p.

Metro Flood Diversion Authority. (2021), *Fargo-Moorhead Area Diversion Project*, Fargo, North Dakota. https://www.mdiversion.gov/

Minnesota Department of Health. (2022), *Surface water Source Water Assessment and Surface Water Intake Protection Plan Guidance*.

Minnesota Department of Natural Resources. (2022), Memo regarding Buffalo aquifer model runs for drought planning, 2 p.

Minnesota Environmental Quality Board. (2020), *Minnesota State Water Plan*. https://www.eqb.state.mn.us/sites/default/files/documents/2020_water-plan%20FINAL.pdf

Minnesota Pollution Control Agency. (2021), *Otter Tail River Watershed WRAPS report*. https://www.pca.state.mn.us/sites/default/files/wq-ws4-82a.pdf

Minnesota Pollution Control Agency. (2020), *Bois de Sioux River Watershed WRAPS report*. https://www.pca.state.mn.us/sites/default/files/wq-ws4-43a.pdf

Minnesota Pollution Control Agency. (2017), *Upper Red River of the North Watershed WRAPS report*. https://www.pca.state.mn.us/sites/default/files/wq-ws4-36a.pdf

Minnesota Pollution Control Agency. (2013), *Mustinka River Watershed Monitoring and Assessment report*. https://www.pca.state.mn.us/sites/default/files/wq-ws3-09020102b.pdf

Minnesota Pollution Control Agency. (2021), *What's In My Neighborhood* application. https://www.pca.state.mn.us/data/whats-my-neighborhood

Moorhead Public Service. (2006), Water Distribution System Modeling and Capital Improvements Study, Ulteig Engineers, Inc., Fargo, ND, 100 p.

Moorhead Public Service Wellhead Protection Team. (2013), *Wellhead protection plan for Moorhead Public Service--Part 2 - Amendment*, Moorhead, Minn., 46 p.

Oswald, J., and Hume, D.S. (2012), *Wellhead protection plan for the city of Moorhead, Minnesota--Part 1 - Amendment*, Leggette, Brashears and Graham, Inc., St. Paul, Minn., 12 p.

Red River Valley Water Supply Project. (2021), http://www.rrvwsp.com/

Red River Watershed Management Board. (2004), *Red River Basin Flood Damage Reduction Framework*. https://www.rrwmb.org/TSAC/TP11.pdf

Schwert, D.P. (2003), *A geologist's perspective on the Red River of the North: history, geography, and planning/management issues.* Proceedings 1st International Water Conference, Red River Basin Institute, Moorhead, Minn, 16 p.

United States Army Corps of Engineers. (2011), *Red River Basin Commission's Long Term Flood Solutions for the Red River Basin.* http://www.mvp.usace.army.mil/Portals/57/docs/Civil%20Works/Projects/Red%20River/A01_AttachmentA1_LTFSR_main_report_excerpt.pdf?ver=2018-04-18-101653-450

United States Environmental Protection Agency. (2021), *National Safe Drinking Water Act Contaminants National Primary Drinking Water Regulations.* https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

University of Minnesota Water Resources Center. (2021), *Banking Groundwater: A study examining aquifer storage and recovery for groundwater sustainability in Minnesota*. https://www.wrc.umn.edu/banking-groundwater-managed-aquifer-recharge

Wilkin County. (2008), Wilkin County Local Water Management Plan. https://www.co.wilkin.mn.us/vertical/sites/%7B6E7AB7CB-4769-4357-B6C8-90E546FFE488%7D/uploads/%7B845DB98B-6CA5-42AB-B585-BE3E4D1AB008%7D.PDF