Stressor Identification

January 2018

Wild Rice River Watershed Stressor Identification Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Acronyms

AUID – Assessment Unit Identification

BMP – Best Management Practices

Chl-a – Chlorophyll-a

CR – County Road

CSAH – County State Aid Highway

cfs – cubic feet per second

DNR – Minnesota Department of Natural Resources

DO – Dissolved Oxygen

EPA – United States Environmental Protection Agency

EPT – Ephemeroptera, Plecoptera, and Trichoptera

F-IBI – Fish Index of Biological Integrity

HSPF – Hydrological Simulation Program - FORTRAN

IBI – Index of Biological Integrity

IWM – Intensive Watershed Monitoring

M-IBI – Macroinvertebrate Index of Biological Integrity

MPCA – Minnesota Pollution Control Agency

MSHA – MPCA's Stream Habitat Assessment

NAIP – National Agriculture Imagery Program

NLCD – National Land Cover Database

SID – Stressor Identification

TALU – Tiered Aquatic Life Use

TIV – Tolerance Indicator Value

TP – Total Phosphorus

TSS – Total Suspended Solids

USGS – United States Geological Survey

WHAF – Watershed Health Assessment Framework

WRRW – Wild Rice River Watershed

WRWD – Wild Rice Watershed District

Executive summary

The Minnesota Pollution Control Agency (MPCA) follows a watershed approach to systematically monitor and assess surface water quality in each of the state's 80 major watersheds. A key component of this approach is Intensive Watershed Monitoring (IWM), which includes biological (i.e., fish and macroinvertebrate) monitoring to evaluate overall stream health. In 2014 and 2015, the MPCA conducted biological monitoring at several stations throughout the Wild Rice River Watershed (WRRW). An Index of Biological Integrity (IBI) score was then calculated for each fish (F-IBI) and macroinvertebrate (M-IBI) monitoring visit. The biological monitoring results for the watershed were assessed to identify individual stream reaches that were not supporting a healthy fish and/or macroinvertebrate assemblage. A reach with a low IBI score(s) (i.e., below an established threshold) is considered "impaired" (i.e., unable to support its designated beneficial use) for aquatic life. A total of seven reaches were determined to have a F-IBI and/or M-IBI impairment in the WRRW, including segments of Felton Creek/County Ditch 45, Garden Slough, Mashaug Creek, South Branch of the Wild Rice River, Spring Creek, and the Wild Rice River.

This report identifies the probable causes, or "stressors", that are likely contributing to the biological impairments in the watershed. Six candidate causes were examined as potential stressors for the biologically impaired reaches: loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, high suspended sediment, low dissolved oxygen (DO), and high temperature. Causal analysis was then performed to determine and evaluate connections between each candidate cause and the biological impairments.

Connectivity barriers are adversely affecting fish passage along segments of Felton Creek/County Ditch 45 (beaver dams and perched culverts), Garden Slough (Mashaug Creek No. 3 Dam) and the Wild Rice River (Lower Rice Lake Dam). Many of the biologically impaired reaches are prone to high and quick peak flows and/or prolonged periods of low or no discharge. Historical changes in land cover (e.g., native vegetation to cropland) and drainage patterns (e.g., channelization and ditching) are the primary anthropogenic factors contributing to this flow regime instability. Alterations to the natural hydrology of the landscape have also caused the degradation of instream habitat (e.g., bank erosion and embeddedness of coarse substrate) for many of the reaches. A number of the reaches are prone to periods of high suspended sediment. Instream and soil erosion are the primary sources of this sediment. Low DO is a stressor for nearly all of the reaches. While the severity of low DO conditions varies amongst the reaches, the lowest concentrations generally occur in the summer, when flow is low and the water temperature is high. Lastly, the headwaters of Felton Creek/County Ditch 45 is unique for the watershed in that it is a coldwater system. However, the impoundment of water caused by beaver dams is believed to be contributing to periods of high temperature, which limits the potential of the reach to support sensitive coldwater taxa.

Introduction

Stressor identification (SID) is a formal and rigorous methodology for determining the causes, or "stressors", that are likely contributing to the biological impairment of aquatic ecosystems (EPA, 2000). The initial step in the SID process (Figure 1) is to define the subject of the analysis (i.e., the case) by determining the geographic scope of the investigation and the effects that will be analyzed. Thereafter, a list of candidate causes (i.e., potential stressors) that may be responsible for the observed biological effects is developed. The candidate causes then undergo causal analysis, which involves the evaluation of available data. Typically, the majority of the data used in the analysis is from the study watershed, although evidence from other case studies or scientific literature can also be drawn upon. Analyses conducted during this step combine measures of the biological response, with direct measures of proximate stressors. Upon completion of causal analysis, strength-of-evidence analysis is used to determine the probable stressors for the biological impairment. Confidence in the final SID results often depends on the quality of data available to the process. In some cases, additional data collection may be necessary to accurately identify the stressors.

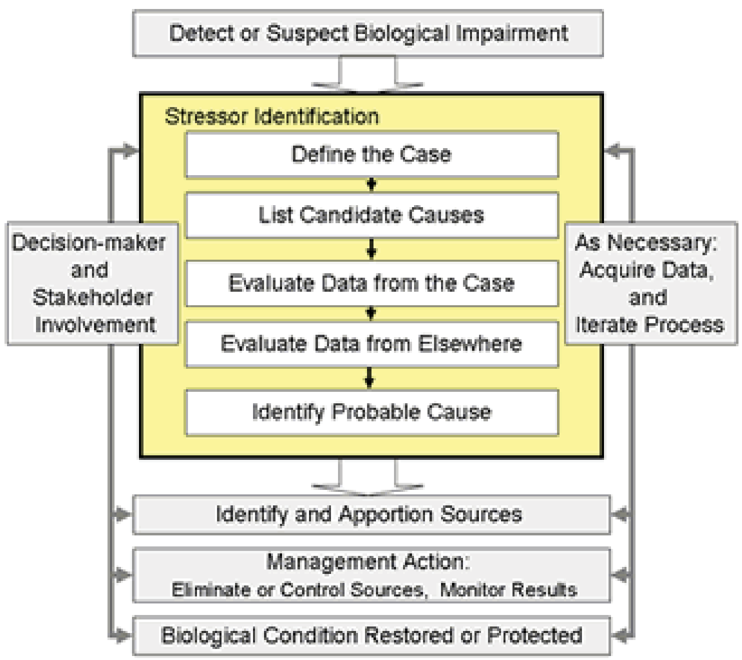


Figure 1. Conceptual model of the SID process (EPA, 2012).

Section 1: Watershed overview

1.1 Physical setting

The WRRW, United States Geological Survey (USGS) Hydrologic Unit Code 09020108, is situated in northwestern Minnesota and is part of the larger Red River of the North Basin. The WRRW has a drainage area of 1,636 square miles and encompasses portions of the following counties, listed in order of the percentage of watershed area: Mahnomen (32%), Norman (28%), Becker (13%), Clay (13%), Clearwater (13%), and Polk (<1%). Cities within the watershed include Bejou, Borup, Felton, Gary, Hendrum, Hitterdal, Mahnomen, Ogema, Twin Valley, Ulen, and Waubun.

1.2 Surface water resources

The Wild Rice River is the prominent water features in the WRRW. The river extends from the outlet of Upper Rice Lake, situated approximately 10 miles southeast of Bagley, to its confluence with the Red River of the North, located nearly 4 miles northwest of Hendrum. The WRRW contains 879 miles of intermittent stream, 637 miles of intermittent drainage ditch, 476 miles of perennial stream and river, and 50 miles of perennial drainage ditch (DNR, 2003). There are also many lakes in the eastern half of the watershed, the largest of which are Lower Rice, Strawberry, Upper Rice, and White Earth.

According to the MPCA (2013), at least 47% of the watercourses in the WRRW have been physically altered (i.e., channelized, ditched, or impounded). These alterations, coupled with historical changes in land cover (i.e., native vegetation to cropland), have altered the natural flow regime of many watercourses, causing them to be prone to high and quick peak flows, along with prolonged periods of low discharge (Van Offelen et al., 2004; WRWD, 2003).

1.3 Geology and soils

The WRRW intersects three distinct physiographic regions. The glacial moraine region encompasses approximately the eastern half of the watershed. An undulating to rolling topography (1-16% slope) and soils of varying textures (sand to clay loam) characterize this region. The beach ridges region, which represents the ancient shorelines of glacial Lake Agassiz, follows a north-south corridor approximately eight miles wide through the watershed; roughly following State Highway 32. The region has an undulating topography (1-8% slope) and coarser textured soils, many of which were derived from sand and gravel deposits. Lastly, the lake plain region is located in the western one-third of the watershed. This region is characterized by an extremely flat topography (0-1% slope) and very fine textured soils (clay) derived from lacustrine sediments deposited in glacial Lake Agassiz.

1.4 Land use and ecoregions

The predominant land use in the WRRW is agricultural crop production. According to the National Land Cover Database (NLCD) 2011 (USGS, 2011), cultivated crops comprised 54% of the watershed. Other notable land cover groups in the watershed included forest (22%), wetlands (9%), hay/pasture (6%), developed (4%), and open water (4%). The WRRW intersects three distinct ecoregions. The Lake Agassiz Plain ecoregion (65%) covers the largest portion of the watershed, while the Northern Lakes and Forests (20%) and North Central Hardwood Forests (15%) ecoregions are found in the eastern extent.

1.5 Ecological health

The Minnesota Department of Natural Resources (DNR) developed the Watershed Health Assessment Framework (WHAF) to assess the overall ecological health of a watershed. The WHAF evaluates and provides a score to each of the five core components of watershed health: hydrology, geomorphology, biology, connectivity, and water quality. Scores are ranked on a scale from 0 (“low”) to 100 (“high”). Figure 2 presents the watershed health scorecard for the WRRW. The mean health score for the watershed was 57. The individual mean component scores for connectivity (31) and biology (41) limited the overall score.

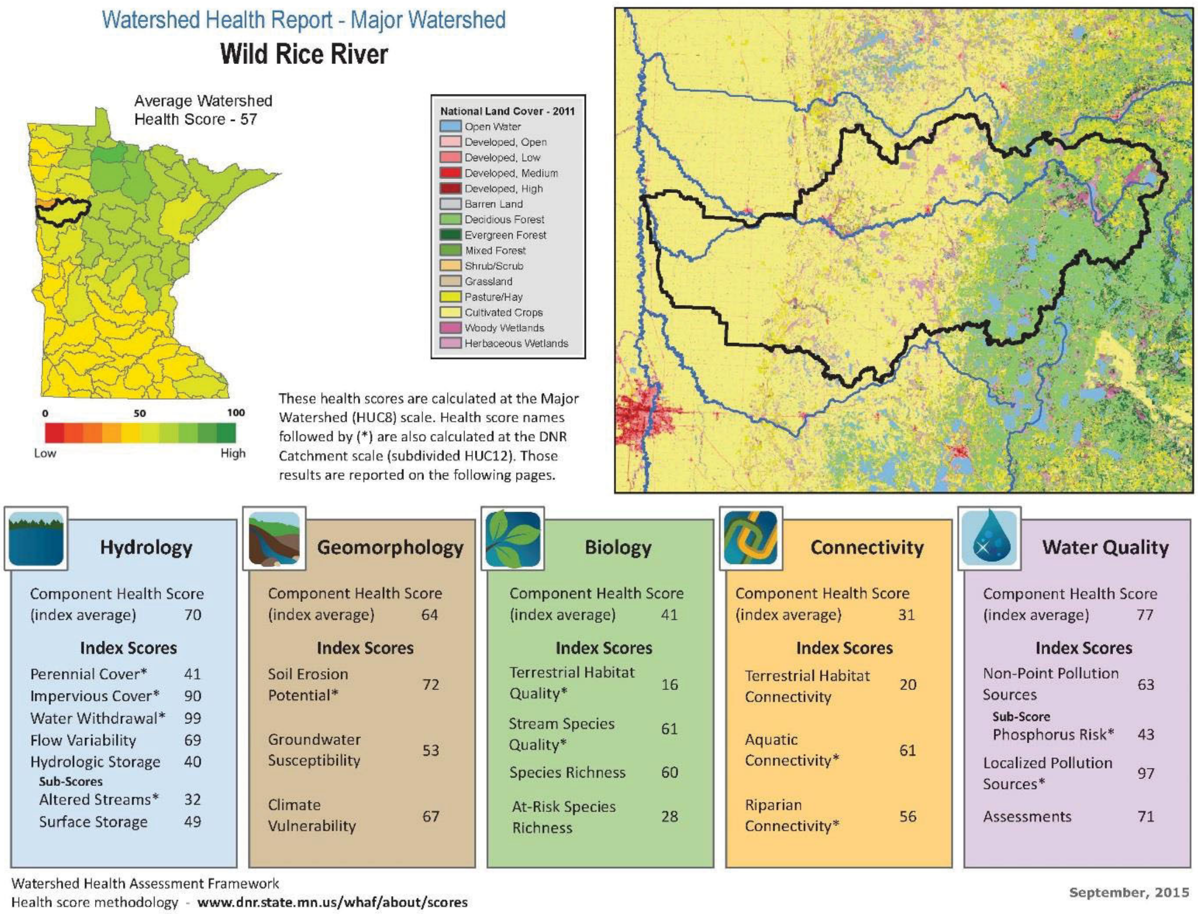


Figure 2. Watershed health assessment scores for the WRRW.

1.6 Hydrological Simulation Program – FORTRAN Model

A Hydrological Simulation Program – FORTRAN (HSPF) model was developed for the WRRW to simulate the hydrology and water quality conditions throughout the watershed on an hourly basis from 1996 to 2009. The HSPF model incorporates watershed-scale Agricultural Runoff Model and Non-Point Source models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. The model enables the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the water quality and quantity at the outlet of each subwatershed. The HSPF model outputs were used in the evaluation of several of the candidate causes outlined in this report.

Section 2: Biological monitoring and impairments

2.1 Watershed approach

The MPCA utilizes a watershed approach (Figure 3) to systematically monitor and assess surface water quality in each of the state's 80 major watersheds. A key component of this approach is IWM, which includes biological (i.e., fish and macroinvertebrate) monitoring to evaluate overall stream health. In 2014 and 2015, the MPCA conducted biological monitoring at several stations throughout the WRRW. An Index of Biological Integrity score was then calculated for each F-IBI and M-IBI monitoring visit. The biological monitoring results for the watershed were assessed to identify individual stream reaches that were not supporting a healthy fish and/or macroinvertebrate assemblage. A reach with a low IBI score(s) (i.e., below an established threshold) is considered "impaired" (i.e., unable to support its designated beneficial use) for aquatic life. The biological impairments of the WRRW are the focus of this SID report. The results of the SID process will guide the development of implementation strategies to correct the impaired conditions, which may include the preparation of a Total Maximum Daily Load study.

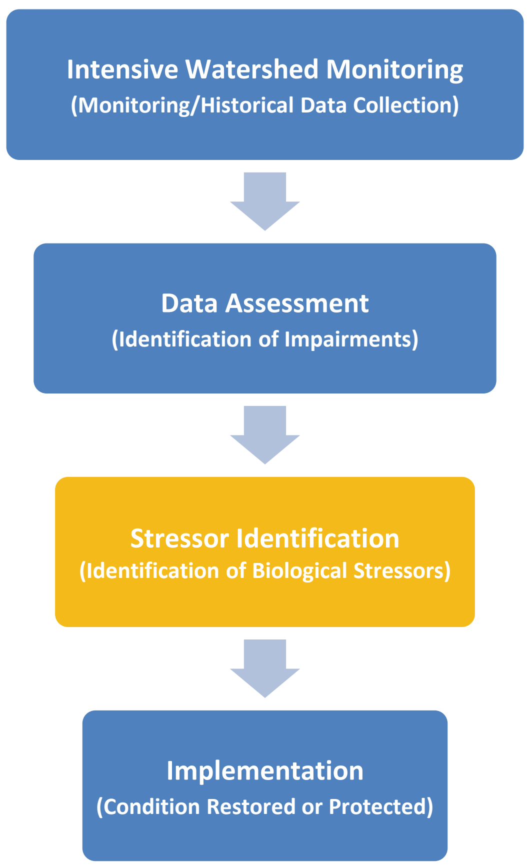


Figure 3. Conceptual model of the watershed approach processes.

2.2 Monitoring stations

Table 1 lists the 64 biological monitoring stations that were sampled for fish and/or macroinvertebrates in the WRRW. The stations are situated along 36 separate reaches; individual reaches will be referred to by their respective three-digit Assessment Unit Identification (AUID) number suffix.

Table 1. List of biological monitoring stations in the WRRW.

AUID suffix	AUID	Name	Monitoring station(s)
501	09020108-501	Wild Rice River	05RD036, 05RD112, 14RD019, 14RD055
504	09020108-504	Wild Rice River	95RD011, 10EM005, 14RD008, 15RD207
505	09020108-505	White Earth River	95RD004, 14RD006, 14RD021
506	09020108-506	Wild Rice River	94RD518, 14RD016
509	09020108-509	Twin Lake Creek	14RD005
510	09020108-510	Wild Rice River	14RD004, 14RD030
512	09020108-512	Wild Rice River	14RD003
519	09020108-519	Marsh Creek	14RD020
532	09020108-532	Unnamed Creek	14RD035, 15RD100
534	09020108-534	Buckboard Creek	05RD100
540	09020108-540	Spring Creek	14RD025
541	09020108-541	Unnamed Creek	07RD011
542	09020108-542	Stiner Creek	14RD013
544	09020108-544	Coon Creek	14RD015
545	09020108-545	Unnamed Creek	14RD001
546	09020108-546	Unnamed Creek	14RD011
551	09020108-551	Hier Creek	14RD017
553	09020108-553	County Ditch 45	14RD051
577	09020108-577	Coon Creek	14RD044
578	09020108-578	Coon Creek	14RD080
579	09020108-579	Garden Slough	14RD037
598	09020108-598	Unnamed Creek	07RD001
640	09020108-640	Unnamed Creek	14RD031
643	09020108-643	Wild Rice River	95RD014, 05RD115, 07RD009, 14RD041
644	09020108-644	Wild Rice River	14RD033, 14RD048, 14RD053
646	09020108-546	Wild Rice River	95RD005
647	09020108-647	Spring Creek	14RD022
648	09020108-648	Spring Creek	14RD007
650	09020108-650	Mashaug Creek	05RD114, 14RD014, 14RD034
651	09020108-651	Marsh Creek	07RD002

Table 1. Continued.

AUID suffix	AUID	Name	Monitoring station(s)
652	09020108-652	Marsh Creek	14RD009, 14RD082
654	09020108-654	Felton Creek/County Ditch 45	10RD080, 14RD046, 15RD012, 15RD035
656	09020108-656	County Ditch 42	07RD027
659	09020108-659	Wild Rice River, South Branch	07RD010, 14RD047, 14RD049
661	09020108-661	Wild Rice River, South Branch	07RD028, 14RD081
662	09020108-662	Wild Rice River, South Branch	94RD012, 05RD069, 14RD012, 14RD042

2.3 Monitoring results

Table 2 provides the F-IBI and M-IBI scores for each of the biological monitoring stations in the WRRW. A total of 14 stations (22%) scored below their F-IBI impairment threshold, while 20 stations (38%) scored below their M-IBI impairment threshold; these stations are highlighted red.

Table 2. Summary of F-IBI and M-IBI scores for biological monitoring stations in the WRRW.

Fish					Macroinvertebrate				
AUID suffix	Station	F-IBI class[1] (Use[3])	F-IBI impairment threshold	F-IBI score (mean)	AUID suffix	Station	M-IBI class[2] (Use[3])	M-IBI impairment threshold	M-IBI score (mean)
501	05RD036	SR(G)	49	78	501	05RD03	Not Sampled		
501	05RD112	SR(G)	49	65	501	05RD11	Not Sampled		
501	14RD019	SR(G)	49	63	501	14RD01	Not Sampled		
501	14RD055	SR(G)	49	80	501	14RD05	PFR(G)	31	38
504	95RD011	NR(G)	38	53	504	95RD01	PFR(G)	31	47
504	10EM00	NR(G)	38	55	504	10EM00	PFR(G)	31	49
504	14RD008	NR(G)	38	47	504	14RD00	PFR(G)	31	37
504	15RD207	NR(G)	38	56	504	15RD20	PFR(G)	31	47
505	95RD004	NS(G)	47	49	505	95RD00	PGP(G)	41	52
505	14RD006	NS(G)	47	54	505	14RD00	SRR(G)	37	37
505	**14RD021**	**NS(G)**	**47**	**43**	505	14RD02	PGP(G)	41	41
506	94RD518	NR(G)	38	59	506	94RD51	PGP(G)	41	58
506	14RD016	NS(G)	47	63	506	14RD01	SRR(G)	37	68
509	**14RD005**	**NS(G)**	**47**	**44**	509	14RD00	Not Sampled		
510	14RD004	NS(G)	47	63	510	14RD00	SRR(G)	37	68
510	14RD030	NS(G)	47	51	510	14RD03	PFR(G)	31	35
512	14RD003	NS(G)	47	55	**512**	**14RD00**	**NGP(G**	**51**	**25**
519	14RD020	LG(M)	15	53	519	14RD02	Not Sampled		
532	14RD035	NC(G)	35	40	**532**	**14RD03**	**NC(G)**	**32**	**16**
532	**15RD100**	**NC(G)**	**35**	**18**	532	15RD10	Not Sampled		
534	05RD100	NC(G)	35	46	**534**	**05RD10**	**NC(G)**	**32**	**23**
540	14RD025	NH(G)	42	67	**540**	**14RD02**	**PGP(G)**	**41**	**37**
541	07RD011	SS(M)	35	57	541	07RD01	PGP(M	22	36

Table 2. Continued.

Fish					Macroinvertebrate				
AUID suffix	Station	F-IBI class1 (Use3)	F-IBI impairment threshold	F-IBI score (mean)	AUID suffix	Station	M-IBI class2 (Use3)	M-IBI impairment threshold	M-IBI score (mean)
542	14RD013	NH(G)	42	69	542	14RD01	PGP(G)	41	42
544	14RD015	NH(G)	42	61	544	14RD01	SRR(G)	37	34
545	14RD001	NH(G)	42	83	545	14RD00	SRR(G)	37	33
546	14RD011	NS(G)	47	57	546	14RD01	SRR(G)	37	47
551	14RD017	NH(G)	42	64	551	14RD01	NGP(G	51	62
553	14RD051	SS(G)	50	65	553	14RD05	PGP(G)	41	34
577	14RD044	NH(G)	42	75	577	14RD04	SRR(G)	37	36
578	14RD080	NH(G)	42	56	578	14RD080	PGP(G)	41	48
579	14RD037	NH(M)	23	16	579	14RD037	Not Sampled		
598	07RD001	NH(M)	23	19	598	07RD001	PGP(M	22	28
640	14RD031	NH(G)	42	73	640	14RD031	SRR(G)	37	38
643	95RD014	NR(G)	38	47	643	95RD014	PFR(G)	31	31
643	05RD115	NR(G)	38	54	643	05RD115	PFR(G)	31	40
643	07RD009	SR(G)	49	54	643	07RD009	PFR(G)	31	40
643	14RD041	NR(G)	38	73	643	14RD041	PFR(G)	31	47
644	14RD033	SR(G)	49	57	644	14RD033	PFR(G)	31	41
644	14RD048	SR(G)	49	81	644	14RD048	PFR(G)	31	36
644	14RD053	SR(G)	49	63	644	14RD053	Not Sampled		
646	95RD005	NS(G)	47	41	646	95RD005	NGP(G	51	56
647	14RD022	NH(M)	23	63	647	14RD022	PGP(M	22	14
648	14RD007	NS(G)	47	54	648	14RD007	SRR(G)	37	45
650	05RD114	NH(G)	42	43	650	05RD114	PGP(G)	41	34
650	14RD014	NS(G)	47	43	650	14RD014	SRR(G)	37	29
650	14RD034	NH(G)	42	45	650	14RD034	Not Sampled		
651	07RD002	NS(M)	35	35	651	07RD002	PGP(M	22	45
652	14RD009	NS(G)	47	69	652	14RD009	SRR(G)	37	41
652	14RD082	NS(G)	47	50	652	14RD082	SRR(G)	37	34
654	10RD080	NC(G)	35	22	654	10RD080	SC(G)	43	41
654	14RD046	SC(G)	50	31	654	14RD046	PGP(G)	41	13
654	15RD012	NC(G)	35	29	654	15RD012	NC(G)	32	27
654	15RD035	SC(G)	50	37	654	15RD035	NC(G)	32	30
656	07RD027	NH(G)	42	40	656	07RD027	PGP(G)	41	42
659	07RD010	SS(G)	50	55	659	07RD010	PGP(G)	41	26
659	14RD047	SS(G)	50	57	659	14RD047	PGP(G)	41	49
659	14RD049	SS(G)	50	56	659	14RD049	PGP(G)	41	40
661	07RD028	NS(M)	35	32	661	07RD028	PGP(M	22	14
661	14RD081	NS(M)	35	24	661	14RD081	Not Sampled		

Table 2. Continued.

Fish					Macroinvertebrate				
AUID suffix	Station	AUID suffix	Station	AUID suffix	Stati on	AUID suffix	Station	AUID suffix	Station
662	94RD012	NS(G)	47	62	662	94RD012	PGP(G)	41	58
662	05RD069	NS(G)	47	51	662	05RD069	Not Sampled		
662	14RD012	NS(G)	47	55	662	14RD012	SRR(G)	37	25
662	14RD042	NS(G)	47	51	662	14RD042	Not Sampled		

[1] F-IBI Classes: Low Gradient Streams (LGS), Northern Coldwater (NC), Northern Headwaters (NH), Northern Rivers (NR), Northern Streams (NS), Southern Coldwater (SC), Southern Rivers (SR), Southern Streams (SS)

[2] M-IBI Class: Northern Coldwater (NC), Northern Forest Streams-Glide/Pool Habitats (NGP), Prairie Forest Rivers (PFR), Prairie Streams-Glide/Pool Habitats (PGP), Southern Coldwater (SC), Southern Streams-Riffle/Run Habitats (SRR)

[3] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

2.4 Assessments and impairments

The biological monitoring results for the WRRW were formally assessed as part of the development of the *Wild Rice River Watershed Monitoring and Assessment Report* (MPCA, 2017b) to determine if individual stream reaches met applicable aquatic life standards. As shown in Table 3, seven reaches were determined to be biologically impaired; these reaches are highlighted red. The relative location of these reaches is displayed in Figure 4.

Table 3. Assessment results for stream reaches with biological monitoring data in the WRRW.

AUID suffix	Name	Description	Length (mi)	Biological impairment(s)
501	Wild Rice River	Wild Rice River, South Branch to Red River	31	None
504	Wild Rice River	White Earth River to Marsh Creek	27	None
505	White Earth River	White Earth Lake to Wild Rice River	26	None
506	Wild Rice River	Twin Lake Creek to White Earth River	26	None
509	Twin Lake Creek	Sargent Lake to Wild Rice River	13	None
510	Wild Rice River	Roy Lake Creek to Twin Lake Creek	25	None
512	Wild Rice River	Lower Rice Lake to Roy Lake Creek	8	None
519	Marsh Creek	Blair Lake to Beaulieu Lake	8	None
532	Unnamed Creek	Sec. 34, T144N, R39W to Bad Boy Creek	2	None
534	Buckboard Creek	Headwaters to Sec. 11, T144N, R38W	7	None
540	Spring Creek	Headwaters to Wild Rice River, South	6	None
541	Unnamed Creek	Unnamed Ditch to Wild Rice River	3	None
542	Stiner Creek	Unnamed Creek to Wild Rice River, South	1	None
544	Coon Creek	Unnamed Creek to Wild Rice River	1	None
545	Unnamed Creek	Unnamed Creek to Unnamed Creek	3	None
546	Unnamed Creek	Unnamed Creek to Wild Rice River	7	None
551	Hier Creek	Unnamed Creek to Wild Rice River	5	None
553	County Ditch 45	Unnamed Ditch to Unnamed Ditch	3	None
577	Coon Creek	Unnamed Creek to Unnamed Creek	4	None

Table 3. Continued.

AUID suffix	Name	Description	Length (mi)	Biological impairment(s)
578	Coon Creek	Unnamed Creek to Unnamed Creek	2	None
579	**Garden Slough**	**Headwaters to Mashaug Creek**	**10**	**F-IBI**
598	Unnamed Creek	Unnamed Ditch to Unnamed Creek	2	None
640	Unnamed Creek	Unnamed Creek to Wild Rice River	1	None
643	Wild Rice River	Marsh Creek to Unnamed Creek	28	None
644	Wild Rice River	Unnamed Creek to Wild Rice River, South	17	None
646	**Wild Rice River**	**Unnamed Creek to Lower Rice Lake**	**17**	**F-IBI**
647	**Spring Creek**	**Headwaters to 140th Avenue**	**8**	**M-IBI**
648	Spring Creek	140th Avenue to Wild Rice River	12	None
650	**Mashaug Creek**	**240th Avenue to Wild Rice River**	**12**	**F-IBI, M-IBI**
651	Marsh Creek	Beaulieu Lake to -95.9973, 47.4054	12	None
652	Marsh Creek	-95.9973, 47.4054 to Wild Rice River	21	None
654	**Felton Creek/County Ditch 45**	**200th Street North to 150th Street North**	**7**	**F-IBI, M-IBI**
656	County Ditch 42	County Road 151 to Unnamed Creek	1	None
659	Wild Rice River, South Branch	County Road 138 to Wild Rice River	8	None
661	**Wild Rice River, South Branch**	**-96.1406, 47.0658 to Unnamed Creek**	**5**	**F-IBI**
662	**Wild Rice River, South Branch**	**Unnamed Creek to Unnamed Creek**	**24**	**M-IBI**

In addition to the abovementioned biological impairments, six reaches in the WRRW have an existing or proposed water quality impairment that affects aquatic life (Table 4).

Table 4. Water quality impairments associated with reaches in the WRRW.

AUID suffix	Name	Description	Water Quality impairment(s)
501	Wild Rice River	Wild Rice River, South Branch to Red River	Turbidity[1,2]
503	Wild Rice River	Marsh Creek to Wild Rice River, South Branch	Turbidity[1,2]
504	Wild Rice River	White Earth River to Marsh Creek	Total Suspended Solids[3]
505	White Earth River	White Earth Lake to Wild Rice River	Turbidity[1,2]
509	Twin Lake Creek	Sargent Lake to Wild Rice River	Total Suspended Solids[3]
521	Marsh Creek	Beaulieu Lake to Wild Rice River	Turbidity[1,2]

[1] Existing impairment included on the 2012 Impaired Waters List.
[2] The turbidity standard has since been replaced with a total suspended solids standard.
[3] New impairment to be included on the proposed 2018 Impaired Waters List.

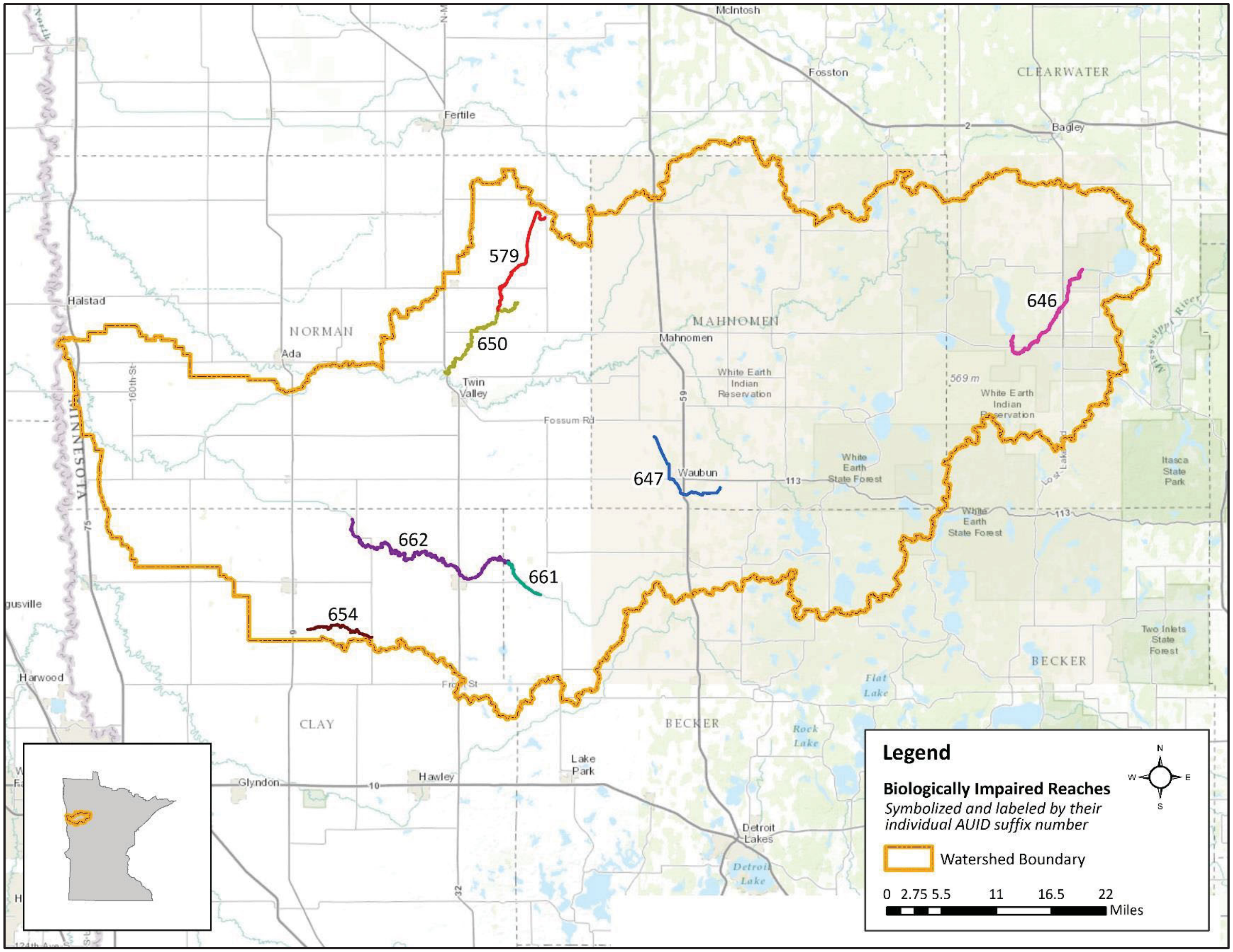


Figure 4. Map of the WRRW and associated biologically impaired reaches.

Section 3: Stressor identification

3.1 Identification of candidate causes

A candidate cause is defined as a “hypothesized cause of an environmental impairment that is sufficiently credible to be analyzed” (EPA, 2012). Identification of a set of candidate causes is an important early step in the SID process and provides the framework for gathering key data for causal analysis. Table 5 lists the nine common biotic stressors that were considered as potential candidate causes in the WRRW; an overview of these stressors is provided in *Stressors to Biological Communities in Minnesota’s Rivers and Streams* (MPCA, 2017a). The list was developed based upon the results of the *Red River Valley Biotic Impairment Assessment* (EOR, 2009) and other completed SID reports in the state. The credibility of each candidate cause as a possible stressor to the fish and/or macroinvertebrate community of the biologically impaired reaches in the watershed was then evaluated through a comprehensive review of available information, including water quality and quantity data, as well as existing plans and reports, including the *Wild Rice River Watershed Monitoring and Assessment Report* (MPCA, 2017b), the *Wild Rice Watershed District’s (WRWD) Watershed Management Plan* (WRWD, 2003), and the *Red River Basin Stream Survey Report: Wild Rice River Watershed 2000* (Van Offelen et al., 2004). Based upon the results of this evaluation, six candidate causes were identified to undergo causal analysis (Section 3.2).

Table 5. Summary of common biotic stressors evaluated as potential candidate causes for the biologically impaired reaches of the WRRW.

Stressor	Candidate cause identification	
	Summary of available information	Candidate cause (Yes/No)
Loss of longitudinal connectivity	Several of the biologically impaired reaches have connectivity barriers (e.g., dams and private road crossings) that are potential obstructions to fish passage.	Yes
Flow regime instability	Many of the biologically impaired reaches are prone to high and quick peak flows, along with prolonged periods of very low discharge.	Yes
Insufficient physical habitat	Several of the biologically impaired reaches have insufficient instream habitat to support a healthy and diverse biotic community.	Yes
High suspended sediment	Several of the biologically impaired reaches have discrete total suspended solids (TSS) values that exceed the applicable state	Yes
Low dissolved oxygen	Several of the biologically impaired reaches have discrete and/or continuous dissolved oxygen (DO) values that are below the applicable state standard. Eutrophication may be a contributing factor to these low DO values.	Yes
High temperature	AUID 654 (Felton Creek/County Ditch 45) only. This is a coldwater stream that experiences high temperature values.	Yes
High nitrate-nitrite	Nitrate-nitrite concentrations associated with the biologically impaired reaches were generally well below the level expected to cause stress to aquatic biota (<10 mg/L).	No
pH	Nearly all of the pH values associated with the biologically impaired reaches were within the state standard range (6.5-9.0).	No
Pesticide toxicity	There is no pesticide data for the biologically impaired reaches. As a result, there is insufficient information to declare pesticide toxicity as a candidate cause at this time.	No

3.2 Causal analysis – Profile of individual biologically impaired reaches

3.2.1 Wild Rice River (AUID 646)

Physical setting

This reach represents the segment of the Wild Rice River from its confluence with an unnamed creek, to the inlet of Lower River Lake (Figure 5); a total length of 17 miles. The reach has a subwatershed area of 79 square miles (50,640 acres). The subwatershed contains 38 miles of perennial river/stream (e.g., AUID 646), 25 miles of intermittent stream, and six miles of perennial drainage ditch (DNR, 2003). According to the MPCA (2013), 13% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded); the entire length of AUID 646 is classified as natural. The NLCD 2011 (USGS, 2011) lists forest (58%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included hay/pasture (15%), wetlands (13%), open water (5%), developed (3%), shrub/scrub (3%), cultivated crops (2%), and herbaceous (1%).

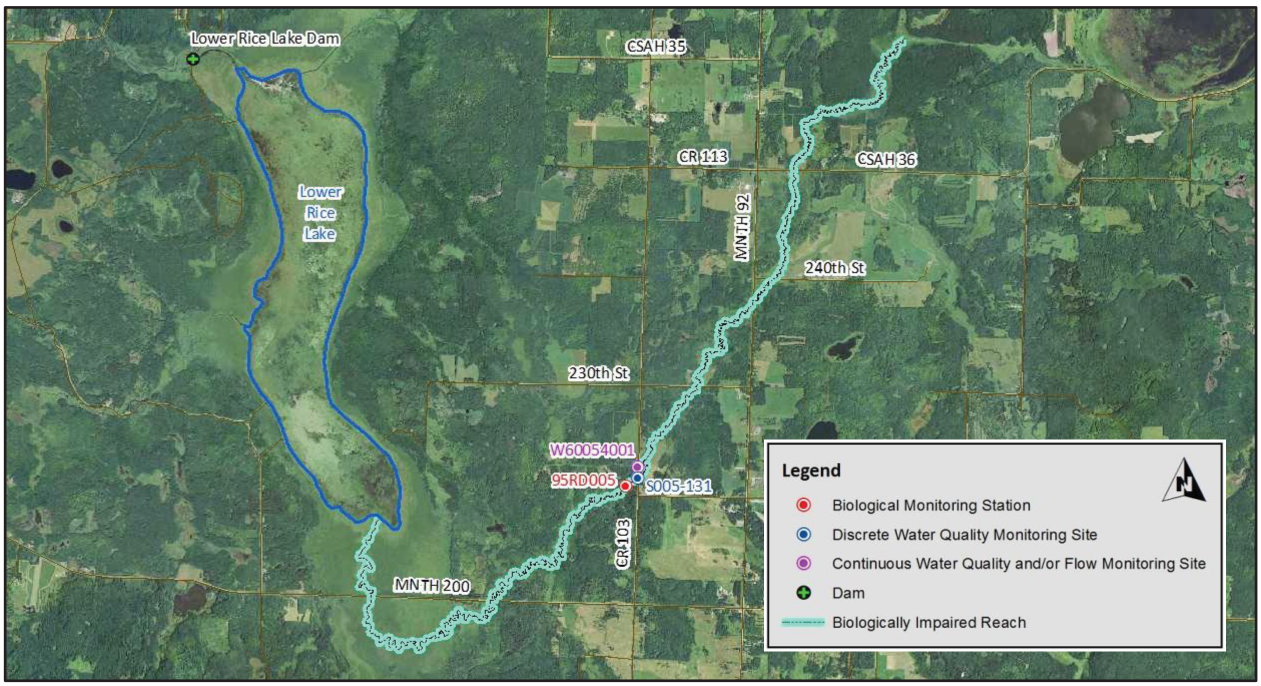


Figure 5. Map of AUID 646 and associated biological monitoring station and water quality monitoring sites (2013 National Agriculture Imagery Program (NAIP) aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 646 was monitored at Station 95RD005 (0.1 mile downstream of the County Road [CR] 103 crossing) on July 31, 2014. The location of the station is shown in Figure 5. The station was designated as General Use within the Northern Streams F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 47. Monitoring of the station yielded an F-IBI score (41) below the impairment threshold. While the fish assemblage included 12 species, it had a high abundance of central mudminnow, which are highly tolerant of environmental disturbance.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 95RD005 along AUID 646. The Lower Rice Lake Dam (Figure 6) is located downstream of the reach on the Wild Rice River, at the outlet of Lower Rice Lake (Dam Drive crossing). The dam is comprised of a series of concrete pillars and adjustable metal gates. The maximum height of the structure is approximately four feet above the downstream water elevation. Depending upon the position of the metal gates, the dam is either a partial or a complete barrier to connectivity. On September 28, 2016, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. The remnants of a beaver dam (Figure 6) were noted at the County State Aid Highway (CSAH) 36 crossing. In addition to the assessment, MPCA SID staff performed a detailed review of an April 14, 2015, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo. In summary, the Lower Rice Lake Dam interferes with connectivity along the reach.

Figure 6. Images of potential connectivity barriers along AUID 646, including the Lower Rice Lake Dam at the Dam Drive crossing on July 20, 2017 (left); and a beaver dam upstream of the CSAH 36 crossing on September 28, 2016 (right).

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for loss of longitudinal connectivity as a stressor to the fish community of AUID 646:

- Below average (<18%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Station 95RD005 (0%)
- Below average (<17%) relative abundance of individuals that are migratory (MgrPct) at Station 95RD005 (11%)

Late maturing and migratory fish require well-connected environments in order to access the habitats and resources necessary to complete their life history. Table 6 contrasts the collective fish assemblage that was sampled immediately upstream and downstream of the Lower Rice Lake Dam. A total of 33 species were sampled at the selected stations below the dam, including two (i.e., silver redhorse and weed shiner) that are considered “vulnerable” to extirpation by connectivity barriers. In comparison, only 12 species were found at Station 95RD005, which is located upstream of the dam. Both of the “vulnerable” species were absent. Additionally, there is insufficient information to determine if the culverts associated with road crossings along the reach are impeding fish passage during high flow conditions (i.e., creating a velocity barrier).

Table 6. Summary of fish species sampled downstream and upstream of the Lower Rice Lake Dam along the Wild Rice River (AUID 512).

Fish Species[1]	Present downstream of the Lower Rice Lake Dam[2]	Present upstream of the Lower Rice Lake Dam[3]
black bullhead	X	X
blacknose dace	X	X
blacknose shiner	X	
blackside darter	X	X
bluegill	X	
brassy minnow	X	
brook stickleback	X	
brown bullhead	X	
central mudminnow	X	X
common carp	X	
common shiner	X	X
creek chub	X	X
fathead minnow	X	
golden redhorse	X	
golden shiner	X	
hornyhead chub	X	
Iowa darter	X	
johnny darter	X	X
lamprey ammocoete	X	
largemouth bass		X
longnose dace	X	
northern pike	X	X
northern redbelly dace	X	
pearl dace	X	
pumpkinseed	X	
rock bass	X	
shorthead redhorse	X	
silver redhorse	X	
spotfin shiner	X	
stonecat	X	
tadpole madtom	X	X
weed shiner	X	
white sucker	X	X
yellow perch	X	X

[1] Species highlighted red are those designated by Aadland (2015) as "vulnerable" and "most vulnerable" to extirpation by barrier dams.

[2] Stations 05RD076 and 14RD030 along AUID 510; and Station 14RD003 along AUID 512

[3] Station 95RD005 along AUID 646

Flow regime instability

Available data

According to the MPCA (2013), 13% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded); the entire length of AUID 646 is classified as natural. The MPCA biological monitoring staff did not encounter any flow-related issues (e.g., intermittency) at Station 95RD005 along AUID 646. There is no flow monitoring data for the reach. The USGS (2016) estimated that the normal range of flow values for the reach at its outlet was 33.5 (Q25; value exceeded 25% of the time) to 8.4 (Q75; value exceeded 75% of the time) cubic feet per second (cfs). Additionally, the estimated median flow (Q50) was 16.2 cfs, while the projected Q5 (value exceeded 5% of the time) flow was 128.0 cfs and the Q95 (value exceeded 95% of the time) flow was 5.4 cfs. The Q25 to Q75 flow values ratio was 4:1, which is indicative of a hydrologically stable system. By comparison, several of the more hydrologically stable rivers in the Red River Basin (i.e., Buffalo River, Clearwater River, and Otter Tail River) had a ratio of 7:1 or less. On September 28, 2016, MPCA SID staff conducted reconnaissance along the reach and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach has a stable flow regime.

Biotic response – fish

The following evidence (Appendix A) is inconclusive and *neither supports nor weakens* the case for flow regime instability as a stressor to the fish community of AUID 646:

- Above average (>64%) combined relative abundance of the three most abundant taxa (DomThreePct) at Station 95RD005 (78%)
- Above average (>24%) relative abundance of taxa that are generalists (GeneralTxPct) at Station 95RD005 (42%)
- Above average (>58%) relative abundance of taxa with a female mature age equal to or less than two years (MA<2TxPct) at Station 95RD005 (67%)
- Below average (<0.97) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 95RD005 (0.62)
- Above average (>12%) relative abundance of taxa that are pioneers (PioneerTxPct) at Station 95RD005 (17%)

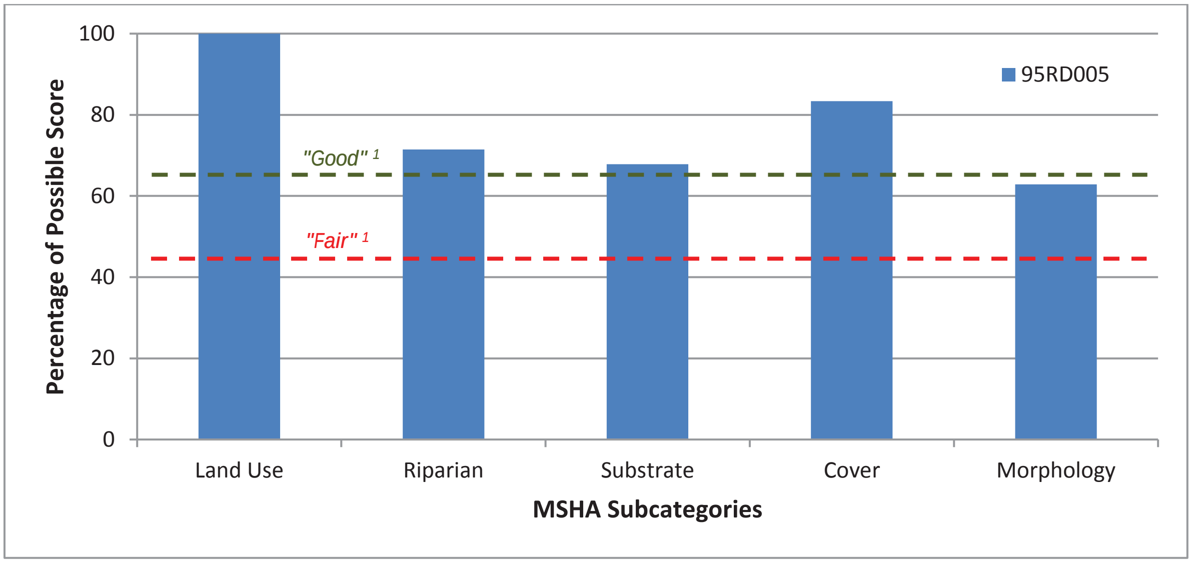
Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). While the abovementioned flow-related metrics indicate stress, the available data suggest that the reach has a relatively stable flow regime.

Insufficient physical habitat

Available data

The physical habitat of AUID 646 was evaluated at Station 95RD005 using the MPCA's Stream Habitat Assessment (MSHA). No alterations have been made to the reach (MPCA, 2013). The station yielded a MSHA score of 71 ("good"). Figure 7 displays the MSHA subcategory results for the station. The station scored well in the land use subcategory due to the surrounding natural conditions. The riparian subcategory score was positively influenced by a "wide" riparian zone width, although a "little" bank erosion was noted. The station scored well in the substrate subcategory offering both riffle habitat and coarse substrate (i.e., boulders and gravel). However, the substrate of the station was slightly degraded by a "little" amount of embeddedness. The station also scored well in the cover subcategory due to the diversity and "moderate" amount of cover present. Noted cover types included boulders, pools, logs, macrophytes (emergent, submergent, and floating leaf), overhanging vegetation, and undercut banks.

Lastly, the morphology subcategory score was favorably affected by "moderate-high" channel stability and "good" channel development. Overall, the reach appears to have adequate physical habitat.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 7. MSHA subcategory results for Station 95RD005 along AUID 646.

Biotic response – fish

The following evidence (Appendix A) is inconclusive and *neither supports nor weakens* the case for insufficient physical habitat as a stressor to the fish community of AUID 646:

- Below average (<29%) relative abundance of individuals that are benthic insectivores, excluding tolerant species (BenInsect-TolPct) at Station 95RD005 (20%)
- Below average (<16%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 95RD005 (0%)
- Below average (<45%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Station 95RD005 (20%)
- Below average (<24%) relative abundance of individuals that predominately utilize riffle habitats (RifflePct) at Station 95RD005 (7%)
- Below average (<45%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 95RD005 (22%)

Insectivores and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes (Aadland et al., 2006). While the abovementioned habitat-related metrics indicate stress, the available data does not suggest that the physical habitat of the reach is limited.

High suspended sediment

Available data

Table 7 summarizes all available discrete total suspended solids (TSS) data for Site S005-131 (CR 103 crossing); the location of the site is shown in Figure 5. There were no exceedances of the 15 mg/L standard. The WRRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 25 and 54% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach likely experiences at least occasional periods of high suspended sediment.

Biotic response – fish

There is *no evidence* of a causal relationship between high-suspended sediment and the F-IBI impairment associated with AUID 646. The available evidence (Appendix A), specifically mean TSS tolerance indicator value (TIV) and probability of meeting the TSS standard, does not suggest that high suspended sediment is a stressor to the fish community.

Table 7. Discrete TSS data for Site S005-131 along AUID 646.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S005-131	2008-2014	26	1	10	3	0

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 95RD005 along AUID 646 at the time of fish monitoring visit. The DO concentration was 8.0 mg/L. Figure 8 displays all available discrete DO data for Site S005-131 (2008-2015; *n*=46). None of the DO values were below the 5 mg/L standard; however, only eight of the measurements were collected prior to 9:00 a.m., when values are typically lowest. Generally, the lowest DO levels were in the months of June, July, and August. The MPCA conducted continuous DO monitoring at Site W60054001 (CR 103 crossing) from July 30, 2014, to August 22, 2014; the location of the site is shown in Figure 5. The monitoring results are provided in Table 8, as well as displayed in Figure 9. None of the DO measurements within the monitoring period were below the standard. Additionally, the WRRW HSPF model estimates that the reach had a DO concentration below the standard between 11 and 91% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach likely experiences at least occasional periods of low DO.

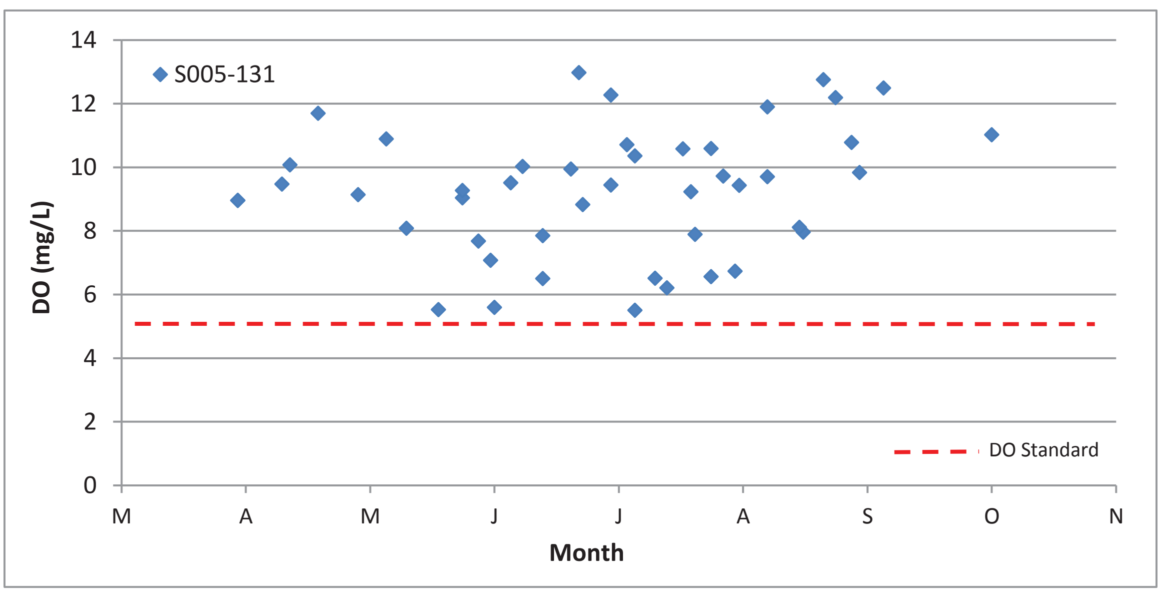


Figure 8. Discrete DO data for Sites S005-131 along AUID 646.

Table 8. Continuous DO data for Site W60054001 along AUID 646.

Start date - End date	*n*	Max. (mg/L)	Min. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 30, 2014 - August 22, 2014	2224	11.3	5.0	0	0	4.5

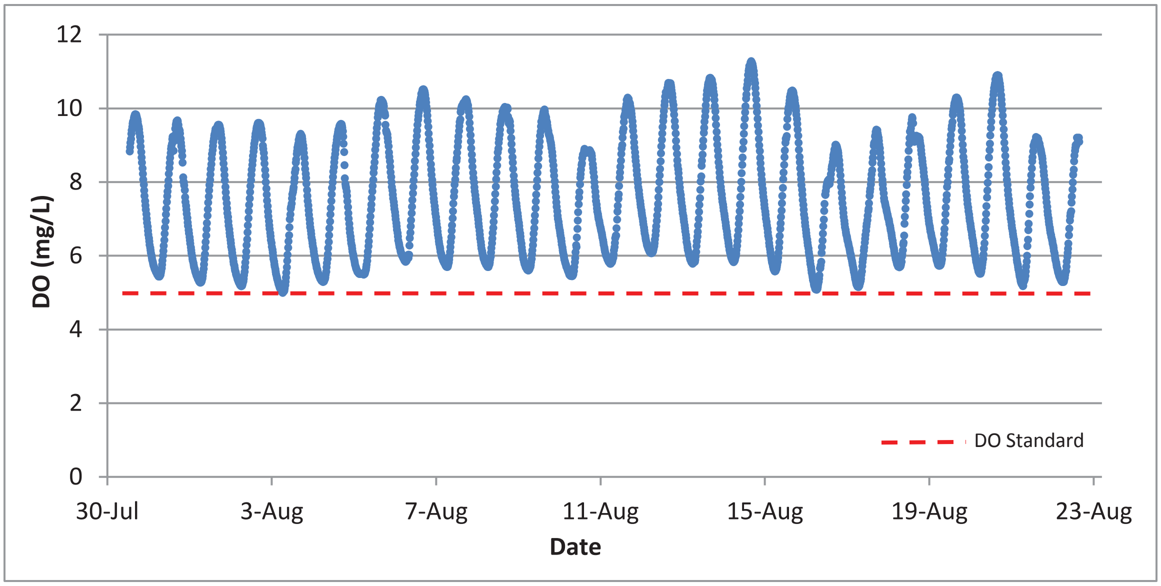


Figure 9. Continuous DO data for Site W60054001 along AUID 646.

Eutrophication-related data for AUID 646 includes the following parameters: total phosphorus (TP) and DO flux. Discrete TP data are available for Site S005-131 (2008-2014, *n*=21). The mean TP concentration for the site was 81 µg/L, while the highest concentration was 173 µg/L and the lowest concentration was 27 µg/L. Approximately 86% of the values exceeded the 50 µg/L North River Nutrient Region TP standard. The mean daily DO flux documented during continuous DO monitoring at Site W60054001 (Table 8) was 4.5 mg/L, which is well above the 3.0 mg/L North River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during a September 28, 2016, reconnaissance visit along the reach. While the reach is prone to high TP concentrations, there is insufficient response variable data to determine if eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

The following evidence (Appendix A) *somewhat supports* the case for low DO as a stressor to the fish community of AUID 646:

- Below average (<7.2 mg/L) mean DO TIV at Station 95RD005 (6.1 mg/L)
- Below average (<55%) probability of meeting the DO standard at Station 95RD005 (16%)

Summary of stressors

The evidence suggests that the F-IBI impairment associated with AUID 646 is attributed to a loss of longitudinal connectivity and, to a less extent, low DO. The Lower Rice Lake Dam appears to be a partial barrier to connectivity. There is a discernable difference in the species composition above and below the structure. Additionally, the data suggests that the reach is prone to at least occasional periods of low

DO. There is a large bog/swamp complex that is located in the upstream portion of the subwatershed that may be naturally discharging low DO water to the river. A summary of recommended actions to alleviate the influence of these stressors is provided in Section 4.2.

3.2.2 Spring Creek (AUID 647)

Physical setting

This reach represents the segment of Spring Creek from its headwaters, to the 140th Avenue crossing (Figure 10); a total length of 8 miles. The reach has a subwatershed area of 47 square miles (29,847 acres). The subwatershed contains 26 miles of intermittent stream, 14 miles of intermittent drainage ditch (e.g., AUID 647 upstream of the 300th Street crossing), and 1 mile of perennial stream (i.e., AUID 647 downstream of the 300th Street crossing) (MDNR, 2003). According to the MPCA (2013), 59% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 647. The NLCD 2011 (USGS, 2011) lists cultivated crops (53%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (14%), forest (12%), hay/pasture (9%), developed (5%), herbaceous (4%), and open water (3%).

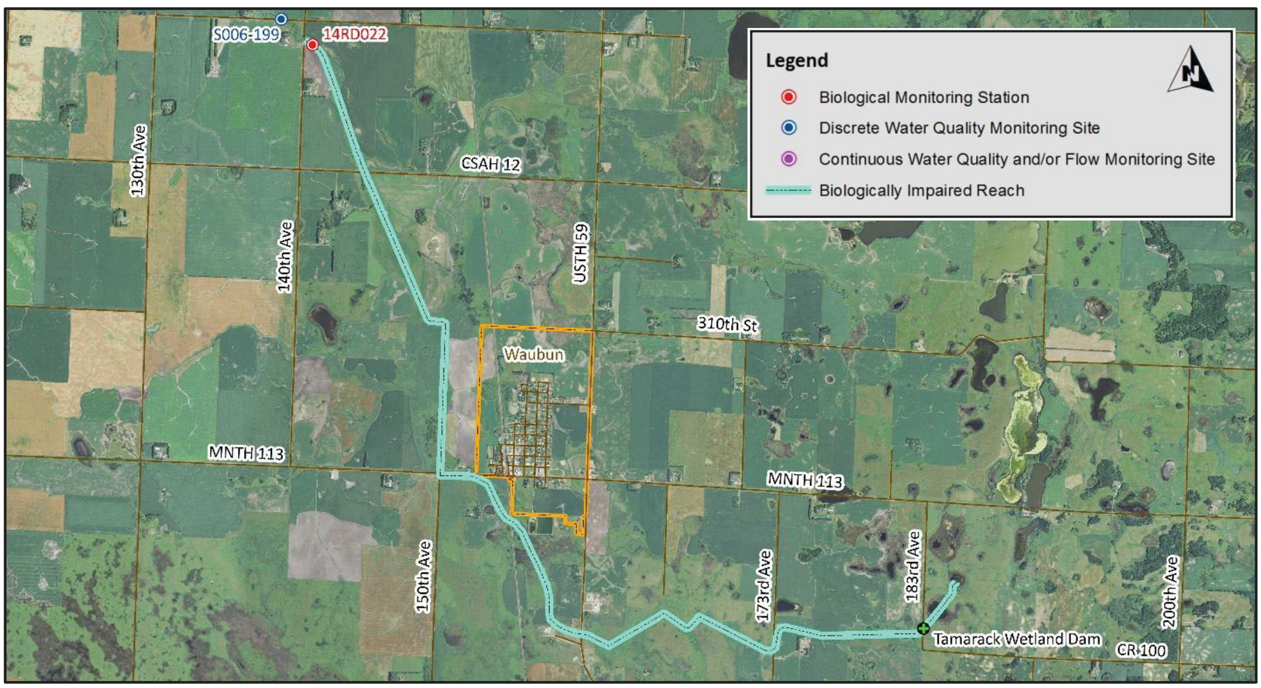


Figure 10. Map of AUID 647 and associated biological monitoring station (2013 NAIP aerial image).

Biological impairments

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 647 was monitored at Station 14RD022 (0.1 mile upstream of the 140th Avenue crossing) on July 31, 2014. The location of the station is shown in Figure 10. The station was designated as Modified Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the impairment threshold for the station is an M-IBI score of 22. Monitoring of the station yielded an M-IBI score (14) substantially below the impairment threshold. Tolerant midges (i.e., *Cricotopus* and *Paratanytarsus*) dominated the macroinvertebrate assemblage of the station.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 14RD022 along AUID 647. According to the DNR (2014), the Tamarack Wetland Dam (Figure 11) is located at the 183rd Avenue crossing, near the upstream end of the reach. The dam, which is owned and operated by the United States Department of Agriculture, is an 8-foot high earthen structure that was completed in 1975 for the purpose of wildlife habitat. On September 28, 2016, MPCA SID staff conducted a connectivity assessment along Spring Creek. Staff viewed all of the road crossings on the creek as part of the assessment. A beaver dam was noted immediately upstream of the 130th Avenue crossing, which is approximately one mile downstream of AUID 647. The beaver dam had an associated pool, but water was noted seeping from its base. In addition to the assessment, MPCA SID staff performed a detailed review of a May 18, 2015, aerial photo (courtesy of Google Earth) of the reach. Staff identified a beaver dam (Figure 11) upstream of the U.S. Highway 59 crossing. The beaver dam was breached at the time, with water spilling over its top. Also, staff noted a private road crossing downstream of the U.S. Highway 59 crossing. The crossing appeared to have an undersized culvert, which could alter stream flow and, thereby, limit connectivity. In summary, the Tamarack Wetland Dam, beaver dams, and private road crossing have the potential to interfere with connectivity along the reach.

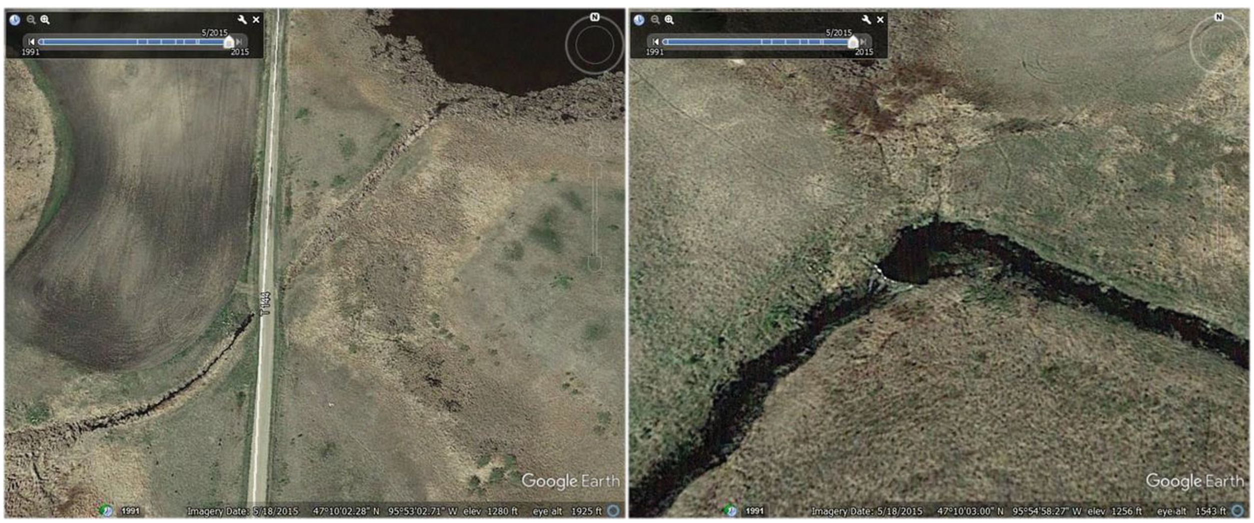


Figure 11. Images of potential connectivity barriers along AUID 647, including the Tamarack Wetland Dam at the 183rd Avenue crossing on May 18, 2015 (left), courtesy of Google Earth; and a beaver dam upstream of the US Highway 59 crossing on May 18, 2015 (right), courtesy of Google Earth.

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 647. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to the MPCA (2013), 59% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 647. The MPCA biological monitoring staff did not encounter any flow-related issues (e.g., intermittency) at Station 14RD022 along AUID 647. There is no flow monitoring data for the reach. The USGS (2016) estimated that the normal range of flow values for the reach at its outlet was 4.5 (Q25) to 0.5 (Q75) cfs. Additionally, the estimated median flow (Q50) was 1.6 cfs, while the projected Q5 flow was 41.6 cfs and the Q95 flow was 0.1 cfs. The Q25 to Q75 flow values ratio was 9:1, which is indicative of a hydrologically stable system. By comparison, several of the more hydrologically stable rivers in the Red River Basin (i.e., Buffalo River, Clearwater River, and Otter Tail River) had a ratio of 7:1 or less. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 4, 2016, August 17, 2016, and September 28, 2016) and documented flow conditions. Minimal flow (≈0.1 cfs) was noted along the upstream extent of the reach (i.e., U.S. Highway 59 crossing) on September 28, 2016. Overall, the available data suggest that the reach is prone to extended periods of minimal to no flow.

Biotic response – macroinvertebrate

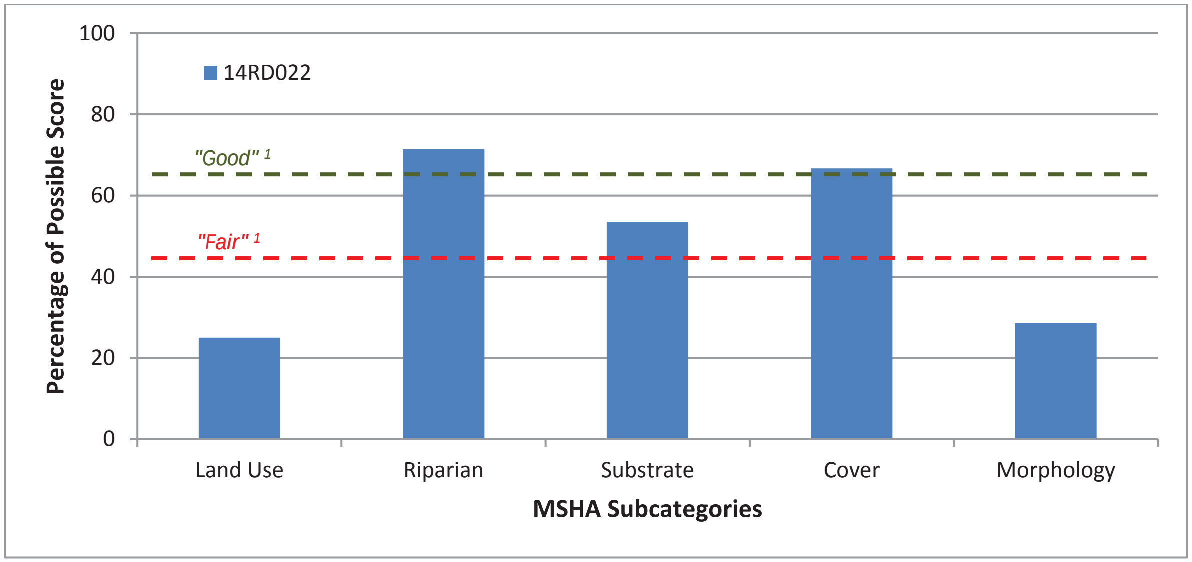
- The following evidence (Appendix B) *somewhat supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 647:
- Below average (<5) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Station 14RD022 (3)
- Below average (<6%) relative abundance of long-lived individuals (LongLivedPct) at Station 14RD022 (0%)
- Below average (<34) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 14RD022 (24)
- Below average (<2%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Station 14RD022 (0%)

Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of Ephemeroptera, Plecoptera, and Trichoptera, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012).

Insufficient physical habitat

Available data

The physical habitat of AUID 647 was evaluated at Station 14RD022 using the MSHA. The entire reach has been channelized (MPCA, 2013). The station yielded a MSHA score of 48 (“fair”). Figure 12 displays the MSHA subcategory results for the station. The predominance of agricultural row crops in the immediate vicinity of the station limited its land use subcategory score. The station scored well in the riparian subcategory due to an “extensive” riparian zone width and no bank erosion. The substrate subcategory score for the station was negatively affected by a lack of riffle habitat and a “moderate” level of embeddedness of its coarse substrate (i.e., gravel). While the station offered an “extensive” amount of cover, the only cover types noted were macrophytes (emergent, submergent, and floating leaf), overhanging vegetation, and undercut banks. Lastly, the morphology subcategory score was limited by a lack of sinuosity, depth variability, and velocity types.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 12. MSHA subcategory results for Station 14RD022 along AUID 647.

On June 8, 2015, Vinje and Clark (2017) completed a Pfankuch stability assessment at Station 14RD022 along AUID 647. The results of this assessment are summarized below:

> *"A Pfankuch stability assessment was completed at [Station] 14RD022 on 6/8/15. The stream type at this location was an E6 (low width-to-depth ratio, silt bed stream). Gravel was observed under the silt/muck in several areas of the reach, so the potential stream type is likely an E4 (low width-to-depth ratio, gravel bed stream). Adjusting the Pfankuch rating to the potential E4 stream type puts this reach in the fair (moderately unstable category). The upper and lower banks mostly rated as excellent, but because this reach was channelized, there was excess deposition of silt/muck along the banks, which rated as poor. Similarly, the channel bottom scored poorly because of the silty/mucky nature of the bed. Overall, as a result of being channelized, this reach lacks the stream power to efficiently move sediment and it lacks the typical facets, and therefore habitat, of a meandering stream. The bankfull width at this site was estimated at approximately 20 ft., so the 10 ft. wide x 8 ft. high corrugated metal pipe culvert at the downstream end of the reach could be compounding the sediment deposition problem, as it was undersized. Although undersized, the culvert did not appear to be a barrier to fish passage. There were no beaver dams located within the study reach, but beaver activity was observed in the area and beaver dams downstream could be influencing fish passage and sediment deposition."*

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by the absence of riffles, embeddedness of coarse substrate, minimal cover types, nominal depth variability, and few velocity types. Vinje and Clark (2017) attributed many of these deficiencies to the effects of past channelization.

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for insufficient physical habitat as a stressor to the macroinvertebrate community of AUID 647:

- Below average (<27%) relative percentage of climber individuals (ClimberPct) at Station 14RD022 (12%)

- Above average (>56%) relative abundance of legless individuals (LeglessPct) at Station 14RD022 (98%)
- Below average (<18%) relative abundance of scraper individuals (ScraperPct) at Station 14RD022 (8%)

Climber and scraper taxa require clean, coarse substrate or other objects to attach themselves to or feed from, while legless macroinvertebrates are generally tolerant of degraded benthic habitat (e.g., embedded coarse substrate).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 14RD022 along AUID 647 at the time of a July 22, 2014, fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 4 mg/L. Table 9 summarizes all available discrete TSS data for Site S006-199 (290th Street crossing); the site is located approximately 0.2 miles downstream of the reach (Figure 10). There were no exceedances of the 30 mg/L standard. The WRRW HSPF model estimates that the reach had a TSS concentration in excess of the standard approximately 6% of the time during the period of 1996 to 2009. Additionally, the aforementioned MSHA results indicate that the deposition of excess fine sediment caused the "moderate" level of embeddedness of coarse substrate documented at Station 14RD022. Figure 13 shows images of an agricultural field (downstream of the CSAH 12 crossing) that is adjacent to the reach and has minimal to no riparian buffer. Overall, the available data suggest that the reach likely experiences at least occasional periods of high suspended sediment.

Table 9. Discrete TSS data for Site S006-199 near AUID 647.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S006-199	2010-2011	22	2	22	9	0

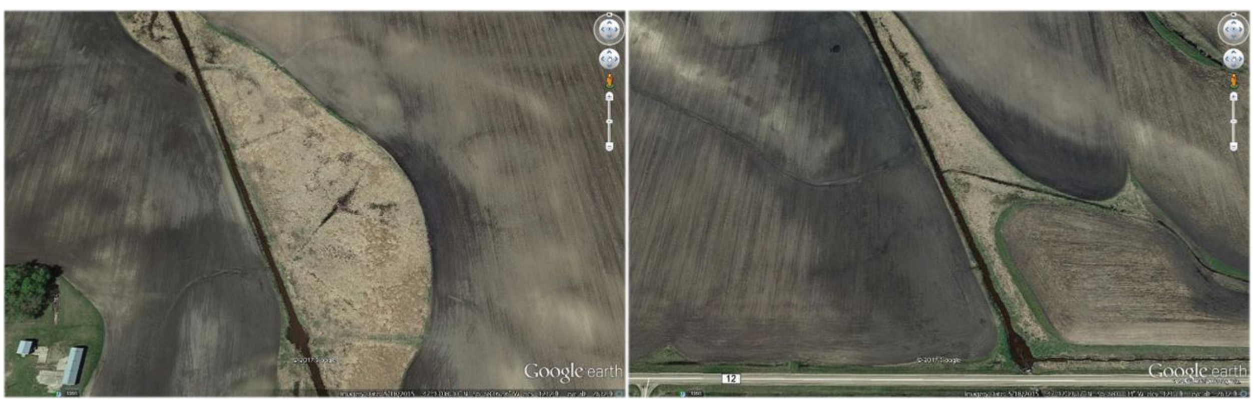


Figure 13. Images of an agricultural field adjacent to AUID 647 that has minimal to no riparian buffer, courtesy of Google Earth.

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for high suspended sediment as a stressor to the macroinvertebrate community of AUID 647:

- Below average (<10%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Station 14RD022 (3%)
- Below average (<1%) relative abundance of high TSS intolerant taxa at Station 14RD022 (0%)

Collector-filterers utilize specialized mechanisms (e.g., silk nets) to strain organic material from the water column. High suspended sediment can interfere with these mechanisms (Arruda et al., 1983; Barbour et al., 1999; Lemley, 1982; Strand and Merritt, 1997).

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 14RD022 along AUID 647 at the time of the fish and macroinvertebrate monitoring visits. The DO concentrations were 6.1 and 4.7 mg/L, respectively. Figure 14 displays all available discrete DO data for Site S006-199 (2010-2011; *n*=21). Only one of the values was below the 5 mg/L standard; however, no measurements were collected prior to 9:00 a.m., when values are typically lowest. Generally, the lowest DO levels were in the months from June to September. Additionally, the WRRW HSPF model estimates that the reach had a DO concentration below the standard approximately 3% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of low DO.

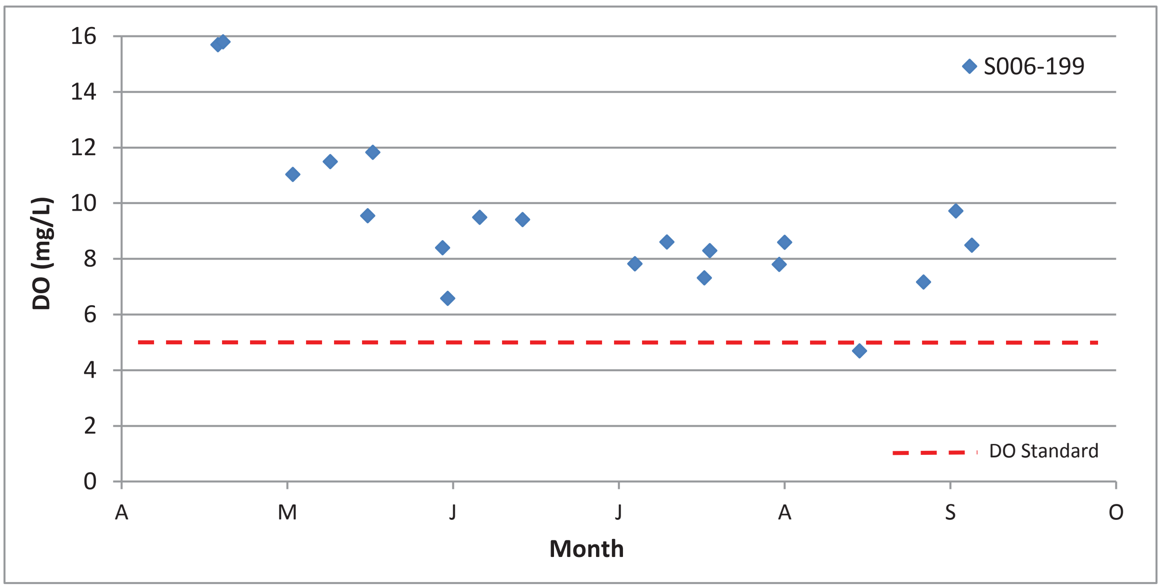


Figure 14. Discrete DO data for Sites S006-199 along AUID 647.

Eutrophication-related data for AUID 647 includes the following parameters: TP, chlorophyll-a (Chl-a), and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Station 14RD022 along AUID 647 at the time of the fish monitoring visit. The sample was analyzed for several parameters, including TP. The station had a TP concentration of 70 µg/L. Discrete TP data are available for Site S006-199 (2010-2011, *n*=22). The mean TP concentration for the site was 74 µg/L, while the highest concentration was 194 µg/L and the lowest concentration was 5 µg/L. There was only one exceedance of the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S006-199 (2010-2011; *n*=20). The mean Chl-a concentration for the site was 5 µg/L, while the highest concentration was 19 µg/L and the lowest concentration was 1 µg/L. There were no exceedances of the 40 µg/L South River Nutrient Region Chl-a standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., August 4, 2016, August 17, 2016, and September 28, 2016). Overall, the limited data and field observations do not suggest that eutrophication is adversely affecting the DO regime of the reach.

Biotic response – macroinvertebrate

The following evidence (Appendix B) is inconclusive and *neither supports nor weakens* the case for low DO as a stressor to the macroinvertebrate community of AUID 647:

- Below average (<5) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Station 14RD022 (3)
- Below average (<34) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 14RD022 (24)
- Above average (>31%) relative abundance of low DO tolerant taxa at Station 14RD022 (34%)

Low DO often limits the taxa richness of macroinvertebrates, particularly members of the orders Ephemeroptera, Plecoptera, and Trichoptera, and favors taxa that are tolerant (Weber, 1973; EPA, 2012). While the abovementioned DO-related metrics indicate stress, the available data suggest that the reach experiences infrequent periods of low DO

Summary of stressors

The evidence suggests that the M-IBI impairment associated with AUID 647 is attributed to insufficient physical habitat and, to a lesser extent, flow regime instability and high suspended sediment. The entire reach has been channelized, which has negatively affected its instream habitat. The biological monitoring station offered few habitat facets. While the station offered some gravel substrate, it was embedded with fine sediment. The reach is prone to extended periods of minimal to no flow. Agricultural drainage is the primary anthropogenic factor contributing to this issue. Additionally, the data suggests that the reach is prone to at least occasional periods of high suspended sediment. Soil erosion from adjacent agricultural field, particularly along the downstream extent of the reach, is the likely source of this sediment. A summary of recommended actions to alleviate the influence of these stressors is provided in Section 4.2.

3.2.3 Garden Slough (AUID 579)

Physical setting

This reach represents Garden Slough, which extends from its headwaters, to its confluence with Mashaug Creek (Figure 15); a total length of 10 miles. The reach has a subwatershed area of 11 square miles (6,902 acres). The subwatershed contains 13 miles of intermittent drainage ditch (e.g., AUID 579) and three miles of intermittent stream (DNR, 2003). According to the MPCA (2013), 57% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 56% of AUID 579. The NLCD 2011 (USGS, 2011) lists cultivated crops (83%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (7%), developed (5%), forest (3%), hay/pasture (1%), and herbaceous (1%).

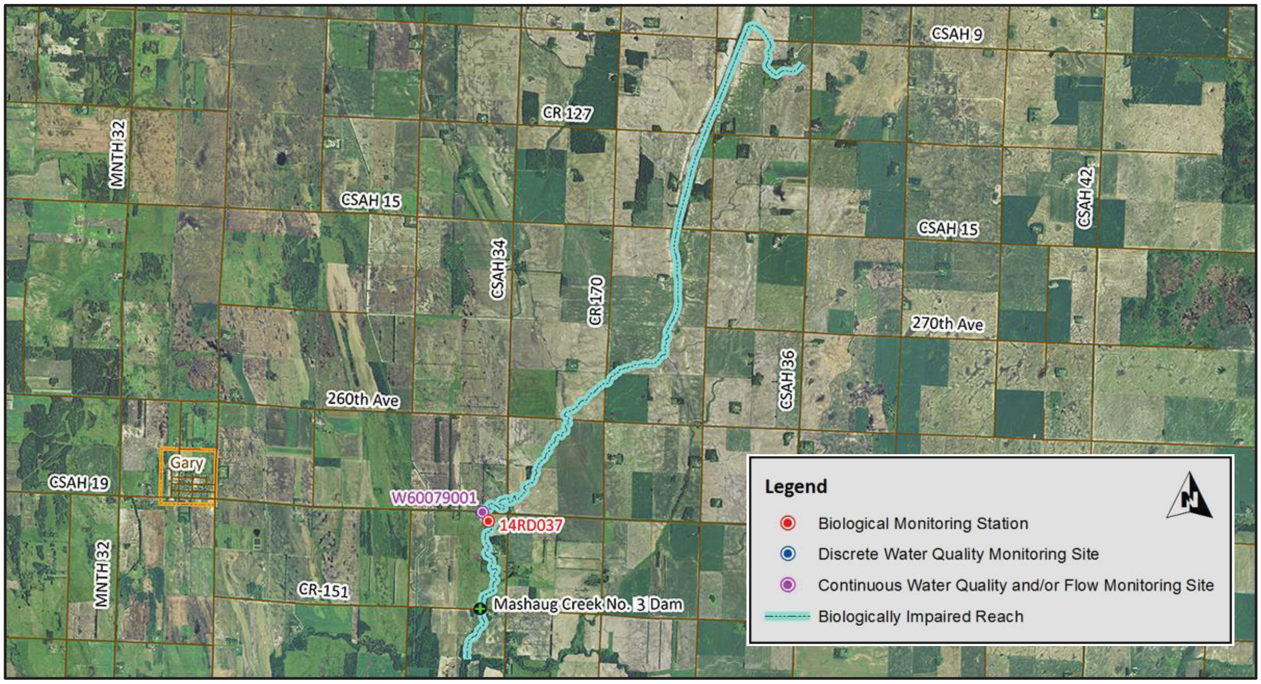


Figure 15. Map of AUID 579 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 579 was monitored at Station 14RD037 (0.1 mile downstream of the CSAH 19 crossing) on June 11, 2014). The location of the station is shown in Figure 15. The station was designated as Modified Use within the Northern Headwaters F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 23. Monitoring of the station yielded an F-IBI score (16) below the impairment threshold. Overall, the fish assemblage of the station was largely dominated by tolerant taxa, specifically brook stickleback, central mudminnow, and fathead minnow.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff noted a beaver dam (Figure 16) upstream of Station 14RD037 on May 17, 2016. The beaver dam had an associated pool and appeared to be a complete barrier to connectivity. According to the DNR (2014), the Mashaug Creek No. 3 Dam (Figure 16) is located at the 240th Avenue crossing, near the downstream end of the reach. The dam, which is owned by Norman County, is a 32-foot high earthen structure that was completed in 1977 for the purpose of flood control. The dam is a complete barrier to connectivity at all flow conditions. On September 14, 2016, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. The beaver dam near Station 14RD037 was still present. No additional obstructions to connectivity were identified. In addition to the assessment, MPCA SID staff performed a detailed review of an April 14, 2015, aerial photo (courtesy of Google Earth) of the reach. Staff identified two beaver dams (Figure 16) downstream of the CSAH 19 crossing. Each of the beaver dams had an associated pool and appeared be a complete barrier to connectivity at the time of the photo. Also, staff noted two private road crossings. One of the crossings was located upstream of the CSAH 34 crossing, while the other was located downstream of the CSAH 19 crossing (Figure 16). Both crossings appeared to have an undersized culvert, which could alter stream flow and, thereby, limit connectivity. In summary, the Mashaug Creek No. 3 Dam is a complete barrier to connectivity, while the beaver dams and private road crossings have the potential to interfere with connectivity along the reach.

Figure 16. Images of connectivity-related issues associated with AUID 579, including the Mashaug Creek No. 3 Dam on September 14, 2016 (upper left); a beaver dam near Station 14RD037 on May 17, 2016 (upper right); a beaver dam downstream of the CSAH 19 crossing on April 14, 2015 (lower left), courtesy of Google Earth; and a private road crossing downstream of the CSAH 19 crossing on April 14, 205 (lower right), courtesy of Google Earth.

Biotic response – fish

The following evidence (Appendix A) *convincingly supports* the case for loss of longitudinal connectivity as a stressor to the fish community of AUID 646:

- Below average (<1%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Station 14RD037 (0%)
- Below average (<8%) relative abundance of individuals that are migratory (MgrPct) at Station 14RD037 (0%)

Late maturing and migratory fish require well-connected environments in order to access the habitats and resources necessary to complete their life history. Table 10 contrasts the collective fish assemblage that was sampled immediately upstream and downstream of the Mashaug Creek No. 3 Dam. A total of 15 species were sampled at the selected stations below the dam, including one (i.e., carmine shiner) that is considered “vulnerable” to extirpation by connectivity barriers. Only four of the species were found at Station 14RD037, which is located upstream of the dam; no carmine shiner were noted. Additionally, there is insufficient information to determine if the culverts associated with road crossings along the reach are impeding fish passage during high flow conditions (i.e., creating a velocity barrier).

Table 10. Summary of fish species sampled downstream and upstream of the Mashaug Creek Dam No. 3 along Garden Slough (AUID 579).

Fish species[1]	Present downstream of the Mashaug Creek Dam No. 3[2]	Present upstream of the Mashaug Creek Dam No. 3[3]
bigmouth shiner	X	
blacknose dace	X	
blackside darter	X	
brassy minnow	X	
brook stickleback	X	X
carmine shiner	X	
central mudminnow	X	X
common shiner	X	
creek chub	X	
fathead minnow	X	X
finescale dace	X	
johnny darter	X	
longnose dace	X	
northern redbelly dace	X	X
white sucker	X	

[1] Species highlighted red are those designated by Aadland (2015) as "vulnerable" and "most vulnerable" to extirpation by barrier dams.
[2] Stations 05RD114, 14RD014, and 14RD034 along AUID 650
[3] Station 14RD037 along AUID 579

Flow regime instability

Available data

According to the DNR (2003), the reach has an intermittent flow regime. Approximately, 57% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 56% of AUID 579 (MPCA, 2013). The MPCA biological monitoring staff was unable to sample Station 14RD037 on August 4, 2014 due to the absence of flow (Figure 17). Additionally, staff encountered stagnant conditions at Station 14RD037 during a May 17, 2016, reconnaissance visit (Figure 17); a beaver dam was noted upstream. There is no flow monitoring data for the reach. The USGS (2016) estimated that the normal range of flow values for the reach at its outlet was 0.2 (Q25) to less than 0.1 (Q75) cfs. Additionally, the estimated median flow (Q50) was less than 0.1 cfs, while the projected Q5 flow was 6.3 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 35:1, which is high and indicative of a flashy system that is highly influenced by runoff. By comparison, several of the more hydrologically stable rivers in the Red River Basin (i.e., Buffalo River, Clearwater River, and Otter Tail River) had a ratio of 7:1 or less. The MPCA SID staff conducted reconnaissance along the reach on four separate dates (i.e., August 4, 2016, August 19, 2016, September 1, 2016, and September 14, 2016) and documented flow conditions. Minimal flow (≈0.1 cfs) was noted along the upstream extent of the reach (i.e., at and upstream of the 260th Avenue crossing) on September 14, 2016. Overall, the available data suggest that the reach is prone to extended periods of minimal to no flow.

Figure 17. Images of stagnant conditions at Station 14RD037 along AUID 579 on August 4, 2014 (left) and May 17, 2016 (right).

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for flow regime instability as a stressor to the fish community of AUID 579:

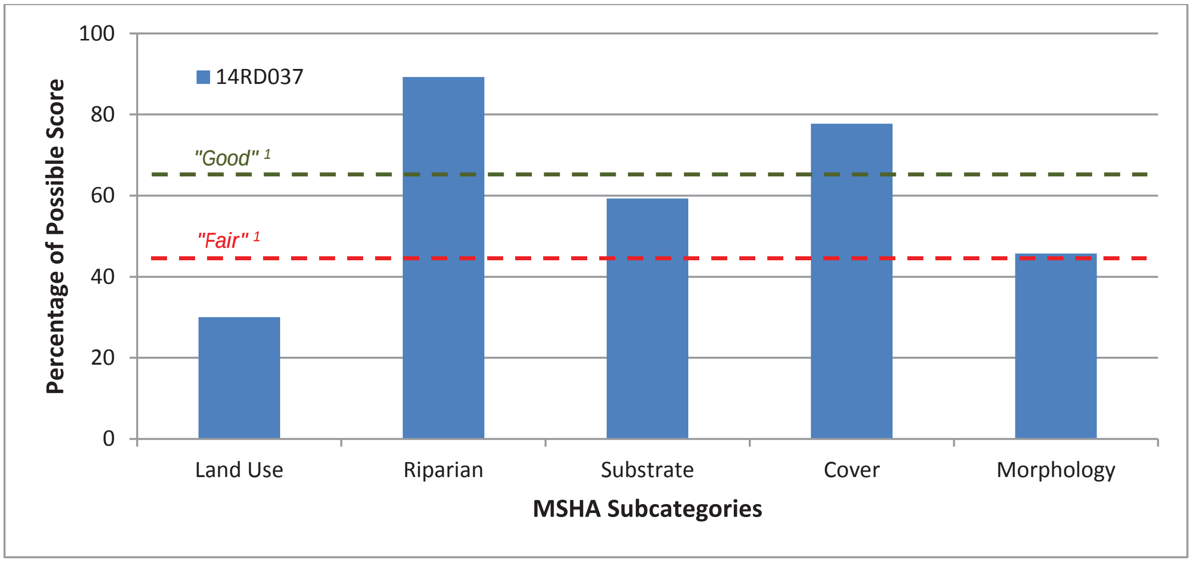
- Above average (>72%) combined relative abundance of the three most abundant taxa (DomThreePct) at Station 14RD037 (92%)
- Above average (>87%) relative abundance of taxa with a female mature age equal to or less than two years (MA<2TxPct) at Station 14RD037 (100%)
- Below average (<1.18) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 14RD037 (0.03)
- Above average (>19%) relative abundance of taxa that are pioneers (PioneerTxPct) at Station 14RD037 (25%)
- Above average (>40%) relative abundance of taxa that are short-lived (SLvdTxPct) at Station 14RD037 (75%)

Flow regime instability tends to limit species diversity and favor taxa that are early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 579 was evaluated at Station 14RD037 using the MSHA. The station is located along a natural segment of the reach (MPCA, 2013). The station yielded a MSHA score of 61 (“fair”). Figure 18 displays the MSHA subcategory results for the station. The predominance of agricultural row crops in the immediate vicinity of the station limited its land use subcategory score. The station scored well in the riparian subcategory due to a “moderate” to “wide” riparian zone width and no bank erosion. While the station offered coarse substrate (i.e., cobble and gravel) and only a “little” amount of embeddedness, the lack of riffle habitat limited the substrate subcategory score. The station also scored well in the cover subcategory due to the diversity and “extensive” amount of cover present. Noted cover types included deep pools, logs, macrophytes (emergent, submergent, and floating leaf), shallows, and overhanging vegetation. Lastly, a limited amount of sinuosity and velocity types adversely affected the morphology subcategory score. Overall, the instream habitat of the reach is primarily limited by the absence of riffles and a lack of velocity types.



[1] The minimum percentage of each subcategory score needed for the station to achieve a “fair” and “good” MSHA rating.

Figure 18. MSHA subcategory results for Station 14RD037 along AUID 579.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for insufficient physical habitat as a stressor to the fish community of AUID 579:

- Below average (<7%) relative abundance of individuals that are benthic insectivores, excluding tolerant species (BenInsect-TolPct) at Station 14RD037 (0%)
- Below average (<10%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Station 14RD037 (0%)
- Above average (>18%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Station 14RD037 (25%)
- Below average (<14%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 14RD037 (0%)
- Below average (<22%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Station 14RD037 (0%)
- Below average (<9%) relative abundance of individuals that predominately utilize riffle habitats (RifflePct) at Station 14RD037 (0%)
- Below average (<19%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 14RD037 (0%)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 14RD037 along AUID 579 at the time of the fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 4 mg/L. Additionally, the WRRW HSPF model estimates that the reach had a TSS concentration in excess of the standard approximately 2% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Biotic response – fish

The following evidence (Appendix A) inconclusive and *neither supports nor weakens* the case for high suspended sediment as a stressor to the fish community of AUID 579:

- Above average (>14 mg/L) mean TSS TIV at Station 14RD037 (16 mg/L)
- Below average (<75%) probability of meeting the TSS standard at Station 14RD037 (70%)

While the abovementioned suspended sediment-related evidence indicate stress, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 14RD037 along AUID 579 at the time of the fish monitoring visit. The DO concentration was 4.3 mg/L. The MPCA conducted continuous DO monitoring at Site W60079001 (CSAH 19 crossing) from August 27, 2016, to September 1, 2016; the location of the site is shown in Figure 15. The monitoring results are provided in Table 11, as well as displayed in Figure 19. While 55% of the total values were below the 5 mg/L standard, 80% of the daily minimum values were below the standard. Additionally, the WRRW HSPF model estimates that the reach had a DO concentration below the standard approximately 98% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

Table 11. Continuous DO data for Site W60079001 along AUID 579.

Start date - End date	*n*	Max. (mg/L)	Min. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 27, 2016 - September 1, 2016	482	7.7	3.2	55	80	1.8

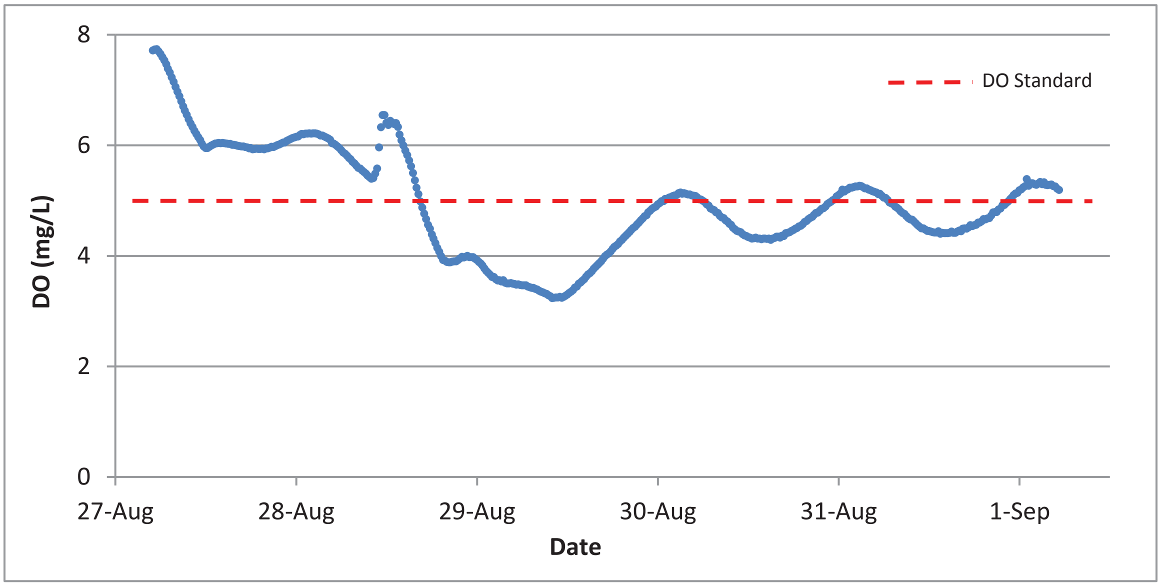


Figure 19. Continuous DO data for Site W60079001 along AUID 579.

Eutrophication-related data for AUID 579 includes the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Station 14RD037 along AUID 579 at the time of the fish monitoring visit. The sample was analyzed for several parameters, including TP. The station had a TP concentration of 306 µg/L. The mean daily DO flux documented during continuous DO monitoring at Site W60079001 (Table 11) was 1.8 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. Also, the MPCA biological monitoring staff noted "lots of filamentous algae" at Station 14RD037 during a June 11, 2014, fish monitoring visit. However, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during four separate reconnaissance visits along the reach (i.e., August 4, 2016, August 19, 2016, September 1, 2016, and September 14, 2016). Overall, there is insufficient data to determine if eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for low DO as a stressor to the fish community of AUID 579:

- Below average (<6.3 mg/L) mean DO TIV at Station 14RD037 (5.6 mg/L)
- Below average (<25%) probability of meeting the DO standard at Station 14RD037 (7%)

Summary of stressors

The evidence suggests that the F-IBI impairment associated with AUID 579 is primarily attributed to a loss of connectivity. Flow regime instability, insufficient physical habitat, and low DO are also substantial stressors. The Mashaug Creek No. 3 Dam is located near the outlet of the reach and is a complete barrier to connectivity. Given its location and size, there is limited opportunity to improve the fish community of the reach with it in place. The reach is prone to extended periods of minimal to no flow. Agricultural drainage is the primary anthropogenic factor contributing to this issue. Many of the watercourses in the subwatershed have been physically altered (e.g., channelized), including a majority of Garden Slough, to more rapidly convey water. This alteration has negatively affected the physical habitat of the reach. The biological monitoring station offered no riffles and limited velocity types. Lastly, the data suggests that the reach is prone to frequent periods of low DO. Insufficient baseflow is believed to be a major contributing factor to this issue. A summary of recommended actions to alleviate the influence of these stressors is provided in Section 4.2.

3.2.4 Mashaug Creek (AUID 650)

Physical setting

This reach represents the segment of Mashaug Creek from the 240th Avenue crossing, to its confluence with the Wild Rice River (Figure 20); a total length of 12 miles. The reach has a subwatershed area of 76 square miles (48,618 acres). The subwatershed contains 90 miles of intermittent drainage ditch, 12 miles of intermittent stream, and 12 miles of perennial stream (i.e., AUID 650) (MDNR, 2003). According to the MPCA (2013), 60% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 3% of AUID 650. The NLCD 2011 (USGS, 2011) lists cultivated crops (74%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (10%), forest (6%), hay/pasture (5%), developed (4%), and herbaceous (1%).

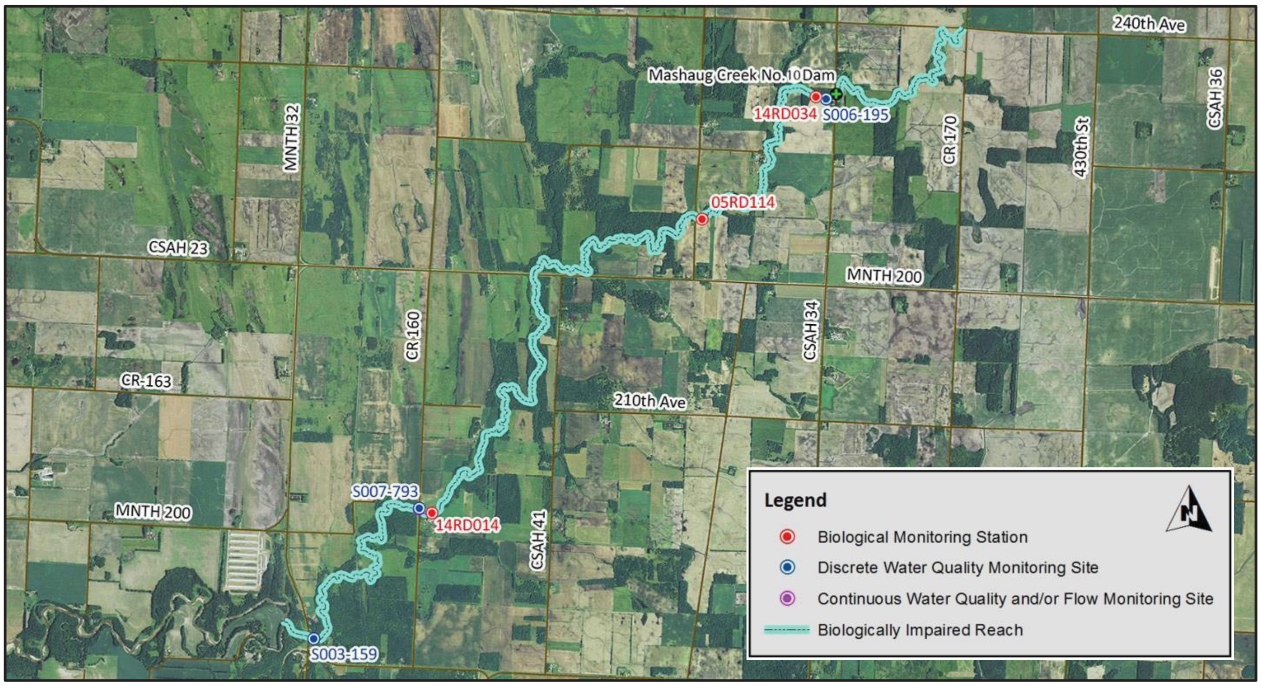


Figure 20. Map of AUID 650 and associated biological monitoring stations and water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 650 was monitored at Station 05RD114 (0.1 mile upstream of the CR 166 crossing) on August 4, 2014; Station 14RD014 (0.1 mile upstream of the CR 160 crossing) on July 16, 2014 (1) and July 14, 2015 (2); and Station 14RD034 (0.1 mile downstream of the CSAH 34 crossing) on June 24, 2014. The location of the stations is shown in Figure 20. Station 05RD114 and 14RD034 were designated as General Use within the Northern Headwaters F-IBI Class. The impairment threshold for the stations is an F-IBI score of 42. Stations 14RD014 was designated as General Use within the Northern Streams F-IBI Class. Accordingly, the impairment threshold for this station is an F-IBI score of 47. Stations 05RD114 (F-IBI=43) and 14RD034 (F-IBI=45) each scored slightly above their respective impairment threshold, while Station 14RD014 (F-IBI=45 and 42) scored below its threshold. Overall, the fish assemblage of the stations was largely dominated by tolerant taxa, specifically creek chub and johnny darter.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 650 was monitored at Station 14RD014 on August 4, 2015. The station was designated as General Use within the Southern Streams-Riffle/Run Habitats M-IBI Class. Accordingly, the impairment threshold for the station is an M-IBI score of 37. Monitoring of the station yielded an M-IBI score (29) below the impairment threshold. Tolerant taxa, specifically *Caenis* (mayflies), *Polypedilum* (midges), and *Rheotanytarsus* (midges), dominated the macroinvertebrate assemblage of the station.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 05RD114, 14RD014, and 14RD034 along AUID 650. According to the DNR (2014), the Mashaug Creek No. 10 Dam (Figure 21) is located at the CSAH 34 crossing, near the upstream end of the reach. The dam, which is jointly owned and operated by Norman County and the WRWD, is a 30-foot high earthen structure that was completed in 1984 for the purpose of flood control. The dam is a complete barrier to connectivity at all flow conditions. On September 28, 2016, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No additional obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of an April 14, 2015, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo. In summary, the Mashaug Creek No. 10 Dam is the only known barrier to connectivity along the reach.

Figure 21. Images of the Mashaug Creek No. 10 Dam on September 28, 2016, including the intake structure (left) and the outflow pipe (right).

Biotic response – fish

The following evidence (Appendix A) is inconclusive and *neither supports nor weakens* the case for loss of longitudinal connectivity as a stressor to the fish community of AUID 650:

- Below average (<18/4%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 05RD114 (0%), 14RD014(1) (0%), 14RD014(2) (0%), and 14RD034 (0%)
- Below average (<17/10%) relative abundance of individuals that are migratory (MgrPct) at Stations 05RD114 (9%), 14RD014(1) (5%), 14RD014(2) (12%), and 14RD034 (3%)

Late maturing and migratory fish require well-connected environments in order to access the habitats and resources necessary to complete their life history. However, there are no known connectivity barriers with which to attribute the abovementioned metric responses. The Mashaug Creek No. 10 Dam is located upstream of the biological monitoring stations. Additionally, there is insufficient information to determine if the culverts associated with road crossings along the reach are impeding fish passage during high flow conditions (i.e., creating a velocity barrier).

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 650. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to the MPCA (2013), 60% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 3% of AUID 650. The MPCA biological monitoring staff was unable to sample Station 14RD014 on August 6, 2014 due to the absence of flow. Additionally, staff was unable to sample Station 14RD034 on August 4, 2015 due to intermittent conditions (Figure 22). There is no flow monitoring data for the reach. The USGS (2016) estimated that the normal range of flow values for the reach at its outlet was 1.9 (Q25) to 0.1 (Q75) cfs. Additionally, the estimated median flow (Q50) was 0.3 cfs, while the projected Q5 flow was 43.2 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 30:1, which is high and indicative of a flashy system that is highly influenced by runoff. By comparison, several of the more hydrologically stable rivers in the Red River Basin (i.e., Buffalo River, Clearwater River, and Otter Tail River) had a ratio of 7:1 or less. The MPCA SID staff conducted reconnaissance along the reach on six separate dates (i.e., August 4, 2016, August 19, 2016, August 29, 2016, September 1, 2016, September 14, 2016, and September 28, 2016) and documented flow conditions. No visible evidence of flow was noted at the CR 160 crossing on August 4, 2016 and August 19, 2016. On August 29, 2016, bankfull conditions were observed at the CR 160 crossing (Figure 22); the subwatershed received up to six inches of rainfall during a storm event the previous evening. When staff returned to the same crossing on September 1, 2016, the water level had dropped approximately six feet (Figure 22). Additionally, a Google Earth Street View image captured at the State Highway 32 crossing in September 2013 shows a nearly dry stream channel (Figure 22). Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

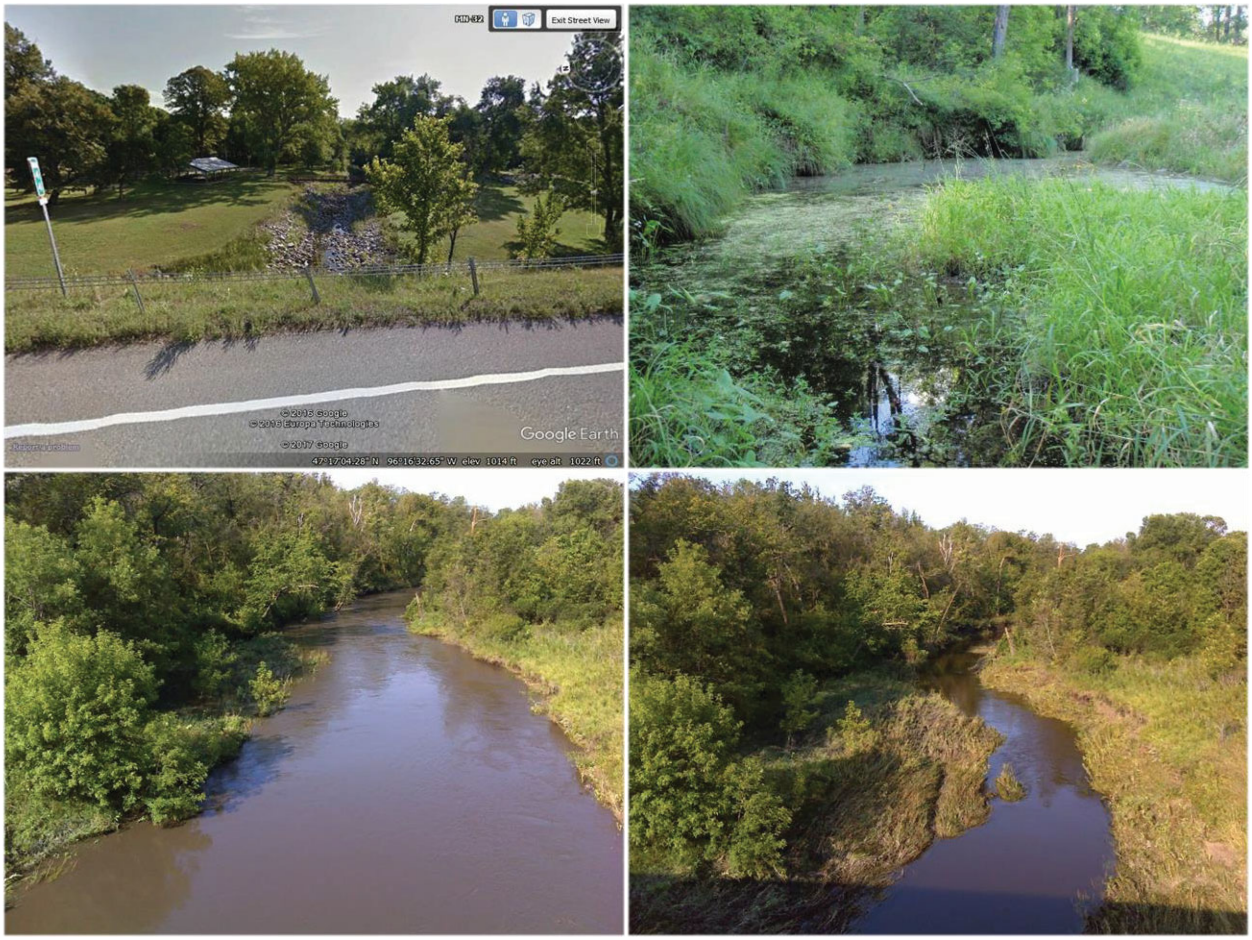


Figure 22. Images of flow regime instability along AUID 650, including a nearly dry stream channel at the State Highway 32 crossing in September 2013 (upper left), courtesy of Google Earth; stagnant conditions at Station 14RD034 on August 4, 2015 (upper right); bankfull conditions at the CR 160 crossing on August 29, 2016 (lower left); and a substantial drop in the water level at the CR 160 crossing on September 1, 2016 (lower right).

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for flow regime instability as a stressor to the fish community of AUID 650:

- Above average (>64/71%) combined relative abundance of the three most abundant taxa (DomThreePct) at Stations 05RD114 (80%), 14RD014(1) (68%), and 14RD014(2) (74%)
- Above average (>24/35%) relative abundance of taxa that are generalists (GeneralTxPct) at Stations 05RD114 (50%), 14RD014(1) (36%), 14RD014(2) (50%), and 14RD034 (42%)
- Above average (>58/78%) relative abundance of taxa with a female mature age equal to or less than two years (MA<2TxPct) at Stations 05RD114 (88%), 14RD014(1) (86%), 14RD014(2) (80%), and 14RD034 (92%)
- Below average (<0.97/0.88) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 05RD114 (0.80), 14RD014(1) (0.85), 14RD014(2) (0.70), and 14RD034 (0.25)
- Above average (>12/19%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 05RD114 (25%), 14RD014(1) (21%), 14RD014(2) (30%), and 14RD034 (25%)
- Above average (>13/27%) relative abundance of taxa that are short-lived (SLvdTxPct) at Stations 05RD114 (38%), 14RD014(1) (50%), 14RD014(2) (40%), and 14RD034 (50%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 650:

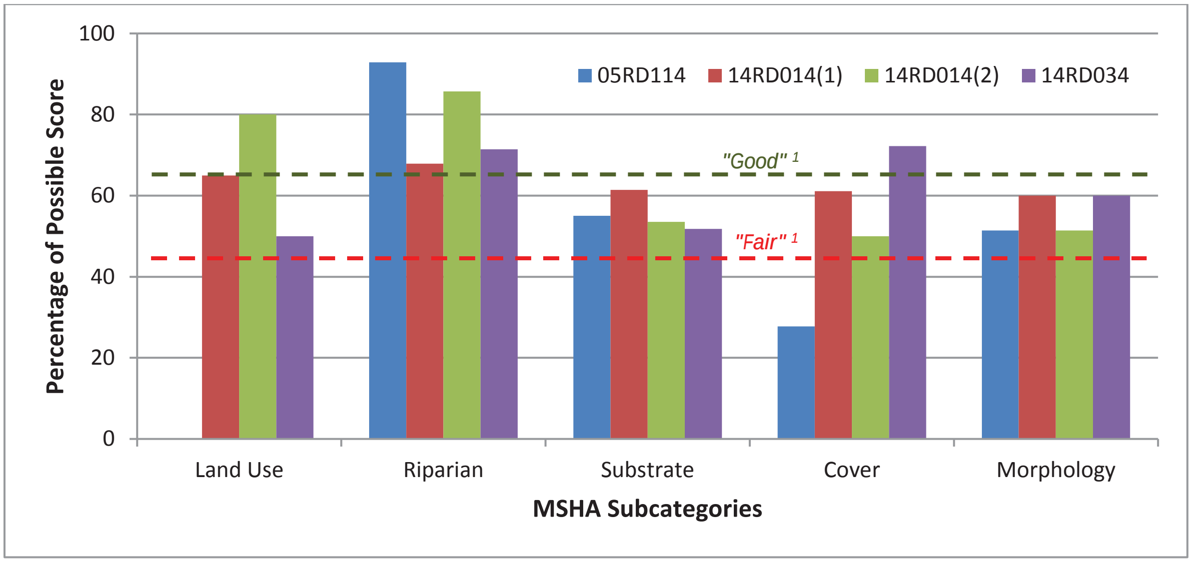
- Below average (<11) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Station 14RD014 (8)
- Below average (<9%) relative abundance of long-lived individuals (LongLivedPct) at Station 14RD014 (0%)
- Above average (>72%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Station 14RD014 (81%)
- Below average (<6%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Station 14RD014 (3%)

Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of Ephemeroptera, Plecoptera, and Trichoptera, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012).

Insufficient physical habitat

Available data

The physical habitat of AUID 650 was evaluated at Stations 05RD114, 14RD014, and 14RD034 using the MSHA. Each of the stations is located along a natural segment of the reach (MPCA, 2013). Stations 05RD114 (MSHA=51/"fair"), 14RD014 (MSHA=62/"fair" and 58/"fair"), and 14RD034 (MSHA=61/"fair") yielded largely uniform scores. Figure 23 displays the MSHA subcategory results for the stations. The predominance of agricultural row crops in the immediate vicinity of Stations 05RD114 and 14RD034 limited their land use subcategory score. The riparian subcategory scores for the stations were positively influenced by a "moderate" to "extensive" riparian zone width. However, a "moderate" amount of bank erosion was noted at Stations 14RD014 and 14RD034. Each of the stations offered riffle habitat and coarse substrate (e.g., gravel, cobble, and boulders), although the quality of the coarse substrate was degraded by a "little" to "moderate" amount of embeddedness. Station 05RD114 scored substantially lower in the cover subcategory than the other stations, providing only a "sparse" amount of cover. Noted cover types along the reach included boulders, deep pools, logs, macrophytes (emergent, submergent, and floating leaf), overhanging vegetation, rootwads, shallows, and undercut banks. Lastly, the stations scored in the "fair" range for the morphology subcategory due in part to "moderate" channel stability and "fair" to "good" channel development.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 23. MSHA subcategory results for Stations 05RD114, 14RD014, and 14RD034 along AUID 650.

Vinje and Clark (2017) completed fluvial geomorphic assessments at Stations 05RD114, 14RD014, and 14RD034 along AUID 650. The results of these assessments are summarized below:

> *"A Pfankuch stability assessment was completed at [Station] 05RD114 on 6/9/15. The stream type at this location was estimated to be an F5 (moderate width-to-depth ratio, entrenched, sand bed stream). Based on observations in the field, the potential stream type is likely a C4 (moderate width-to-depth ratio, gravel bed stream). Adjusting the Pfankuch rating to the potential C4 stream type puts this reach in the poor (unstable) category. Overall, this reach scored fair to poor in all but one Pfankuch rating category. The upper banks had steep slope gradients, showed evidence of mass wasting, and contained moderate to heavy amounts of dead or downed trees that could contribute to debris jams. While there was good vegetative bank protection, there was increased pressure on the banks as a result of incision. In addition to being incised, this reach appeared to be entrenched and was mostly cut-off from its floodplain at 2x the maximum bankfull depth at the riffles. The incised conditions throughout this reach made determining bankfull difficult because of the general lack of bankfull indicators. The incision was also leading to significant cutting on the lower banks. The stream bed was primarily a loose assortment of sand, with some small gravel, and was generally lacking in pool depth and holding cover. There were two 12.5 ft. wide x 7.5 ft. high concrete pipe arch culverts at the downstream road crossing. The culverts appeared to be properly sized and were likely not barriers to fish passage. However, the left culvert (looking downstream) was partially blocked by debris on the upstream end and was completely blocked with sediment on the downstream end. The right culvert conveyed most of the flow and had 1 ft. of sand deposition in the bottom at the upstream end."*

> *"A Pfankuch stability assessment was completed at [Station] 14RD014 on 6/9/15. The stream type at this location was estimated to be an F5 (moderate width-to-depth ratio, entrenched, sand bed stream). Based on observations in the field, the potential stream type is likely a C4 (moderate width-to-depth ratio, gravel bed stream). Adjusting the Pfankuch rating to the potential C4 stream type puts this reach in the fair (moderately unstable) category; however, the score was only a couple of points from being in the poor (unstable) category. Overall, this reach scored fair to poor in almost all Pfankuch rating categories. The upper banks had steep slope gradients, showed evidence of mass wasting, and contained moderate to heavy amounts of dead or downed trees that could contribute to debris jams. While there was good vegetative bank protection, there was increased pressure on*

the banks as a result of incision. In addition to being incised, this reach appeared to be entrenched and completely cut-off from a floodplain at 2x the maximum bankfull depth at the riffles. The incised conditions throughout this reach made determining bankfull difficult because of the general lack of bankfull indicators. The incision was also leading to significant cutting on the lower banks, as was the presence of woody debris in several locations. In addition to the sediment contributions from the upper and lower banks, a gully with sediment delta was observed within this reach. Moderate amounts of sand and small gravel deposition were observed on both side and mid-channel bars. The stream bed was primarily a loose assortment of sand and small gravel where slopes were flat, but larger gravel and cobble were present where the grade steepened. The reach was generally lacking in pool depth and holding cover, except at the downstream end of the reach, near the bridge."

"A Pfankuch stability assessment and Rosgen Levell II geomorphology survey were completed at [Station] 14RD034 on 10/28/16 and 10/31/16. Based on the geomorphology survey, the stream type at this location was a borderline E4/F4 (low to moderate width-to-depth ratio, gravel bed stream). One riffle had a width-to-depth ratio of 10.4 and was slightly entrenched (entrenchment ratio = 3.22), classifying it as an E stream type. The other riffle had a width-to-depth ratio of 12 and was entrenched (entrenchment ratio = 1.27), classifying it as an F stream type. In general, this reach appeared to be trending toward an F stream type, but its potential appeared to be either an E or C stream type. Adjusting the Pfankuch rating to the potential stream type (E4/C4), this reach rated as fair (moderately unstable). There was good vegetative bank protection on the upper banks, but because of the incision (average bank height ratio = 1.7), the upper banks were steep and showed some evidence of mass wasting. The incised conditions were also evident on the lower banks, where significant bank cutting was occurring. Although the stream had access to a narrow floodplain in some areas, flood flows of 2x the maximum bankfull depth at the riffles appeared to be mostly confined to the channel, leading to increased pressure on the banks. The pebble count for this reach indicated the dominant substrate type was small gravel (D_{50} = 4.43 mm); however, there was a layer of loose sand on top of moderately packed gravel throughout much of the reach. A large gully with a sediment delta was also observed within the reach, adding to the sediment supply. At the time of the survey, the water was mostly stagnant, but the pools appeared to have adequate depth for a stream of this size (14 sq. mi. drainage area). Beaver activity was observed within the reach and could be having an impact on flow, as well as fish passage and stability. However, the most likely cause of instability within this reach is the water control structure at the upstream road crossing. Below the water control structure outlet is significant bed scour and bank erosion caused by an undersized culvert (≈ 6 ft. circular concrete pipe)."

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by bank erosion and the embeddedness of coarse substrate. Additionally, Vinje and Clark (2017) identified substantial instability at all of the biological monitoring stations. Incision and entrenchment have resulted in mass wasting and bank cutting. The Mashaug Creek No. 10 Dam appears to be responsible for much of the instability at Station 14RD034. A lack of pool depth and holding cover were noted deficiencies at Stations 05RD114 and 14RD014.

Biotic response – fish

The following evidence (Appendix A) *somewhat supports* the case for insufficient physical habitat as a stressor to the fish community of AUID 650:

- Below average (<29/17%) relative abundance of individuals that are benthic insectivores, excluding tolerant species (BenInsect-TolPct) at Stations 14RD014(1) (19%), 14RD014(2) (21%), and 14RD034 (4%)

- Below average (<14%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Station 14RD034 (8%)
- Above average (>10/14%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 14RD014(1) (29%), 14RD014(2) (20%), and 14RD034 (25%)
- Below average (<16/14%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 05RD114 (5%), 14RD014(1) (10%), 14RD014(2) (5%), and 14RD034 (5%)
- Below average (<45/28%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 05RD114 (27%), 14RD014(1) (20%), 14RD014(2) (21%), and 14RD034 (8%)
- Below average (<24/17%) relative abundance of individuals that predominately utilize riffle habitats (RifflePct) at Stations 05RD114 (8%), 14RD014(1) (5%), 14RD014(2) (12%), and 14RD034 (3%)
- Below average (<45/36%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Stations 05RD114 (16%), 14RD014(1) (38%), 14RD014(2) (27%), and 14RD034 (17%)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for insufficient physical habitat as a stressor to the macroinvertebrate community of AUID 650:

- Above average (>8%) relative abundance of burrower individuals (BurrowerPct) at Station 14RD014 (12%)
- Below average (<50%) relative percentage of clinger individuals (ClingerPct) at Station 14RD014 (37%)
- Above average (>36%) relative abundance of legless individuals (LeglessPct) at Station 14RD014 (71%)
- Below average (<16%) relative percentage of scraper individuals (ScraperPct) at Station 14RD014 (10%)

Clinger and scraper taxa require clean, coarse substrate or other objects to attach themselves to or feed from, while burrower and legless macroinvertebrates are generally tolerant of degraded benthic habitat (e.g., embedded coarse substrate).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD114, 14RD014, and 14RD034 along AUID 650 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The stations had TSS concentrations ranging from 6 to 15 mg/L. Table 12 summarizes all available discrete TSS data for Sites S003-159 (Heiberg Park Bridge crossing), S006-195 (CSAH 34 crossing), and S007-793 (CR 160 crossing); the location of the sites is shown in Figure 20. Each of the sites had only one exceedance of the 30 mg/L standard. The WRRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 5 and 7% of the time during the period of 1996 to 2009. Additionally, the aforementioned MSHA results indicate that the deposition of excess fine sediment caused the “moderate” level of embeddedness of coarse substrate documented at Stations 14RD014 and 14RD034. Figure 24 shows images of streambank instability along the reach. Overall, the available data suggest that the reach experiences at least occasional periods of high suspended sediment.

Table 12. Discrete TSS data for Sites S003-159, S006-195, and S007-793 along AUID 650.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S003-159	2002-2009	14	1	69	11	1
S006-195	2010-2011	22	1	210	15	1
S007-793	2014-2015	11	3	64	15	1

Figure 24. Images of bank instability along AUID 650, including Station 95RD014 on August 21, 2014 (left) and Station 14RD034 on June 24, 2014 (right).

Biotic response – fish

The following evidence (Appendix A) *somewhat supports* the case for high suspended sediment as a stressor to the fish community of AUID 650:

- Above average (>12/13 mg/L) mean TSS TIV at Stations 05RD114 (15 mg/L), 14RD014(1) (14 mg/L), 14RD014(2) (15 mg/L), and 14RD034 (15 mg/L)
- Below average (<83%) probability of meeting the TSS standard at Stations 05RD114 (75%), 14RD014(1) (78%), 14RD014(2) (76%), and 14RD034 (75%)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for high suspended sediment as a stressor to the macroinvertebrate community of AUID 650:

- Below average (<27%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Station 14RD014 (25%)
- Below average (<5%) relative abundance of high TSS intolerant taxa at Station 14RD014 (1%)

Collector-filterers utilize specialized mechanisms (e.g., silk nets) to strain organic material from the water column. High suspended sediment can interfere with these mechanisms (Arruda et al., 1983; Barbour et al., 1999; Lemley, 1982; Strand and Merritt, 1997).

Low dissolved oxygen

Available data

MPCA biological monitoring staff collected a combined six discrete DO measurements at Stations 05RD114, 14RD014, and 14RD034 along AUID 650 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 6.0 to 9.9 mg/L. Figure 25 displays all available discrete DO data for Sites S003-159 (2002-2016; *n*=37), S006-195 (2010-2011; *n*=21), and S007-793 (2014-2015; *n*=24). Collectively, only one value was below the 5 mg/L standard; however, only four of the measurements were collected prior to 9:00 a.m., when values are typically lowest. Generally, the lowest DO levels were in the months of June, July, and August. Additionally, the WRRW HSPF model estimates that the reach had a DO concentration below the standard between 9 and 70% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences at least occasional periods of low DO.

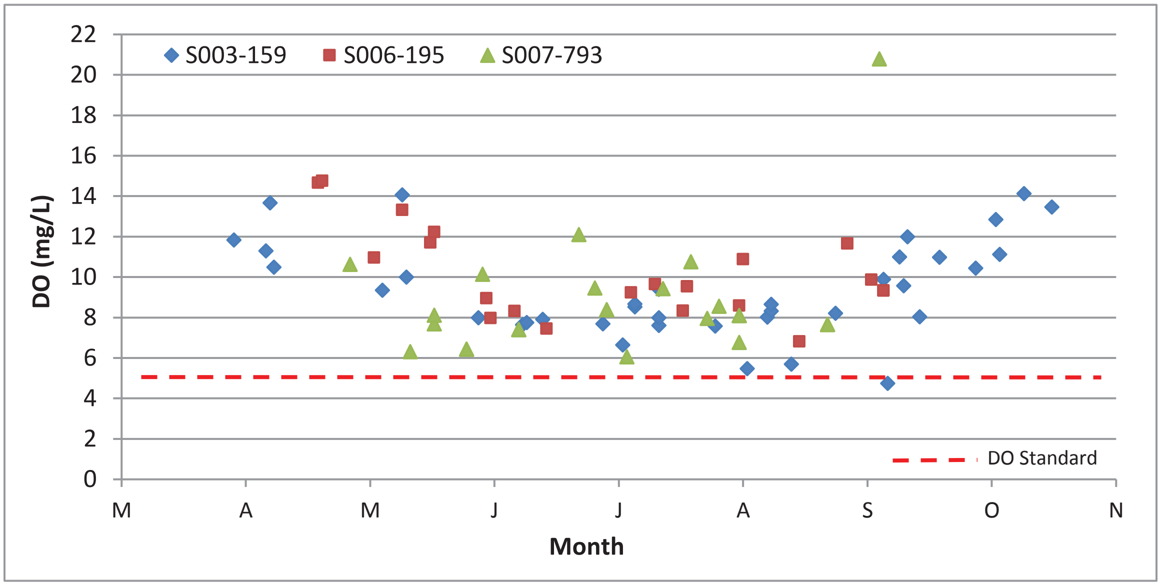


Figure 25. Discrete DO data for Sites S003-159, S006-195, and S007-793 along AUID 650.

Eutrophication-related data for AUID 650 includes the following parameters: TP and Chl-a. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD114, 14RD014, and 14RD034 along AUID 650 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TP. The stations had TP concentrations of 173, 244, and 178 µg/L, respectively. Discrete TP data are available for Sites S003-159 (2002-2009; *n*=21), S006-196 (2010-2011; *n*=22), and S007-793 (2014-2015; *n*=11). Collectively, the mean TP concentration for the sites was 115 µg/L, while the highest concentration was 504 µg/L and the lowest concentration was 30 µg/L. Approximately 26% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Sites S003-159 (2008-2009; *n*=13) and S006-196 (2010-2011; *n*=22). The mean Chl-a concentration for the site was 6 µg/L, while the highest concentration was 21 µg/L and the lowest concentration was 1 µg/L. There were no exceedances of the 40 µg/L South River Nutrient Region Chl-a standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during five separate reconnaissance visits along the reach (i.e., August 4, 2016, August 19, 2016, September 1, 2016, September 14, 2016, and September 28, 2016). While the reach is prone to high TP concentrations, the limited response variable (i.e., Chl-a) data and field observations do not suggest that eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

The following evidence (Appendix A) *somewhat supports* the case for low DO as a stressor to the fish community of AUID 650:

- Below average (<6.9 mg/L) mean DO TIV at Station 14RD034 (6.5 mg/L)
- Below average (<45%) probability of meeting the DO standard at Station 14RD034 (27%)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for low DO as a stressor to the macroinvertebrate community of AUID 650:

- Below average (<11) taxa richness of EPT at Station 14RD014 (8)
- Below average (<7.1 mg/L) mean DO TIV at Station 14RD014 (6.7 mg/L)
- Above average (>9%) relative abundance of low DO tolerant taxa at Station 14RD014 (19%)
- Below average (<25%) relative abundance of low DO intolerant taxa at Station 14RD014 (5%)

Low DO often limits the taxa richness of macroinvertebrates, particularly members of the orders EPT, and favors taxa that are tolerant (Weber, 1973; EPA, 2012).

Summary of stressors

The evidence suggests that the F-IBI impairment associated with AUID 650 is attributed to flow regime instability and, to a lesser extent, insufficient physical habitat, high-suspended sediment, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of flow regime instability, insufficient physical habitat, high-suspended sediment, and low DO. The reach is prone to extreme peak flows, as well as extended periods of minimal to no flow. Agricultural drainage is the primary anthropogenic factor contributing to this issue. Instream and soil erosion has degraded the quality of instream habitat (e.g., embeddedness of coarse substrate and decrease in pool depth) and causes at least occasional periods of high-suspended sediment. Lastly, the data suggests that the reach is prone to periods of low DO. Insufficient baseflow is likely a contributing factor to this issue. A summary of recommended actions to alleviate the influence of these stressors is provided in Section 4.2.

3.2.5 South Branch of the Wild Rice River (AUID 661)

Physical setting

This reach represents the segment of the South Branch of the Wild Rice River from immediately downstream of the 340th Street crossing, to its confluence with an unnamed creek (Figure 26); a total length of 5 miles. The reach has a subwatershed area of 76 square miles (48,777 acres). The subwatershed contains 124 miles of intermittent stream, 27 miles of perennial river/stream (e.g., AUID 661), and 1 mile of intermittent drainage ditch (DNR, 2003). According to the MPCA (2013), 66% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 661. The NLCD 2011 (USGS, 2011) lists cultivated crops (74%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (8%), hay/pasture (6%), developed (4%), forest (4%), herbaceous (2%), and open water (2%).

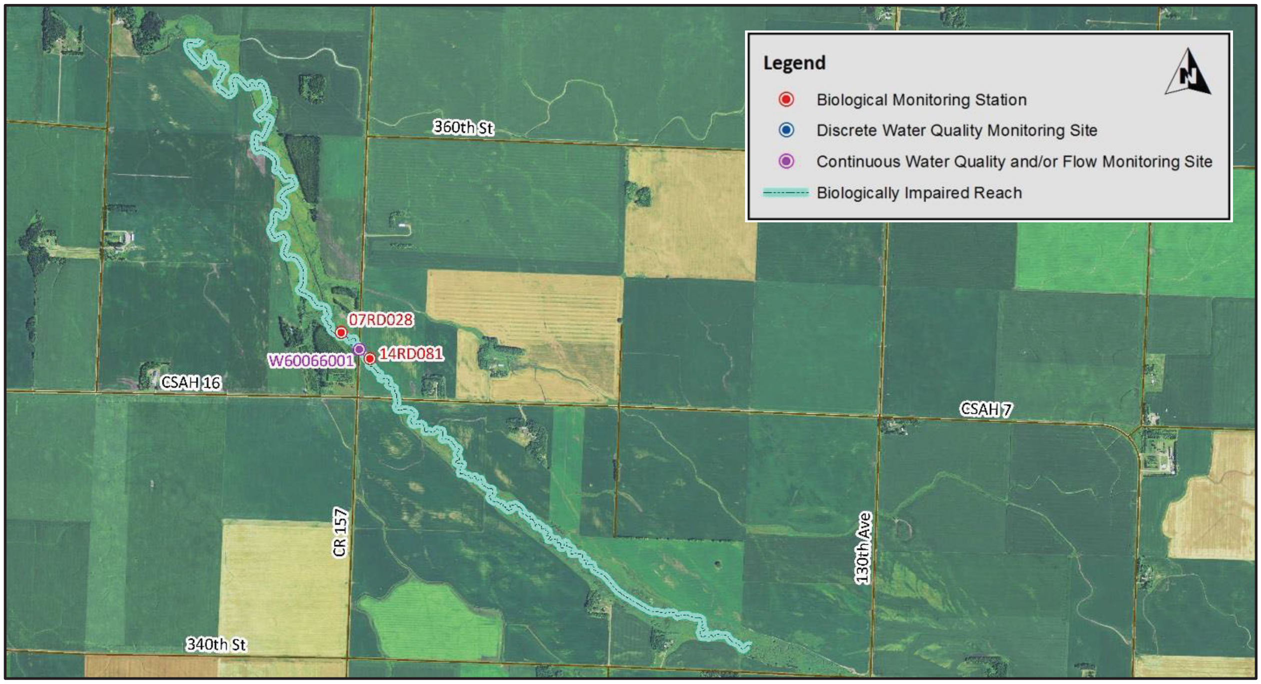


Figure 26. Map of AUID 661 and associated biological monitoring stations and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 661 was monitored at Station 07RD028 (0.1 mile downstream of the CR 157 crossing) on August 6, 2007 (1) and July 8, 2015 (2); and Station 14RD081 (0.1 mile upstream of the CR 157 crossing) on June 15, 2015. The location of the stations is shown in Figure 26. The stations were designated as Modified Use within the Northern Streams F-IBI Class. The impairment threshold for the stations is an F-IBI score of 35. The 2007 sample at Station 07RD028 (F-IBI=44) yielded a score above the impairment threshold, while the 2015 samples at Stations 07RD028 (F-IBI=23) and 14RD081 (F-IBI=24) scored substantially below the threshold. Tolerant taxa, specifically common shiner, creek chub, fathead minnow, and johnny darter, dominated the collective fish assemblage of the stations.

Candidate causes

Loss of longitudinal connectivity

Available data

According to a local landowner (personal communication, 2016) who lives and farms near the CR 157 crossing, beaver dams are common along the reach. The MPCA biological monitoring staff noted a beaver dam at Station 07RD028 at the time of the August 4, 2015, macroinvertebrate monitoring visit. According to the DNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. On September 14, 2016, MPCA SID staff conducted a connectivity assessment along the South Branch of the Wild Rice River. Staff viewed all of the road crossings on the river as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a May 18, 2015, aerial photo (courtesy of Google Earth) of the reach. The remnants of two beaver dams were noted downstream of the CR 157 crossing. In summary, beaver dams have the potential to interfere with connectivity along the reach.

Biotic response – fish

The following evidence (Appendix A) is inconclusive and *neither supports nor weakens* the case for loss of longitudinal connectivity as a stressor to the fish community of AUID 661:

- Below average (<7%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 07RD028(1) (0%), 07RD028(2) (0%), and 14RD081 (0%)
- Below average (<19%) relative abundance of individuals that are migratory (MgrPct) at Stations 07RD028(1) (7%), 07RD028(2) (6%), and 14RD081 (7%)

Late maturing and migratory fish require well-connected environments in order to access the habitats and resources necessary to complete their life history. However, there are no known connectivity barriers with which to attribute the abovementioned metric responses. While the reach is prone to beaver activity, there is no evidence that a beaver dam(s) was interfering with connectivity at the time of the fish monitoring visits. Additionally, there is insufficient information to determine if the culverts associated with road crossings along the reach are impeding fish passage during high flow conditions (i.e., creating a velocity barrier).

Flow regime instability

Available data

According to the MPCA (2013), 66% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 661. The MPCA biological monitoring staff noted intermittent conditions at Station 07RD028 on August 6, 2007 (Figure 27). Additionally, staff was unable to sample Station 14RD081 on August 4, 2014 (Figure 27) and August 27, 2014 due to the absence of flow. There is no flow monitoring data for the reach. The USGS (2016) estimated that the normal range of flow values for the reach at its outlet was 6.3 (Q25) to 0.5 (Q75) cfs. Additionally, the estimated median flow (Q50) was 1.7 cfs, while the projected Q5 flow was 65.6 cfs and the Q95 flow was 0.1 cfs. The Q25 to Q75 flow values ratio was 12:1, which is indicative of a relatively hydrologically stable system. By comparison, several of the more hydrologically stable rivers in the Red River Basin (i.e., Buffalo River, Clearwater River, and Otter Tail River) had a ratio of 7:1 or less. The MPCA SID staff conducted reconnaissance along the reach on four separate dates (i.e., August 4, 2016, August 11, 2016, August 24, 2016, and September 14, 2016) and documented flow conditions. Minimal flow (≈0.1 cfs) was noted at the CR 157 crossing on August 24, 2016. Overall, the available data suggest that the reach is prone to extended periods of minimal to no flow.

Figure 27. Images of intermittent/stagnant conditions along AUID 661, including Station 07RD028 on August 6, 2007 (right); and Station 14RD081 on August 4, 2014 (left).

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for flow regime instability as a stressor to the fish community of AUID 661:

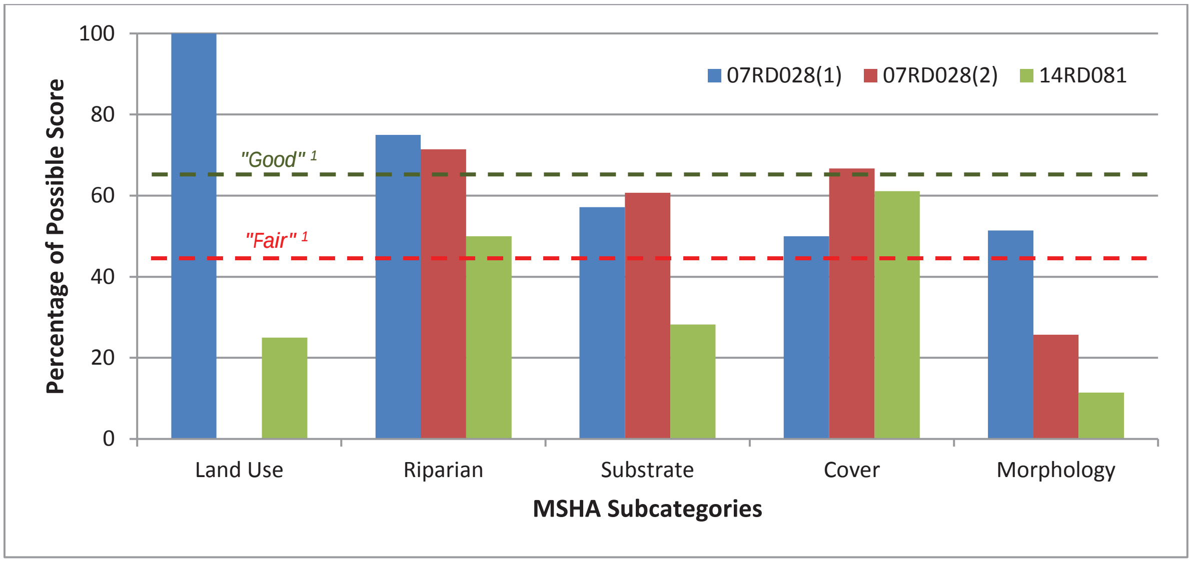
- Above average (>75%) combined relative abundance of the three most abundant taxa (DomThreePct) at Stations 07RD028(2) (83%) and 14RD081 (80%)
- Above average (>25%) relative abundance of taxa that are generalists (GeneralTxPct) at Stations 07RD028(1) (33%), 07RD028(2) (50%), and 14RD081 (42%)
- Above average (>67%) relative abundance of taxa with a female mature age equal to or less than two years (MA<2TxPct) at Stations 07RD028(1) (78%), 07RD028(2) (88%), and 14RD081 (92%)
- Below average (<0.86) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 07RD028(2) (0.10)
- Above average (>15%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 07RD028(1) (17%), 07RD028(2) (25%), and 14RD081 (17%)
- Above average (>18%) relative abundance of taxa that are short-lived (SLvdTxPct) at Stations 07RD028(1) (33%), 07RD028(2) (38%), and 14RD081 (42%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 661 was evaluated at Stations 07RD028 and 14RD081 using the MSHA. The entire reach has been channelized (MPCA, 2013). Station 07RD028 (MSHA=58/"fair" and 48/"fair") yielded MSHA scores that were substantially above that of Station 14RD081 (MSHA=31/"poor"). Figure 28 displays the MSHA subcategory results for the stations. In 2015, both stations scored poorly in the land use subcategory due to the predominance of agricultural row crops immediately surrounding the stations. Station 07RD028 yielded higher scores in the riparian subcategory than Station 14RD081 due to an "extensive" riparian width. However, a "little" amount of bank erosion was noted at both stations. The stations had no riffle habitat and only limited coarse substrate (i.e., gravel) with a "moderate" to "severe" amount of embeddedness. Collectively, the stations provided a number of cover types, including boulders, deep pools, logs, macrophytes (emergent, submergent, and floating leaf), overhanging vegetation, and undercut banks. Lastly, the morphology subcategory scores for the stations were adversely affected by limited depth variability, sinuosity, and velocity types.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 28. MSHA subcategory results for Stations 07RD028 and 14RD081 along AUID 661.

Vinje and Clark (2017) completed fluvial geomorphic assessments at Stations 07RD028 and 14RD081 along AUID 661. The results of these assessments are summarized below:

> *"A Pfankuch stability assessment was completed at [Station] 07RD028 on 6/9/2015. The stream type was an E5 (sand bed with narrow width-to-depth ratio). The total Pfankuch score was 72, which is considered good (stable), but was only 3 points above fair (moderately unstable). The upper banks were in excellent condition: nearly flat above bankfull, no evidence of mass erosion, minor potential for debris jams, and vegetative cover was diverse and robust. The metrics on the lower banks were variable. The channel capacity indicated that the channel was not incised (excellent), but the bank rock content rated as poor. Some obstructions to flow were observed and bank cutting was occurring in some areas along the reach. The channel bottom was predominantly sand-sized particles. The channel bottom was in good condition: mostly dull substrate, moderately packing with some overlap, and 5-30% of the channel was affected by scour and/or deposition. Aquatic vegetation was abundant."*

> *"A Pfankuch stability assessment and Rosgen Level II geomorphology survey were completed at [Station] 14RD081 on 9/26/16 and 9/27/16. Based on the geomorphology survey, the stream type at this location was an E4 (low width-to-depth ratio, gravel bed stream). Although this reach was channelized, the Pfankuch rating was good (stable). The upper banks were well vegetated, had low bank slope gradients, and showed no evidence of mass wasting. The lower banks showed little cutting or deposition, but did score lower in the channel capacity category as a result of some incision (bank height ratio = 1.3). Although slightly incised, the stream had access to a wide floodplain at 2x the maximum bankfull riffle depths, so it was not entrenched (average entrenchment ratio = 24). The water was too deep to do a pebble count at the time of the survey, but the bed appeared to be primarily small gravel overlaid by areas of silt/muck. Where gravel was exposed, it was moderately packed and the bed appeared to be stable. Scouring and deposition was the channel bottom category that scored the worst as a result of the silty/mucky nature of the bed in low velocity areas where gravel wasn't exposed. Overall, as a result of being channelized, this reach lacks the stream power to efficiently move sediment, and it also lacks the typical facets, and therefore habitat, of a meandering stream. However, at the time of survey, there was sufficient water depth for holding*

cover, as the stream was lentic in nature – deep, but with very little flow. Based on 5/18/2015 aerial photography, there was likely a beaver dam downstream of the survey reach that caused the observed conditions. Besides potentially contributing to the deposition issues within the reach, the beaver activity may be impeding fish passage. The two 14 ft. wide x 8 ft. high concrete box culverts at the downstream end of the reach were properly sized and did not appear to be barriers to fish passage."

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by the absence of riffles, embeddedness of coarse substrate, minimal depth variability, and few velocity types. Vinje and Clark (2017) attributed many of these deficiencies to the effects of past channelization.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for insufficient physical habitat as a stressor to the fish community of AUID 661:

- Below average (<22%) relative abundance of individuals that are benthic insectivores, excluding tolerant species (BenInsect-TolPct) at Stations 07RD028(1) (15%), 07RD028(2) (0%), and 14RD081 (0%)
- Below average (<18%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Stations 07RD028(1) (11%), 07RD028(2) (0%), and 14RD081 (8%)
- Above average (>13%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 07RD028(1) (22%), 07RD028(2) (25%), and 14RD081 (17%)
- Below average (<7%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 07RD028(2) (6%) and 14RD081 (6%)
- Below average (<32%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 07RD028(1) (23%), 07RD028(2) (6%), and 14RD081 (6%)
- Below average (<19%) relative abundance of individuals that predominately utilize riffle habitats (RifflePct) at Stations 07RD028(1) (10%), 07RD028(2) (6%), and 14RD081 (7%)
- Below average (<38%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Stations 07RD028(1) (29%), 07RD028(2) (7%), and 14RD081 (23%)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Stations 07RD028 and 14RD081 along AUID 661 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The stations had TSS concentrations of 5 and 9 mg/L, respectively. The WRRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 16 and 17% of the time during the period of 1996 to 2009. Additionally, the aforementioned MSHA results indicate that the deposition of excess fine sediment caused the "moderate" to "severe" level of embeddedness of coarse substrate documented at Stations 07RD028 and 14RD081. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

Biotic response – fish

The following evidence (Appendix A) *somewhat supports* the case for high suspended sediment as a stressor to the fish community of AUID 661:

- Above average (>14 mg/L) mean TSS TIV at Stations 07RD028(1) (16 mg/L), 07RD028(2) (19 mg/L), and 14RD081 (18 mg/L)
- Below average (<76%) probability of meeting the TSS standard at Stations 07RD028(1) (69%), 07RD028(2) (45%), and 14RD081 (54%)

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected discrete DO measurements at Station 07RD028 along AUID 661 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 5.9 to 7.6 mg/L. The MPCA conducted continuous DO monitoring at Site W60066001 (CR 157 crossing) from August 11, 2016, to August 24, 2016; the location of the site is shown in Figure 26. The monitoring results are provided in Table 13, as well as displayed in Figure 29. While 43% of the total values were below the 5 mg/L standard, 86% of the daily minimum values were below the standard. Additionally, the WRRW HSPF model estimates that the reach had a DO concentration below the standard between 45 and 46% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

Table 13. Continuous DO data for Site W60066001 along AUID 661.

Start date - End date	*n*	Max. (mg/L)	Min. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 11, 2016 - August 24, 2016	1238	9.7	3.3	43	86	3.1

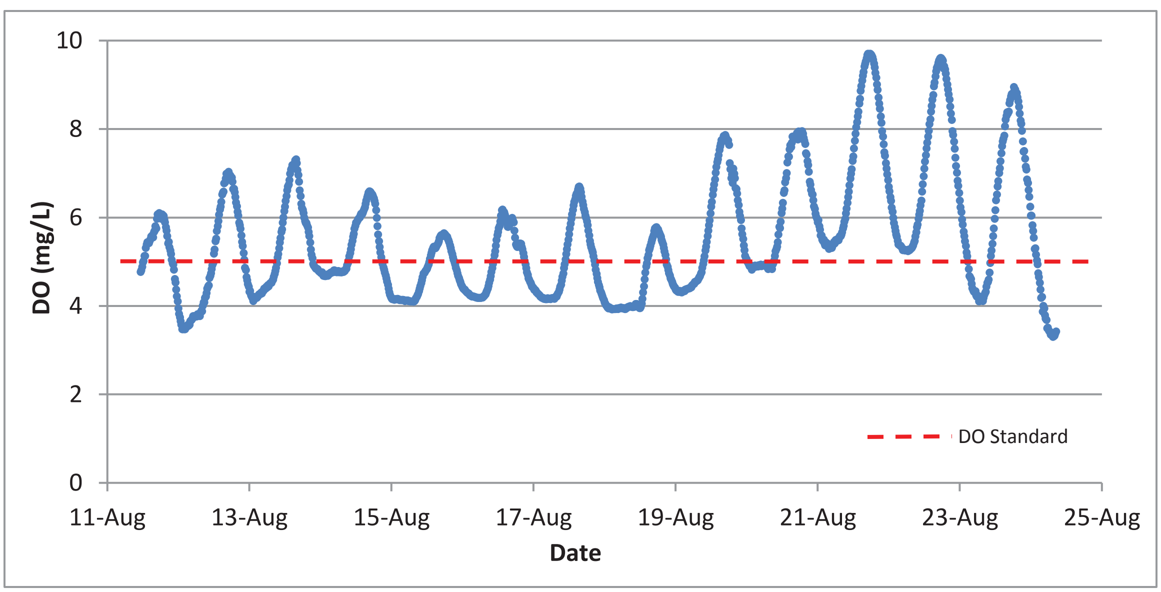


Figure 29. Continuous DO data for Site W60066001 along AUID 661.

Eutrophication-related data for AUID 661 includes the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 07RD028 and 14RD081 along AUID 661 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TP. The stations had TP concentrations ranging from 140 to 317 µg/L. The mean daily DO flux documented during continuous DO monitoring at Site W60066001 (Table 13) was 3.1 mg/L, which is below the 4.5 mg/L South River Nutrient Region DO flux standard. Also, the MPCA biological monitoring staff noted "floating algae throughout the reach" during an August 4, 2015, macroinvertebrate monitoring visit. However, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during four separate reconnaissance visits along the reach (i.e., August 4, 2016, August 11, 2016, August 24, 2016, and September 14, 2016). Overall, there is insufficient data to determine if eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

The following evidence (Appendix A) *somewhat supports* the case for low DO as a stressor to the fish community of AUID 661:

- Below average (<6.7 mg/L) mean DO TIV at Stations 07RD028(2) (6.2 mg/L) and 14RD081 (6.5 mg/L)
- Below average (<38%) probability of meeting the DO standard at Stations 07RD028(2) (19%) and 14RD081 (26%)

Summary of stressors

The evidence suggests that the F-IBI impairment associated with AUID 661 is attributed to flow regime instability, insufficient physical habitat, and, to a lesser extent, high suspended sediment and low DO. The reach is prone to extended periods of minimal to no flow. Agricultural drainage is the primary anthropogenic factor contributing to this issue. Many of the watercourses in the subwatershed have been physically altered (e.g., channelized), including the entire length of this reach, to more rapidly convey water. This alteration has negatively affected the physical habitat of the reach. The biological monitoring stations offered no riffles, limited depth variability, minimal sinuosity, and few velocity types. Additionally, instream and soil erosion has degraded the quality of instream habitat (e.g., embeddedness of coarse substrate) and causes at least occasional periods of high suspended sediment. Lastly, the data suggests that the reach is prone to periods of low DO. Insufficient baseflow is likely a contributing factor to this issue. A summary of recommended actions to alleviate the influence of these stressors is provided in Section 4.2.

3.2.6 South Branch of the Wild Rice River (AUID 662)

Physical setting

This reach represents the segment of the South Branch of the Wild Rice River from its confluence with an unnamed creek, to its confluence with an unnamed creek (Figure 30); a total length of 24 miles. The reach has a subwatershed area of 195 square miles (124,657 acres). The subwatershed contains 252 miles of intermittent stream, 55 miles of perennial river/stream (e.g., AUID 662), 19 miles of intermittent drainage ditch, and 1 mile of perennial drainage ditch (DNR, 2003). According to the MPCA (2013), 61% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 6% of AUID 662. The NLCD 2011 (USGS, 2011) lists cultivated crops (76%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (8%), hay/pasture (5%), developed (5%), forest (4%), and open water (2%).

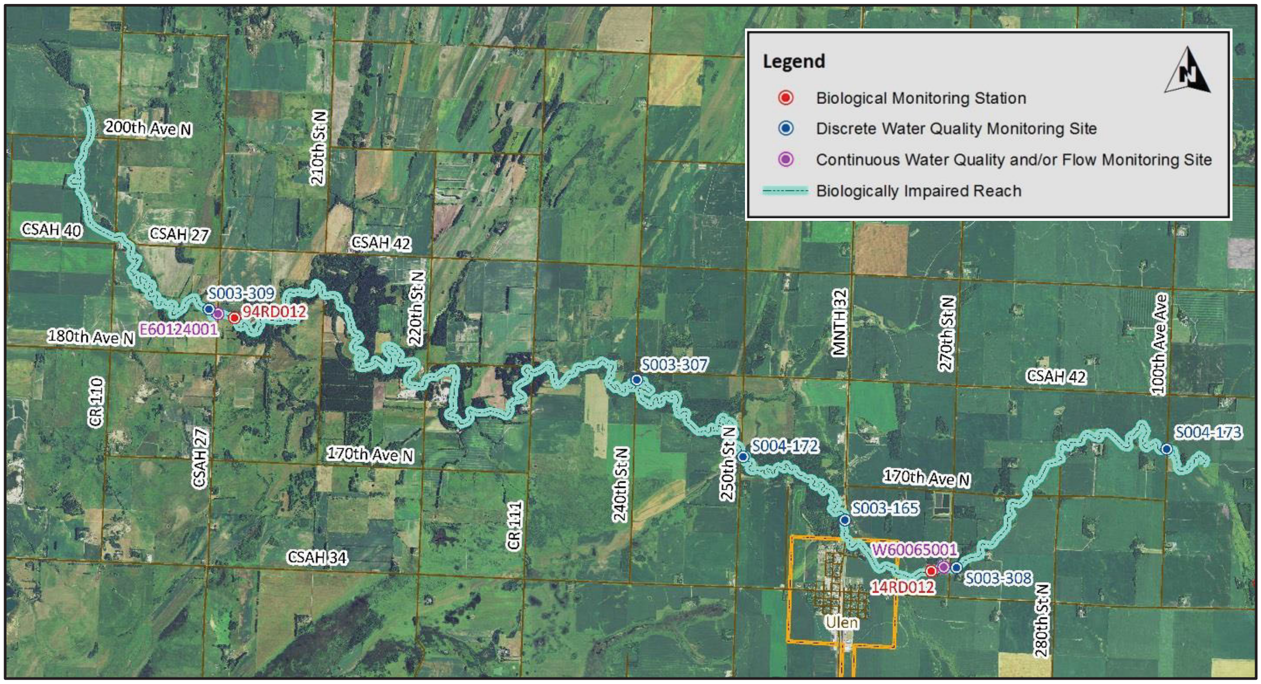


Figure 30. Map of AUID 662 and associated biological monitoring stations and water quality/flow monitoring sites (2013 NAIP aerial image).

Biological impairments

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 662 was monitored at Station 14RD012 (0.1 mile downstream of the 270th Street North crossing) on August 4, 2014; and Station 94RD012 (0.2 mile upstream of the CSAH 27 crossing) on August 4, 2014. The location of the stations is shown in Figure 30. The stations were designated as General Use within the Southern Streams-Riffle/Run Habitats M-IBI Class. The impairment threshold for the stations is an M-IBI score of 37. Station 94RD012 (M-IBI=42) scored above the impairment threshold, while Station 14RD012 (M-IBI=25) scored substantially below the threshold. Tolerant midges (i.e., *Polypedilum* and *Rheotanytarsus*) dominated the collective macroinvertebrate assemblage of the stations.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 94RD012 and 14RD012 along AUID 662. According to the DNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. On September 14, 2016, MPCA SID staff conducted a connectivity assessment along the South Branch of the Wild Rice River. Staff viewed all of the road crossings on the river as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a May 18, 2015, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo. In summary, there are no known obstructions to connectivity along the reach.

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 662. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to the MPCA (2013), 61% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 6% of AUID 662. The MPCA biological monitoring staff did not encounter any flow-related issues (e.g., intermittency) at Stations 94RD012 and 14RD012 along AUID 662. The DNR and MPCA have cooperatively conducted continuous flow monitoring at Site E60124001 (CR 27 crossing) since 2004; the location of the site is shown in Figure 30. Table 14 presents the percentile flow values for the site. The highest mean daily peak flow recorded at the site was 4140.0 cfs, while the lowest flow was 1.1 cfs. Figure 31 provides the 2014 and 2015 annual hydrographs for the site; IWM was conducted during these years. The site exhibited extreme variability in flow values throughout both years. The USGS (2016) estimated that the normal range of flow values for the reach at its outlet was 11.1 (Q25) to 0.7 (Q75) cfs. Additionally, the estimated median flow (Q50) was 2.6 cfs, while the projected Q5 flow was 133.0 cfs and the Q95 flow was 0.1 cfs. The Q25 to Q75 flow values ratio was 16:1, which is indicative of a relatively hydrologically stable system. By comparison, several of the more hydrologically stable rivers in the Red River Basin (i.e., Buffalo River, Clearwater River, and Otter Tail River) had a ratio of 7:1 or less. The MPCA SID staff conducted reconnaissance along the reach on four separate dates (i.e., August 4, 2016, August 11, 2016, August 24, 2016, and September 14, 2016) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach has a fairly stable flow regime, but is prone to high peak flows.

Table 14. Percentile flow values for Site E60124001 along AUID 662 from 2004 to 2016.

Date range	*n*	Percentile values – Mean daily discharge (cfs)						
		5th	10th	20th	40th	60th	80th	100th
2004-2016	4453	2.4	3.2	4.6	8.0	16.3	53.8	4140.0

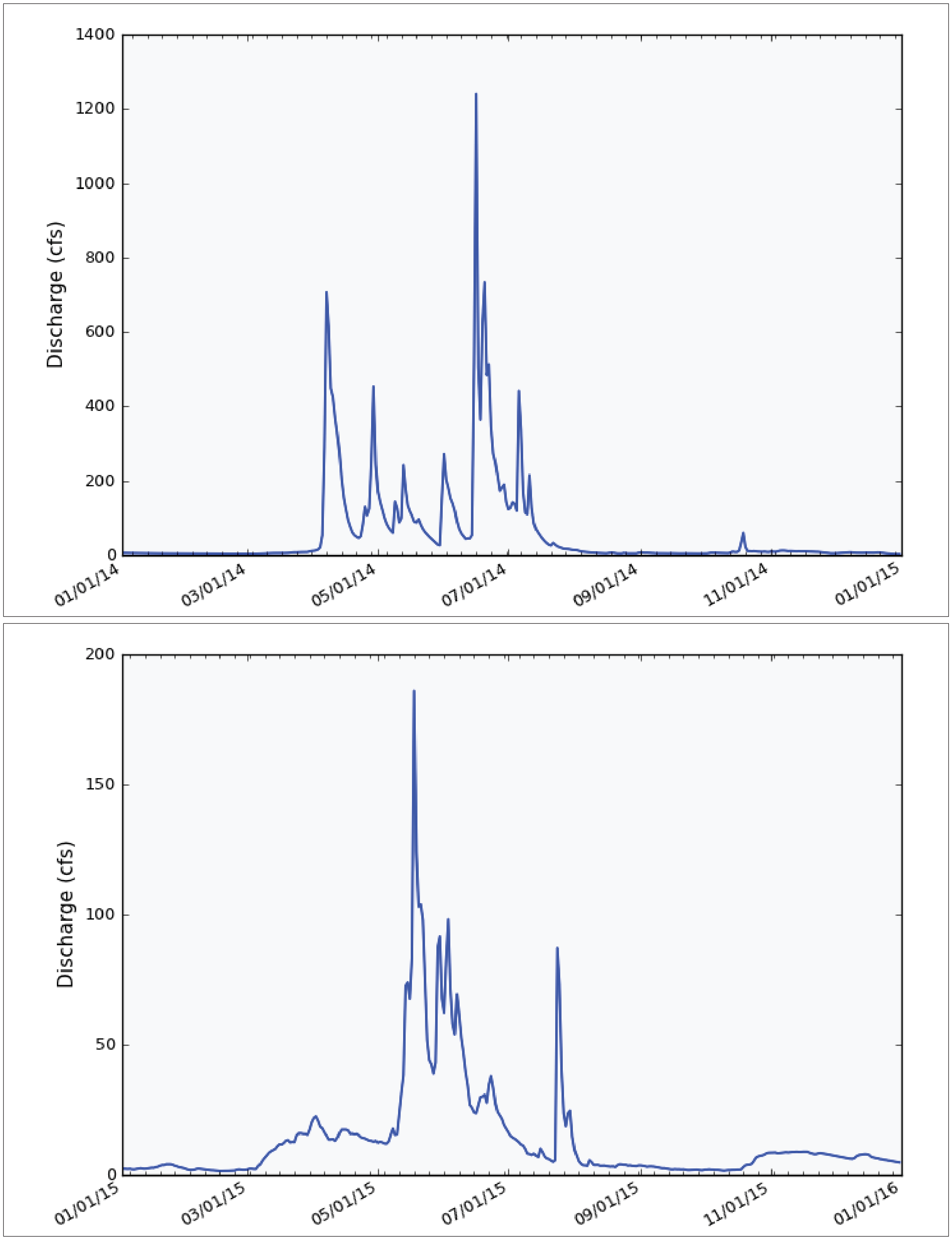


Figure 31. Annual (2014 and 2015) hydrographs for Site E60124001 along AUID 662.

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 662:

- Below average (<11) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Stations 14RD012 (4) and 94RD012 (8)

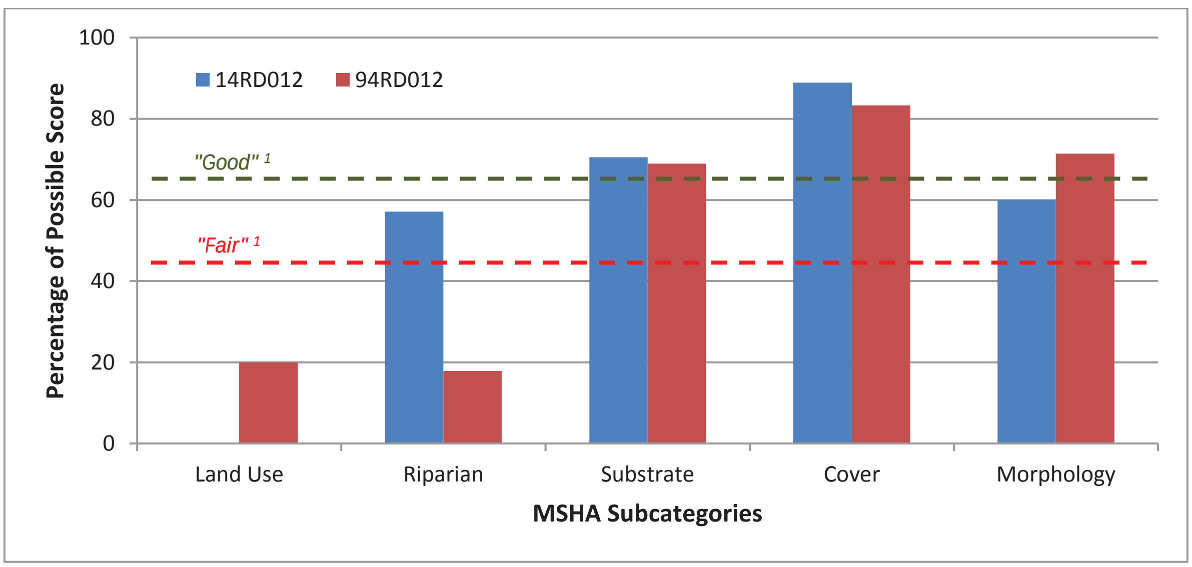
- Below average (<9%) relative abundance of long-lived individuals (LongLivedPct) at Station 14RD012 (3%)
- Below average (<42) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 14RD012 (20) and 94RD012 (23)
- Above average (>72%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Station 14RD012 (75%)
- Below average (<6%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Stations 14RD012 (1%) and 94RD012 (4%)

Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of EPT, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012).

Insufficient physical habitat

Available data

The physical habitat of AUID 662 was evaluated at Stations 14RD012 and 94RD012 using the MSHA. Each of the stations is located along a natural segment of the reach (MPCA, 2013). Stations 14RD012 (65/"fair") and 94RD012 (63/"fair") yielded similar MSHA scores. Figure 32 displays the MSHA subcategory results for the stations. The predominance of agricultural row crops in the immediate vicinity of the stations limited the land use subcategory scores. A "very narrow" riparian zone width, as well as a "moderate" to "heavy" amount of bank erosion, adversely affected the riparian subcategory score for both stations. The stations scored well in the substrate subcategory, offering riffle habitat and coarse substrate (i.e., boulders, cobble, and gravel) with "little" embeddedness. The stations scored exceptionally well in the cover subcategory due to the diversity and "moderate" to "extensive" amount of cover present. Noted cover types included boulders, deep pools, logs, macrophytes (emergent and submergent), overhanging vegetation, oxbows, rootwads, shallows, and undercut banks. Lastly, the morphology subcategory scores were positively influenced by "excellent" channel development.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 32. MSHA subcategory results for Stations 14RD012 and 94RD012 along AUID 662.

Vinje and Clark (2017) completed fluvial geomorphic assessments at Stations 14RD012 and 94RD012 along AUID 662. The results of these assessments are summarized below:

> *A Pfankuch stability assessment was completed at [Station] 14RD012 on 6/9/2015. The stream type was an E5 (sand bed with narrow width-to-depth ratio). The total Pfankuch score was 87, which is considered fair (moderately unstable). The upper bank metrics rated in the good to poor range. They scored poorly due to a steep bank above bankfull, but the rest of the upper bank metrics (mass erosion, debris jam potential, and vegetative bank protection) score good. On the lower banks, the metrics indicated the channel was not incised and there was little to no new deposition. However, the bank rock content was less than 20% and significant bank cutting (12-24" high) was occurring. The channel bottom consisted predominantly of sand-sized particles. The bottom seemed to be in good condition. The surfaces were mostly dull, indicating a stable substrate, and the particles were moderately packed with some overlapping. Scour and deposition was occurring. Aquatic vegetation was abundant (excellent).*
>
> *A Pfankuch stability assessment and Rosgen Level II geomorphology survey were completed at [Station] 94RD012 on 9/27/16 – 9/29/16. Based on the geomorphology survey, the stream type at this location was a borderline B4c/D4 (overly wide and shallow gravel bed stream with some areas of channel braiding, and moderately entrenched to entrenched conditions). The potential stream type for this reach is likely a C4, or potentially a more moderate width-to-depth ratio B4c (current w/d ratios ≈ 60-70). For a C4 stream type, the Pfankuch rating was fair (moderately unstable), and for a B4c stream type, the Pfankuch rating was poor (unstable). The upper bank categories all scored poorly as a result of steep banks, mass wasting, and very poor vegetative bank protection. Throughout much of the reach, the upper banks were contributing large amounts of sand to the channel where grazing was occurring. Because of coarse sediment deposition, the lower banks were generally stable and in good condition from a bank rock content and cutting perspective. However, the channel capacity rated poorly because of the extremely high width-to-depth ratios and the resulting departure from reference width-to-depth ratios. Lower bank deposition also scored poorly because of the accelerated bar development and channel braiding that was observed. The pebble count for this reach indicated the dominant substrate type was gravel (D_{50} = 46.36 mm), but cobble-sized particles were also common, and sand and boulder-sized particles were also tallied. There was a good bottom size distribution and particles were well consolidated, but excess deposition had led to some pool filling. However, there were two pools that were well scoured and provided sufficient depth and holding cover for fish. Overall, this reach appeared to be experiencing a major channel evolution process as a result of extremely high quantities of coarse bedload. The drivers of the channel evolution likely include downstream channelization, changes in boundary conditions, and hydrologic changes in the watershed.*

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by bank erosion. Vinje and Clark (2017) also noted mass wasting at Station 94RD012 and suggested that the reach has entered into a state of channel evolution.

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for insufficient physical habitat as a stressor to the macroinvertebrate community of AUID 662:

- Below average (<15%) relative percentage of climber individuals (ClimberPct) at Station 94RD012 (7%)
- Above average (>36%) relative abundance of legless individuals (LeglessPct) at Station 14RD012 (68%)

- Below average (<16%) relative percentage of scraper individuals (ScraperPct) at Stations 14RD012 (3%) and 94RD012 (10%)

Climber and scraper taxa require clean, coarse substrate or other objects to attach themselves to or feed from, while legless macroinvertebrates are generally tolerant of degraded benthic habitat (e.g., embedded coarse substrate).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 94RD012 along AUID 662 at the time of the July 24, 2014, fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 9 mg/L. Table 15 summarizes all available discrete TSS data for Sites S003-165 (State Highway 32 crossing), S003-307 (240th Street North crossing), S003-308 (270th Street North crossing), and S003-309 (CSAH 27 crossing); the location of these sites is shown in Figure 30. Sites S003-308 (23%) and S003-309 (20%) had the highest standard exceedance rates. The WRRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 17 and 18% of the time during the period of 1996 to 2009. Figure 33 shows images of streambank instability along the reach. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

Table 15. Discrete TSS data for Sites S003-165, S003-307, S003-308, and S003-309 along AUID 662.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S003-165	2002-2011	30	3	76	11	1
S003-307	2002	1	2	2	2	0
S003-308	2002-2015	13	3	66	20	3
S003-309	2009-2016	79	1	210	24	16

Figure 33. Images of bank erosion at Station 94RD012 along AUID 650 on May 19, 2014 (left) and July 24, 2014 (right).

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for high suspended sediment as a stressor to the macroinvertebrate community of AUID 662:

- Above average (>16 mg/L) mean TSS TIV at Station 14RD012 (17 mg/L)
- Above average (>35%) relative abundance of high TSS tolerant taxa at Stations 14RD012 (53%)
- Below average (<5%) relative abundance of high TSS intolerant taxa at Stations 14RD012 (0%)

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a combined four discrete DO measurements at Stations 94RD012 and 14RD012 along AUID 662 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 5.9 to 12.2 mg/L. While none of the values were below the 5 mg/L standard, Station 14RD012 had an extremely high DO concentration (12.2 mg/L) and saturation percentage (153%) at the time of the August 4, 2014, macroinvertebrate monitoring visit. Such elevated DO conditions are commonly caused by excessive aquatic plant (i.e., algae and submergent macrophyte) growth. Figure 34 displays all available discrete DO data for Sites S003-165 (2002-2011; *n*=29), S003-307 (2002-2008; *n*=25), S003-308 (2002-2015; *n*=30), S003-309 (2002-2016; *n*=97), S004-172 (250th Street North crossing; 2005-2008; *n*=22), and S004-173 (100th Avenue crossing; 2006-2008; *n*=15). None of the values were below the standard; however, only 38 of the measurements were collected prior to 9:00 a.m., when values are typically lowest. Generally, the lowest DO levels were in the months of July and August. The MPCA conducted continuous DO monitoring at Site W60065001 (270th Street North crossing) from July 31, 2014, to August 12, 2014 and from August 11, 2016, to August 24, 2016; the location of the site is shown in Figure 30. The monitoring results are provided in Table 16, as well as displayed in Figures 35 and 36. Collectively, very few (1 and 4%) of the measurement were below the standard during the monitoring periods. However, 21% of the daily minimum values were below the standard during the August 2016 monitoring period. Additionally, the WRRW HSPF model estimates that the reach had a DO concentration below the standard between 21 and 46% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences at least occasional periods of low DO.

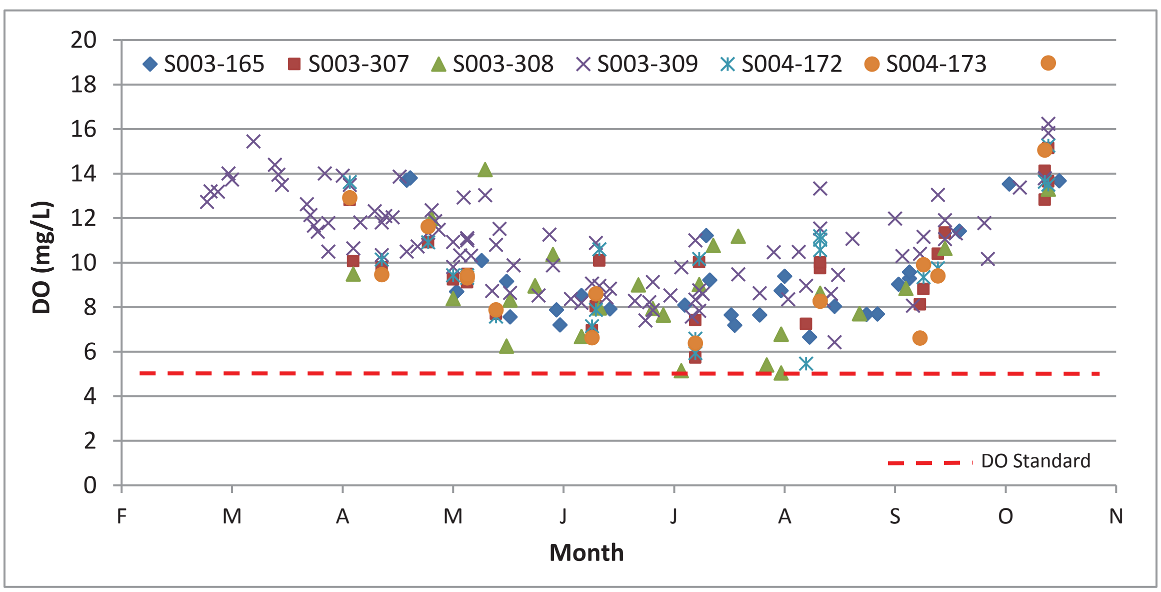


Figure 34. Discrete DO data for Sites S003-165, S003-307, S003-308, S003-309, S004-172, and S004-173 along AUID 662.

Table 16. Continuous DO data for Site W60065001 along AUID 662.

Start date - End date	*n*	Max. (mg/L)	Min. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 31, 2014 - August 12, 2014	1194	14.8	4.9	1	8	6.3
August 11, 2016 - August 24, 2016	1239	10.7	4.2	4	21	4.1

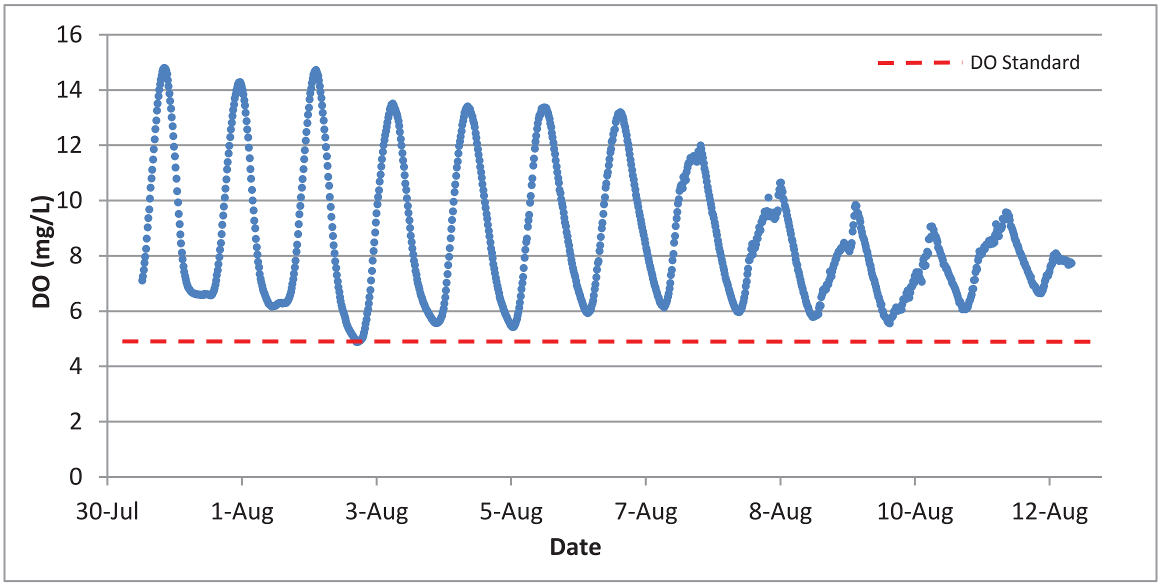


Figure 35. Continuous DO data (2014) for Site W60065001 along AUID 662.

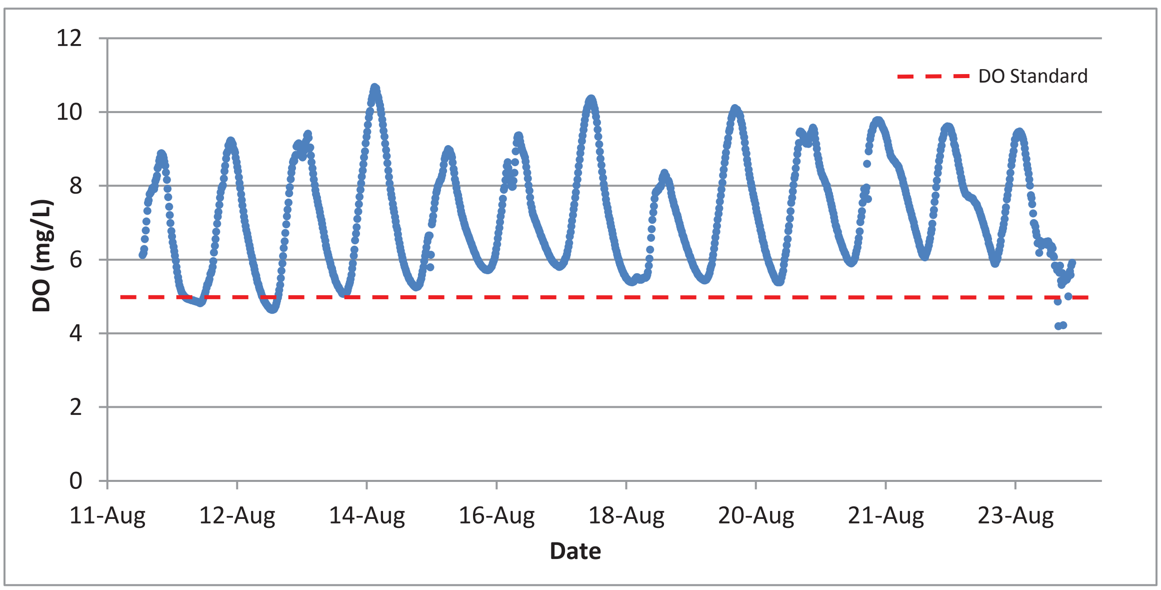


Figure 36. Continuous DO data (2016) for Site W60065001 along AUID 662.

Eutrophication-related data for AUID 662 includes the following parameters: TP, Chl-a, and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Station 94RD012 along AUID 662 at the time of the fish monitoring visit. The sample was analyzed for several parameters, including TP. The station had TP concentration of 163 µg/L. Discrete TP data are available for Sites S003-165 (2002-2011; *n*=25), S003-307 (2002; *n*=1), S003-308 (2002-2015; *n*=13), and S003-309 (2014-2016; *n*=76). Collectively, the mean TP concentration for the sites was 173 µg/L, while the highest concentration was 469 µg/L and the lowest concentration was 15 µg/L. Approximately 46% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S003-165 (2010-2011; *n*=22). The mean Chl-a concentration for the site was 7 µg/L, while the highest concentration was 23 µg/L and the lowest concentration was 1 µg/L. There were no exceedances of the 40 µg/L South River Nutrient Region Chl-a standard. The mean daily DO flux documented during continuous DO monitoring at Site W60065001 (Table 16) was 6.3 and 4.1 mg/L, respectively. The South River Nutrient Region DO flux standard is 4.5 mg/L. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during four separate reconnaissance visits along the reach (i.e., August 4, 2016, August 11, 2016, August 24, 2016, and September 14, 2016). While the reach is prone to high TP concentrations, there is insufficient response variable data (e.g., Chl-a) to determine if eutrophication is adversely affecting the DO regime of the reach.

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for low DO as a stressor to the macroinvertebrate community of AUID 662:

- Below average (<11) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Stations 14RD012 (4) and 94RD012 (8)
- Below average (<42) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 14RD012 (20) and 94RD012 (23)
- Below average (<25%) relative abundance of low DO intolerant taxa at Station 14RD012 (11%)

Low DO often limits the taxa richness of macroinvertebrates, particularly members of the orders EPT, and favors taxa that are tolerant (Weber, 1973; EPA, 2012).

Summary of stressors

The evidence suggests that the M-IBI impairment associated with AUID 662 is attributed to flow regime instability, insufficient physical habitat, high suspended sediment, and low DO. The reach is prone to high peak flows. Agricultural drainage is the primary anthropogenic factor contributing to this issue; many of the watercourses in the subwatershed have been physically altered (e.g., channelized) to more rapidly convey water. Substantial bank erosion was noted at the biological monitoring stations. Instream and soil erosion are a notable threats to the quality of instream habitat, as well as sources of suspended sediment. The data suggests that the reach is prone to frequent periods of high suspended sediment. Lastly, the reach is subject to at least occasional periods of low DO. A summary of recommended actions to alleviate the influence of these stressors is provided in Section 4.2.

3.2.7 Felton Creek/County Ditch 45 (AUID 654)

Physical setting

This reach represents the segment of Felton Creek/County Ditch 45 from the 200th Street North crossing, to the 150th Street North crossing (Figure 37); a total length of 7 miles. The reach has a subwatershed area of 27 square miles (17,146 acres). The subwatershed contains 6 miles of perennial stream (i.e., AUID 654), 6 miles of perennial drainage ditch, and 5 miles of intermittent stream (DNR, 2003). According to the MPCA (2013), 34% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 8% of AUID 654. The NLCD 2011 (USGS, 2011) lists cultivated crops (61%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (15%), hay/pasture (11%), herbaceous (5%), developed (3%), forest (3%), and open water (2%).

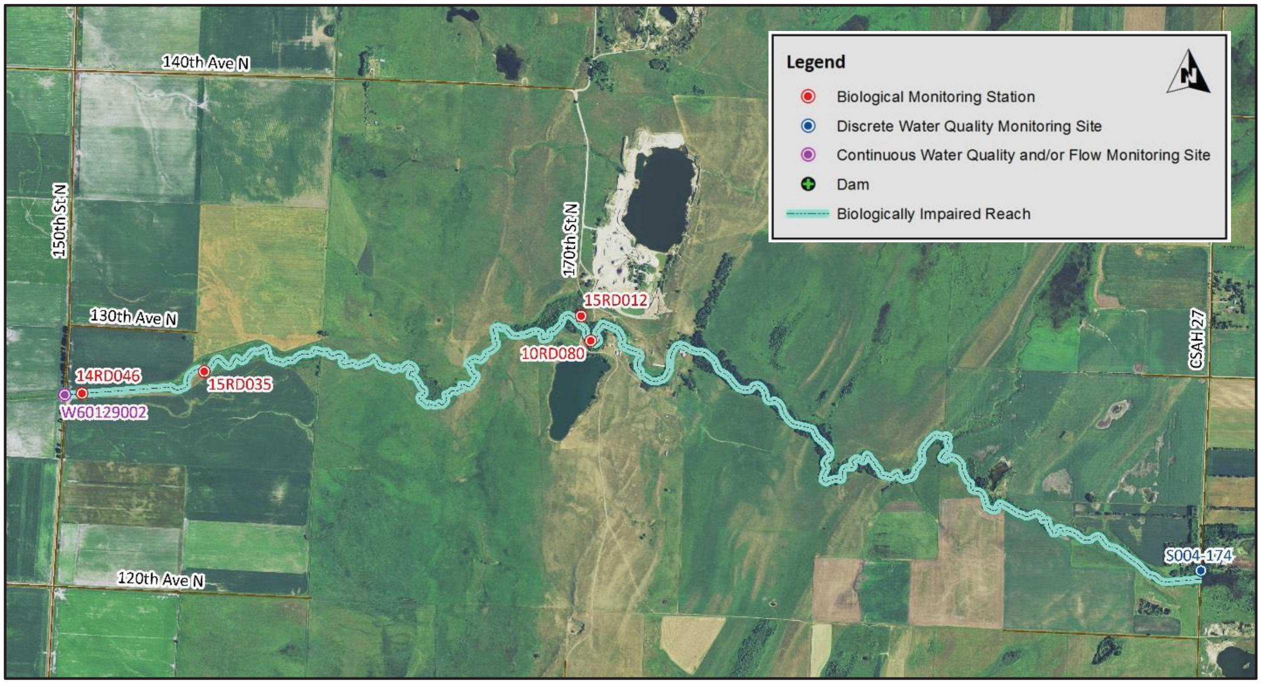


Figure 37. Map of AUID 654 and associated biological monitoring stations and flow/water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 654 was monitored at Station 10RD080 (0.1 mile upstream of the 170th Street North crossing) on July 10, 2010 (1), June 15, 2015 (2), and September 8, 2015 (3); Station 14RD046 (0.1 mile upstream of the 150th Street North crossing) on July 17, 2014(1) and July 8, 2015 (2); Station 15RD012 (0.1 mile downstream of the 170th Street North crossing) on June 15, 2015; and Station 15RD035 (0.6 mile upstream of the 150th Street North crossing) on July 8, 2015. The location of the stations is shown in Figure 37. Stations 10RD080 and 15RD012 were designated as General Use within the Northern Coldwater F-IBI Class. The impairment threshold for the stations is an F-IBI score of 35. Stations 14RD046 and 15RD035 was designated as General Use within the Southern Coldwater F-IBI Class. Accordingly, the impairment threshold for these stations is an F-IBI score of 50. Stations 10RD080 (F-IBI=20, 21, and 27), 14RD046 (F-IBI=34 and 29), 15RD012 (F-IBI=29), and 15RD035 (F-IBI=37) each scored below their respective impairment threshold. Blacknose dace, creek chub, and pearl dace dominated the collective fish assemblage of the stations.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 654 was monitored at Station 10RD080 on September 22, 2010 (1,2) and August 4, 2015 (3); Station 14RD046 on August 5, 2014(1) and August 4, 2015 (2); Station 15RD012 on August 4, 2015; and Station 15RD035 on August 4, 2015. The stations were designated as General Use within the Northern Coldwater M-IBI Class. Accordingly, the impairment threshold for the station is an M-IBI score of 32. Stations 10RD080(2) (M-IBI=40), 14RD046(2) (M-IBI=41), and 15RD035

(M-IBI=41) scored above the impairment threshold, while Stations 10RD080(1) (M-IBI=27), 10RD080(3) (M-IBI=24), 14RD046(1) (M-IBI=29), and 15RD012 (M-IBI=24) scored below the threshold. The most dominant taxa sampled at the stations were *Baetis* (mayflies), *Brachycentrus* (mayflies), and *Polypedilum* (midges).

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff documented a series of three perched culverts (Figure 38) at the 170th Street North crossing; Station 10RD080 is located immediately upstream of the crossing and Station 15RD012 is located immediately downstream of the crossing. The culverts are perched up to approximately one foot above the downstream water surface, thereby constituting a total barrier to connectivity during low flow conditions; fish passage is likely possible at moderate and high stage levels. The monitoring staff also noted the remnants of a beaver dam (Figure 38) at Station 14RD046 at the time of the August 5, 2014, macroinvertebrate monitoring visit, as well as a beaver dam (Figure 38) at Station 15RD035 on September 8, 2015. The latter beaver dam appeared to be a complete barrier to connectivity. According to the DNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. On October 10, 2016, MPCA SID staff conducted a connectivity assessment along Felton Creek/County Ditch 45. Staff viewed all of the road crossings on the system as part of the assessment. The remnants of a beaver dam were noted upstream of the 110th Avenue, which is approximately 14 miles downstream of AUID 654. In addition to the assessment, MPCA SID staff performed a detailed review of a May 4, 2016, aerial photo (courtesy of Google Earth) of the reach. Staff identified two private road crossings (Figure 38) upstream of the 170th Street North crossing. Both crossings appeared to have an undersized culvert(s), which could alter stream flow and, thereby, limit connectivity. In summary, the perched culverts, beaver dams, and private road crossings all have the potential to interfere with connectivity along the reach. Additionally, the fact that the reach is a coldwater system that is geographically isolated in a watershed that is nearly entirely comprised of warmwater systems is an impediment to connectivity. Coldwater taxa are limited to the extent of the reach and would not be able to migrate to or recolonize from the warmwater systems downstream.

Figure 38. Images of connectivity-related issues associated with AUID 654, including perched culverts at the 170th Street North crossing on August 7, 2014 (upper left); the remnants of a beaver dam at Station 14RD046 on August 5, 2014 (upper right); a beaver dam at Station 15RD035 on September 8, 2015 (lower left); and a private road crossing upstream of the 170th crossing on May 4, 2016 (lower right), courtesy of Google Earth.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for loss of longitudinal connectivity as a stressor to the fish community of AUID 654:

- Below average (<60/21%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 10RD080(1) (0%), 10RD080(2) (0%), 10RD080(3) (0%), 14RD046(1) (1%), 14RD046(2) (0%), 15RD012 (0%), and 15RD035 (0%)
- Below average (<68/22%) relative abundance of individuals that are migratory (MgrPct) at Stations 10RD080(1) (5%), 10RD080(2) (2%), 10RD080(3) (6%), 14RD046(1) (8%), 14RD046(2) (3%), 15RD012 (3%), and 15RD035 (0%)

Late maturing and migratory fish require well-connected environments in order to access the habitats and resources necessary to complete their life history. Table 17 contrasts the collective fish assemblage that was sampled immediately upstream and downstream of the perched culverts at the 170th Street North crossing. A total of 12 species were sampled at the selected stations below the dam. Of these species, eight were found at Station 10RD080, which is located upstream of the crossing. According to Aadland (2015), only golden redhorse is considered "somewhat vulnerable" to extirpation by connectivity barriers; the other species are considered "least vulnerable". Additionally, there is insufficient information to determine if the culverts associated with road crossings along the reach are impeding fish passage during high flow conditions (i.e., creating a velocity barrier).

Table 17. Summary of fish species sampled downstream and upstream of the perched culverts at the 170th Street North crossing along AUID 654.

Fish species[1]	Present downstream of the 170th Street North crossing[1]	Present upstream of the 170th Street North crossing[2]
bigmouth shiner	X	
blacknose dace	X	X
brook stickleback	X	
central mudminnow	X	
common shiner	X	X
creek chub	X	X
fathead minnow		X
golden redhorse	X	
johnny darter	X	X
longnose dace	X	X
northern redbelly dace	X	X
pearl dace	X	X
white sucker	X	X

[1] Stations 14RD046, 15RD012, and 15RD035 along AUID 654

[2] Station 10RD080 along AUID 654

According to N. Olson (personal communication, 2015), the DNR stocked the reach with brook trout on multiple occasions between 1947 and 1983. In 1980, the DNR completed a survey of the reach and documented several trout up to a half a pound in size. Additionally, notes indicate that anglers caught "nice" trout in 1982. Based upon past history, the DNR believes that "trout could be successful if beaver control effort were undertaken and easements were obtained".

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 654. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to the MPCA (2013), 34% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 8% of AUID 654. The MPCA biological monitoring staff did not encounter any flow-related issues (e.g., intermittency) at Stations 10RD080, 14RD046, 15RD012, and 15RD035 along AUID 654. There is no flow monitoring data for the reach. The USGS (2016) estimated that the normal range of flow values for the reach at its outlet was 2.2 (Q25) to 0.2 (Q75) cfs. Additionally, the estimated median flow (Q50) was 0.6 cfs, while the projected Q5 flow was 25.7 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 13:1, which is indicative of a relatively hydrologically stable system. By comparison, several of the more hydrologically stable rivers in the Red River Basin (i.e., Buffalo River, Clearwater River, and Otter Tail River) had a ratio of 7:1 or less. The MPCA SID staff conducted reconnaissance along the reach on four separate dates (i.e., August 11, 2016, August 24, 2016, October 10, 2016, and October 12, 2016) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach has a fairly stable flow regime.

Biotic response – fish

The following evidence (Appendix A) *somewhat supports* the case for flow regime instability as a stressor to the fish community of AUID 654:

- Above average (>92%) combined relative abundance of the three most abundant taxa (DomThreePct) at Station 15RD035 (95%)
- Above average (>23/34%) relative abundance of taxa that are generalists (GeneralTxPct) at Stations 10RD080(1) (40%), 10RD080(3) (44%), 14RD046(1) (44%), 14RD046(2) (44%), 15RD012 (40%), and 15RD035 (29%)
- Above average (>37/62%) relative abundance of taxa with a female mature age equal to or less than two years (MA<2TxPct) at Stations 10RD080(1) (80%), 10RD080(2) (78%), 10RD080(3) (89%), 14RD046(1) (78%), 14RD046(2) (89%), 15RD012 (80%), and 15RD035 (100%)
- Below average (<0.76/0.47) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 10RD080(2) (0.19), 14RD046(1) (0.06), 14RD046(2) (0.05), 15RD012 (0.25), and 15RD035 (0.05)
- Above average (>12/16%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 10RD080(1) (30%), 10RD080(2) (22%), 10RD080(3) (22%), 14RD046(2) (22%), 15RD012 (20%), and 15RD035 (29%)
- Above average (>14/22%) relative abundance of taxa that are short-lived (SLvdTxPct) at Stations 10RD080(1) (40%), 10RD080(2) (33%), 10RD080(3) (33%), 14RD046(1) (44%), 14RD046(2) (33%), 15RD012 (30%), and 15RD035 (43%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 654:

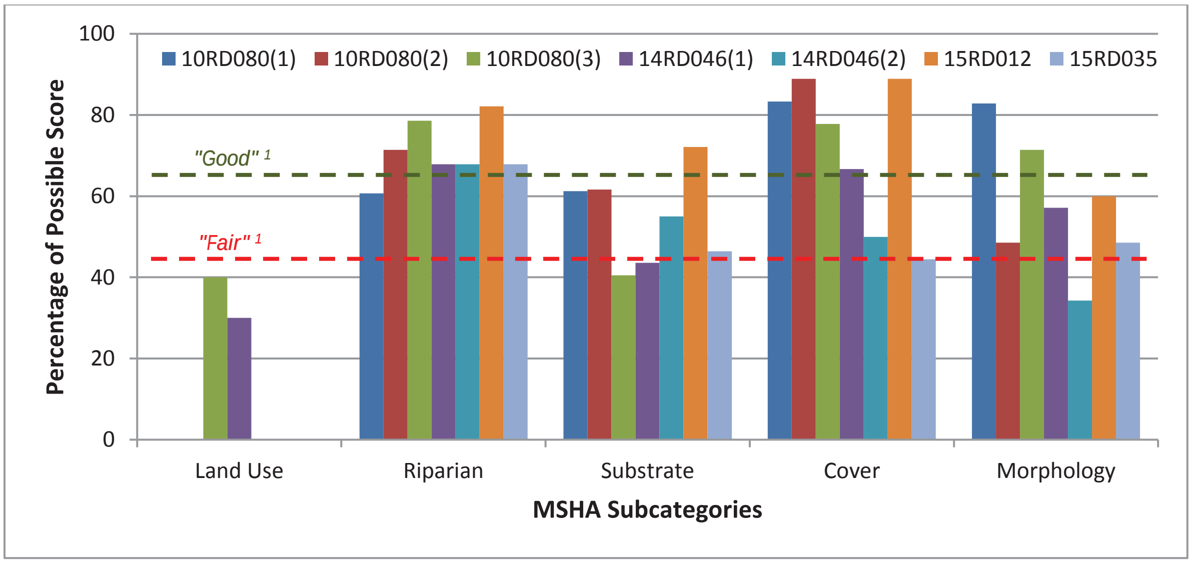
- Below average (<16) taxa richness of EPT at Stations 10RD080(1) (15), 10RD080(3) (10), 14RD046(1) (7), 14RD046(2) (9), 15RD012 (6), and 15RD035 (10)
- Below average (<9%) relative abundance of long-lived individuals (LongLivedPct) at Stations 10RD080(3) (6%), 14RD046(1) (4%), and 15RD012 (3%)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 10RD080(3) (39), 14RD046(1) (36), 14RD046(2) (39), 15RD012 (30), and 15RD035 (32)
- Above average (>47%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Stations 10RD080(1) (63%), 10RD080(2) (55%), 10RD080(3) (74%), 14RD046(1) (72%), 14RD046(2) (77%), 15RD012 (73%), and 15RD035 (81%)
- Below average (<16%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Stations 10RD080(1) (8%), 10RD080(2) (11%), 10RD080(3) (1%), 14RD046(1) (13%), and 15RD012 (1%)

Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of EPT, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012).

Insufficient physical habitat

Available data

The physical habitat of AUID 654 was evaluated at Stations 10RD080, 14RD046, 15RD012, and 15RD035 using the MSHA. Stations 10RD080, 15RD012, and 15RD035 are located along natural portions of the reach, while Station 14RD046 is situated along a channelized segment of the reach (MPCA, 2013). Stations 10RD080 (MSHA=70/"good", 60/"fair", and 63/"fair") and 15RD012 (MSHA=69/"good") scored noticeably higher than Stations 14RD046 (MSHA=55/"fair" and 46/"fair") and 15RD035 (MSHA=47/"fair"), which are located along the downstream extent of the reach. Figure 39 displays the MSHA subcategory results for the stations. The predominance of agricultural row crops, mining, and open pasture in the immediate vicinity of the stations severely limited the land use subcategory scores. The stations scored universally well in the riparian subcategory due a "moderate" to "extensive" riparian zone width, as well as minimal bank erosion. Each of the stations offered riffle habitat and coarse substrate (e.g., boulders, cobble, and gravel). However, a "moderate" to "severe" amount of embeddedness was noted at Stations 10RD080, 14RD046, and 15RD035. With the exception of 15RD035, each of the stations offered at least a "moderate" amount of cover. Noted cover types included boulders, deep pools, logs, macrophytes (emergent and submergent), overhanging vegetation, oxbows, rootwads, shallows, and undercut banks. Lastly, the morphology subcategory scores for the stations varied considerably; however, each of the stations had at least "moderate" channel stability and "fair" channel development.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 39. MSHA subcategory results for Stations 10RD080, 14RD046, 15RD012, and 15RD035 along AUID 654.

Vinje and Clark (2017) completed fluvial geomorphic assessments at Stations 10RD080, 14RD046, and 15RD035 along AUID 654. The results of these assessments are summarized below:

> *"A Pfankuch stability assessment was completed at [Station] 10RD080 on 6/9/2015. The stream type was an E5 (sand bed with narrow width-to-depth ratio). The total Pfankuch score was 73, which is considered good (stable), but is only 2 points above fair (moderately unstable). The upper banks appeared to be in good condition. The landform slope above bankfull was relatively flat and there was no evidence of mass erosion. The banks were vegetated with a robust diversity of species. The lower banks had a few metrics that scored fair to poor. Bank rock content within the banks was low (poor) and there was a moderate level of deposition (fair). The good news for the lower banks was there were few obstructions to flow and those present were firmly imbedded. There was some*

cutting on the lower banks. The channel bottom consisted predominantly of sand-sized particles. Metrics that scored fair included rock angularity and brightness. The particles were moderately packed with some overlapping with some variation in the size of particles present (silt/clay, sand, and gravel). Overall, this site was in good condition. Immediately downstream of this site, under the private driveway, the culverts did not provide a great crossing. There were 3 corrugated metal culverts (the middle one was slightly larger). They were aligned at an angle almost 90 degrees perpendicular to incoming flow. There was evidence of water backing up behind these culverts. At the time of the visit, they were also partially blocked by downed wood and beaver activity. The landowner expressed interest in getting these problematic culverts replaced. On a side note, looking upstream into the pasture area, the field crossings looked small for stream stability, though we did not see these in-person."

"A Pfankuch stability assessment was completed at [Station] 14RD046 on 6/8/2015. The stream type was an E5 (sand bed with narrow width-to-depth ratio). The total Pfankuch score was 64, which is considered good (stable). Felton Creek in also a county ditch at this location. The channel meanders within floodplain berms that are set about 125 feet apart. The bankfull channel is approximately 14 feet wide. Though a full survey of the channel was not completed, the creek appears to be slightly incised at this location. Though confined to within the berms during flooding, the creek has an adequate-sized floodplain and was probably not entrenched. The upper banks appeared to be in good condition. The landform slope above bankfull was relatively flat, mass erosion was infrequent and mostly healed over. The banks were vegetated with a robust diversity of species. The lower banks had a few metrics that scored fair to poor. Bank rock content within the banks was low (poor) and there was significant cutting (12-24") along the reach (fair). The good news for the lower banks was there were few obstructions to flow and those present were firmly imbedded. There was little to no deposition on the lower banks. The channel bottom consisted predominantly of sand-sized particles. Metrics that scored fair included brightness and aquatic vegetation. The particles were moderately packed with some overlapping and scour and/or deposition was affecting less than 5% of the study reach. Overall, this site was in good condition."

"A Pfankuch stability assessment and Rosgen Levell II geomorphology survey were completed at [Station] 15RD035 on 8/30/2016 and 8/31/16. The stream type was an E5 (sand bed with a narrow width-to-depth ratio). The total Pfankuch score was 81, which is considered fair (moderately unstable). The mean, minimum, and maximum (of the maximum) bankfull pool depths were 4.2 feet, 4 feet, and 4.5 feet, respectively. The mean, minimum, and maximum (at the top of) bankfull riffle depths were 3.1 feet, 3 feet, and 3.2 feet. At the time of the survey the water was low and the pools and riffles had approximately 1.4 feet and .5 feet of water, respectively. Though the maximum bankfull pool depths were around 4 feet, the pools were very short (in length on long pro) and did not maintain those depths for long. The Pfankuch metrics showed steep slopes and a moderate level of mass erosion on the banks above bankfull. There was a small amount of debris jam potential and robust vegetation on the upper banks. On the lower banks, the channel capacity was slightly incised and there was a very low amount of rock fragments in the bank. Some cutting of the banks and light deposition was occurring along this reach. The condition of the bottom metrics is likely pulling the score down. The particles were well rounded and were predominantly bright, indicating that the substrate is moving. The consolidation was mostly loose with no apparent overlap. There was a moderate level of deposition occurring and perennial vegetation was absent."

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by its surrounding land use and the embeddedness of coarse substrate. Vinje and Clark (2017) noted that the reach was fairly stable; however some mass erosion was noted at Station 15RD035.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for insufficient physical habitat as a stressor to the fish community of AUID 654:

- Below average (<21/22%) relative abundance of individuals that are benthic insectivores, excluding tolerant species (BenInsect-TolPct) at Stations 10RD080(1) (5%), 10RD080(2) (5%), 10RD080(3) (5%), 14RD046(1) (1%), 14RD046(2) (2%), 15RD012 (16%), and 15RD035 (1%)
- Below average (<16/12%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Stations 10RD080(1) (10%), 10RD080(2) (11%), 10RD080(3) (11%), 14RD046(1) (0%), 14RD046(2) (11%), 15RD012 (10%), and 15RD035 (14%)
- Above average (>8%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 10RD080(1) (20%), 10RD080(2) (11%), 10RD080(3) (11%), and 15RD012 (10%)
- Below average (<20%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 10RD080(2) (12%) and 15RD012 (19%)
- Below average (<22/30%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 10RD080(2) (15%), 14RD046(1) (5%), 14RD046(2) (7%), 15RD012 (23%), and 15RD035 (6%)
- Below average (<35/29%) relative abundance of individuals that predominately utilize riffle habitats (RifflePct) at Stations 10RD080(1) (9%), 10RD080(2) (4%), 10RD080(3) (6%), 14RD046(1) (6%), 14RD046(2) (3%), 15RD012 (15%), and 15RD035 (0%)
- Below average (<45%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Stations 10RD080(1) (15%), 10RD080(2) (11%), and 10RD080(3) (19%)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for insufficient physical habitat as a stressor to the macroinvertebrate community of AUID 654:

- Above average (>7%) relative abundance of burrower individuals (BurrowerPct) at Stations 14RD046(1) (9%) and 14RD046(2) (12%)
- Below average (<16%) relative percentage of climber individuals (ClimberPct) at Stations 10RD080(1) (6%), 10RD080(2) (5%), and 15RD035 (7%)
- Below average (<54%) relative percentage of clinger individuals (ClingerPct) at Stations 10RD080(1) (53%), 10RD080(3) (45%), 14RD046(1) (27%), and 14RD046(2) (52%)
- Above average (>33%) relative abundance of legless individuals (LeglessPct) at Stations 10RD080(3) (56%), 14RD046(1) (42%), and 15RD012 (41%)
- Below average (<15%) relative percentage of scraper individuals (ScraperPct) at Stations 10RD080(1) (13%), 10RD080(3) (6%), 14RD046(1) (6%), 15RD012 (4%), and 15RD035 (14%)
- Above average (>14%) relative abundance of sprawler individuals (SprawlerPct) at Stations 10RD080(3) (22%) and 15RD012 (19%)

Climber, clinger, and scraper taxa require clean, coarse substrate or other objects to attach themselves to or feed from, while burrower, legless, and sprawler macroinvertebrates are tolerant of degraded benthic habitat (e.g., embedded coarse substrate).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Stations 10RD080, 14RD046, 15RD012, and 15RD035 along 654 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The stations had TSS concentrations ranging from 4 to 12 mg/L. The WRRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 17 and 19% of the time during the period of 1996 to 2009. Additionally, the aforementioned MSHA results indicate that the deposition of excess fine sediment caused the "moderate" to "severe" level of embeddedness of coarse substrate documented at Stations 10RD080, 14RD046, and 15RD035. Overall, the available data suggest that the reach experiences periods of high suspended sediment.

Biotic response – fish

The following evidence (Appendix A) *somewhat supports* the case for high suspended sediment as a stressor to the fish community of AUID 654:

- Above average (>10 mg/L) mean TSS TIV at Stations 10RD080(1) (11 mg/L), 10RD080(2) (12 mg/L), 10RD080(3) (13 mg/L), 14RD046(1) (13 mg/L), 14RD046(2) (13 mg/L), 15RD012 (11 mg/L), and 15RD035 (13 mg/L)
- Below average (<60%) probability of meeting the TSS standard at Stations 10RD080(1) (59%), 10RD080(2) (57%), 10RD080(3) (56%), 14RD046(1) (55%), 14RD046(2) (56%), 15RD012 (59%), and 15RD035 (57%)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for high suspended sediment as a stressor to the macroinvertebrate community of AUID 654:

- Below average (<30%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Stations 10RD080(2) (27%), 10RD080(3) (14%), 14RD046(1) (14%), and 14RD046(2) (27%)
- Above average (>12 mg/L) mean TSS TIV at Stations 10RD080(1) (14 mg/L), 10RD080(2) (13 mg/L), 10RD080(3) (15 mg/L), 14RD046(1) (19 mg/L), 14RD046(2) (19 mg/L), 15RD012 (15 mg/L), and 15RD035 (17 mg/L)
- Above average (>14%) relative abundance of high TSS tolerant taxa at Stations 10RD080(3) (31%), 14RD046(1) (59%), 14RD046(2) (41%), 15RD012 (39%), and 15RD035 (29%)
- Below average (<23%) relative abundance of high TSS intolerant taxa at Stations 10RD080(1) (5%), 10RD080(2) (9%), 10RD080(3) (2%), 14RD046(1) (1%), 14RD046(2) (0%), 15RD012 (1%), and 15RD035 (0%)

Collector-filterers utilize specialized mechanisms (e.g., silk nets) to strain organic material from the water column. High suspended sediment can interfere with these mechanisms (Arruda et al., 1983; Barbour et al., 1999; Lemley, 1982; Strand and Merritt, 1997).

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a combined 14 discrete DO measurements at Stations 10RD080, 14RD046, 15RD012, and 15RD035 along AUID 654 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 7.0 to 11.0 mg/L. Figure 40 displays all available discrete DO data for Site S004-174 (CSAH 27 crossing; 2006; *n*=8); the location of the site is shown in Figure 37. Six of the values were below the 7 mg/L standard; however, none of the measurements were collected prior to 9:00 a.m., when values are typically lowest. The MPCA conducted continuous DO monitoring at

Site W60129002 (150th Street North crossing) from August 11, 2016, to August 24, 2016; the location of the site is shown in Figure 37. The monitoring results are provided in Table 18, as well as displayed in Figure 41. None of the DO measurements within the monitoring period were below the standard. Additionally, the WRRW HSPF model estimates that the reach had a DO concentration below the standard between 50 and 52% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences at least occasional periods of low DO.

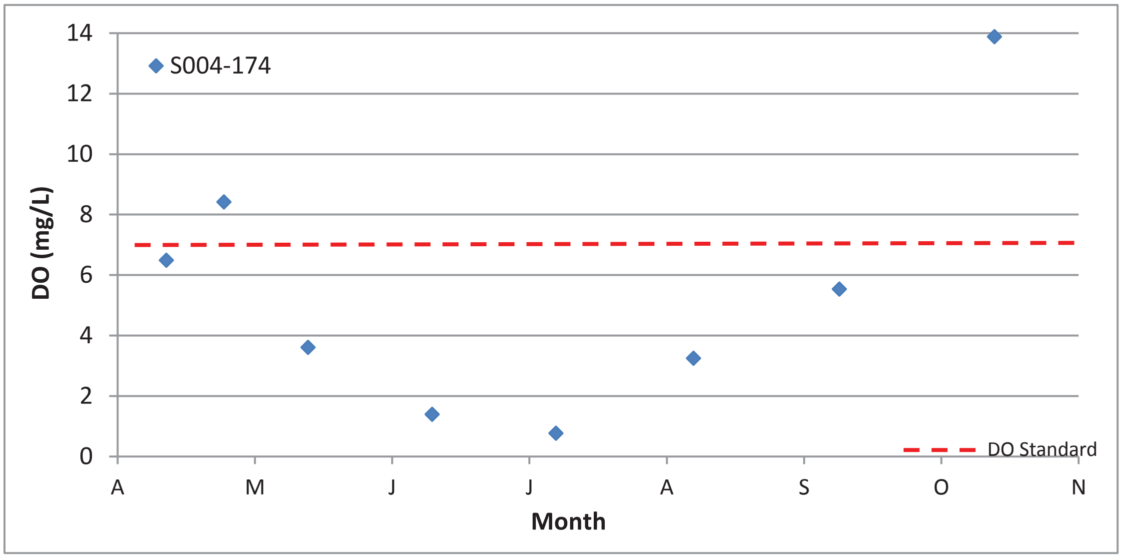


Figure 40. Discrete DO data for Site S004-174 along AUID 654.

Table 18. Continuous DO data for Site W60129002 along AUID 654.

Start date - End date	*n*	Max. (mg/L)	Min. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 11, 2016 - August 24, 2016	1236	10.0	6.2	0	0	2.8

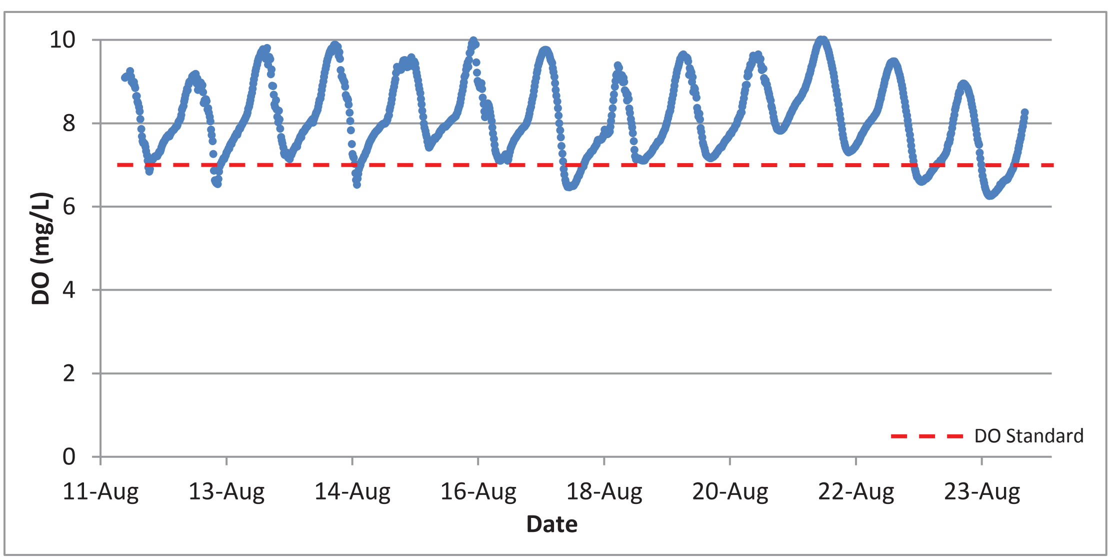


Figure 41. Continuous DO data for Site W60129002 along AUID 654.

Eutrophication-related data for AUID 654 includes the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 10RD080, 14RD046, 15RD012, and 15RD035 along AUID 654 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TP. The stations had TP concentrations ranging from 25 to 89 µg/L. The mean daily DO flux documented during continuous DO monitoring at Site W60129002 (Table 18) was 2.8 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during four separate reconnaissance visits along the reach (i.e., August 11, 2016, August 24, 2016, October 10, 2016, and October 12, 2016). Overall, there is insufficient data to determine if eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for low DO as a stressor to the fish community of AUID 654:

- Below average (<8.8/7.8 mg/L) mean DO TIV at Stations 10RD080(1) (6.4 mg/L), 10RD080(2) (6.1 mg/L), 10RD080(3) (6.8 mg/L), 14RD046(1) (7.5 mg/L), 14RD046(2) (7.4 mg/L), 15RD012 (7.2 mg/L), and 15RD035 (7.6 mg/L)
- Below average (<90/80%) probability of meeting the DO standard at Stations 10RD080(1) (8%), 10RD080(2) (3%), 10RD080(3) (24%), 14RD046(1) (72%), 14RD046(2) (66%), 15RD012 (49%), and 15RD035 (77%)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *somewhat supports* the case for low DO as a stressor to the macroinvertebrate community of AUID 654:

- Above average (>5) Hilsenhoff's Biotic Index value (HBI_MN) at Stations 10RD080(1) (6), 10RD080(2) (6), 10RD080(3) (7), 14RD046(1) (7), 14RD046(2) (7), 15RD012 (7), and 15RD035 (6)
- Below average (<16) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Stations 10RD080(1) (15), 10RD080(3) (10), 14RD046(1) (7), 14RD046(2) (9), 15RD012 (6), and 15RD035 (10)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 10RD080(3) (39), 14RD046(1) (36), 14RD046(2) (39), 15RD012 (30), and 15RD035 (32)
- Above average (>5%) relative abundance of low DO tolerant taxa at Station 14RD046(2) (6%)
- Below average (<46%) relative abundance of low DO intolerant taxa at Stations 14RD046(1) (18%) and 14RD046(2) (27%)

Low DO often limits the taxa richness of macroinvertebrates, particularly members of the orders Ephemeroptera, Plecoptera, and Trichoptera, and favors taxa that are tolerant (Weber, 1973; EPA, 2012).

High temperature

Available data

The MPCA biological monitoring staff collected a combined 14 discrete temperature measurements at Stations 10RD080, 14RD046, 15RD012, and 15RD035 along AUID 654 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 11.8 to 20.9°C. The MPCA biological monitoring staff also conducted continuous water temperature data at Station 10RD080 in 2010, 2014, and 2015. Table 19 provides summary statistics for each of these years. The mean minimum summer temperature ranged from 16.0 to 18.0°C, while the mean maximum temperature ranged from 18.2 to 21.2°C. The mean daily temperature variation for these periods was minimal (3.1-3.6°C); however, the mean monthly temperature variation was up to 10.5°C. In each of the years, values of 22.2°C or greater were experienced, which can be detrimental to brook trout. In 2010 and 2014, there were multiple hour periods in which the temperature was 23.8°C or greater, which is generally lethal to brook trout. Additionally, the MPCA conducted continuous water quality monitoring at Site W60129002 from August 11, 2016, to August 24, 2016. The temperature monitoring results are displayed in Figure 42. The maximum value was 26.6°C, while the minimum value was 12.9°C. The mean daily temperature flux over the period was 7.4°C. Overall, the available data suggest that the reach experiences periods of high temperature. The segment of the reach near Station 10RD080 has the greatest potential to support a healthy coldwater-oriented biotic community.

Table 19. Continuous temperature data for Station 10RD080 along AUID 654.

Year	Summer months only data						% of total values ≥22.2°C[1]	# of multiple hour periods ≥23.8°C[1]
	Mean (°C)	Mean minimum (°C)	Mean maximum (°C)	Mean daily variation (°C)	Mean weekly variation (°C)	Mean monthly variation (°C)		
2010	19.6	18.0	21.2	3.2	6.2	8.6	16	6
2014	17.5	16.0	19.1	3.1	6.2	8.9	4	2
2015	16.2	16.6	18.2	3.6	6.8	10.5	<1	0

[1] Brook trout can briefly tolerate temperatures near 22.2°C, but temperatures of 23.8°C or greater for a few hours are generally lethal (Flick, 1991).

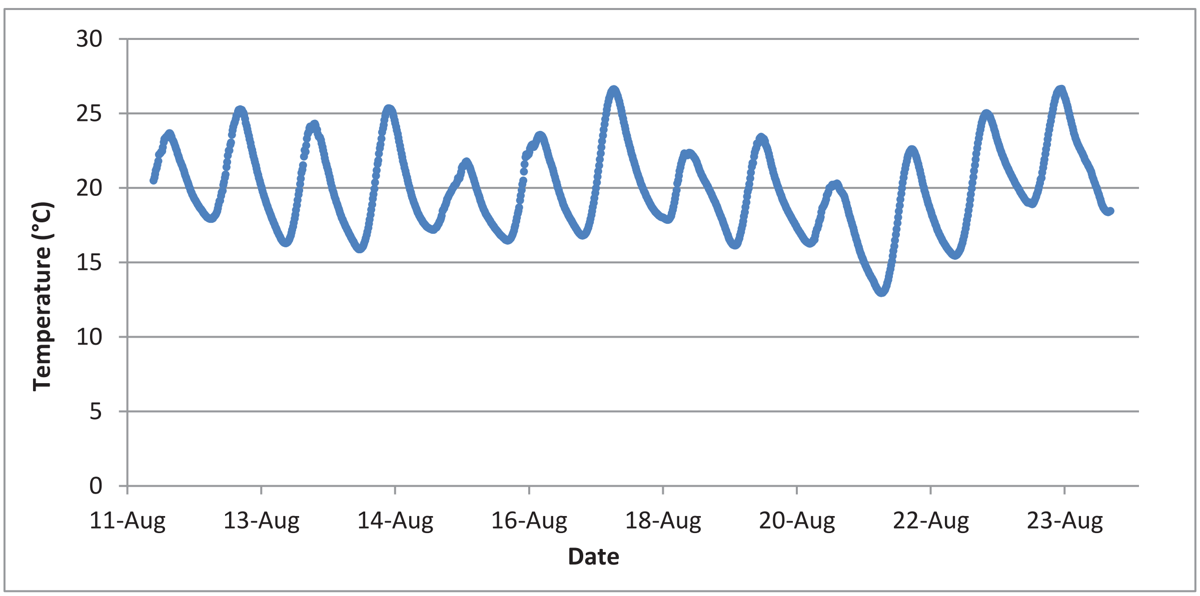


Figure 42. Continuous temperature data for Site W60129002 along AUID 654.

Biotic response – fish

The following evidence (Appendix A) *convincingly supports* the case for high temperature as a stressor to the fish community of AUID 654:

- Below average (<64/43%) relative abundance of coldwater and coolwater species (ColdCoolTxPct) at Stations 10RD080(1) (30%), 10RD080(2) (33%), 10RD080(3) (22%), 14RD046(1) (22%), 14RD046(2) (11%), 15RD012 (30%), and 15RD035 (14%)
- Below average (<47/22%) relative abundance of coldwater taxa (ColdTxPct) at Stations 10RD080(1) (0%), 10RD080(2) (0%), 10RD080(3) (0%), 14RD046(1) (0%), 14RD046(2) (0%), 15RD012 (0%), and 15RD035 (0%)
- Above average (>17.3/19.4°C) mean temperature TIV at Stations 10RD080(1) (20.0°C), 10RD080(2) (20.1°C), 10RD080(3) (20.3°C), 14RD046(1) (20.4°C), 14RD046(2) (20.4°C), 15RD012 (20.2°C), and 15RD035 (20.3°C)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for high temperature as a stressor to the macroinvertebrate community of AUID 654:

- Above average (>19.0°C) mean temperature TIV at Stations 10RD080(1) (19.1°C), 10RD080(3) (19.1°C), 14RD046(1) (20.6°C), 14RD046(2) (20.4°C), 15RD012 (19.4°C), and 15RD035 (19.5°C)

Summary of stressors

The evidence suggests that the F-IBI impairment associated with AUID 654 is attributed to high temperature, loss of longitudinal connectivity, insufficient physical habitat, low DO, and, to a lesser extent, flow regime instability and high suspended sediment. Additionally, the evidence indicates that the M-IBI impairment is likely the result of high temperature, insufficient physical habitat, high suspended sediment, and, to a less extent, flow regime instability and low DO. While the reach is designated as a coldwater system, it is prone to high temperatures, particularly in the late summer months. A number of potential connectivity barriers were identified along the reach, including perched culverts, beaver dams, and private road crossings. The impoundment of water caused by beaver dams is believed to be a major contributing factor to high temperature values. In addition to these barriers, the fact that coldwater taxa are isolated to this reach and cannot migrate to or recolonize from warmwater systems downstream, is an impediment to connectivity. Instream and soil erosion have degraded the quality of instream habitat (e.g., embeddedness of coarse substrate) and cause periods of high suspended sediment. The reach is subject to at least occasional periods of low DO. Groundwater and wetland discharge are likely contributing factors to this condition. Lastly, the reach has a fairly stable flow regime, but may be prone to occasional periods of minimal flow. A summary of recommended actions to alleviate the influence of these stressors is provided in Section 4.2.

Section 4: Conclusions and recommendations

4.1 Conclusions

Table 20 presents a summary of the stressors associated with the biologically impaired reaches in the WRRW. Connectivity barriers are adversely affecting fish passage along segments of Felton Creek/County Ditch 45 (beaver dams and perched culverts), Garden Slough (Mashaug Creek No. 3 Dam) and the Wild Rice River (Lower Rice Lake Dam). Many of the biologically impaired reaches are prone to high and quick peak flows and/or prolonged periods of low or no discharge. Historical changes in land cover (e.g., native vegetation to cropland) and drainage patterns (e.g., channelization and ditching) are the primary anthropogenic factors contributing to this flow regime instability. Alterations to the natural hydrology of the landscape have also caused the degradation of instream habitat (e.g., bank erosion and embeddedness of coarse substrate) for many of the reaches. A number of the reaches are prone to periods of high suspended sediment. Instream and soil erosion are the primary sources of this sediment. Low DO is a stressor for nearly all of the reaches. While the severity of low DO conditions varies amongst the reaches, the lowest concentrations generally occur in the summer, when flow is low and the water temperature is high. Lastly, the headwaters of Felton Creek/County Ditch 45 is unique for the watershed in that it is a coldwater system. However, the impoundment of water caused by beaver dams is believed to be contributing to periods of high temperature, which limits the potential of the reach to support sensitive coldwater taxa.

Table 20. Summary of the stressors associated with the biologically impaired reaches in the WRRW.

Reach name (AUID suffix)	Biological impairment(s)	Candidate causes[1]					
		Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen	High Temperature
Wild Rive River (AUID 646)	F-IBI	++	0	0	NE	+	NA
Spring Creek (AUID 647)	M-IBI	NE	+	++	+	0	NA
Garden Slough (AUID 579)	F-IBI	+++	++	++	0	++	NA
Mashaug Creek (AUID 650)	F-IBI	0	++	+	+	+	NA
	M-IBI	NE	+	+	+	+	
Wild Rice River, South Brach (AUID 661)	F-IBI	0	++	++	+	+	NA
Wild Rice River, South Brach (AUID 662)	M-IBI	NE	+	+	+	+	NA
Felton Creek/ County Ditch 45 (AUID 654	F-IBI	++	+	++	+	++	+++
	M-IBI	NE	+	++	++	+	++

[1] **Key:** +++ the available evidence *convincingly supports* the case for the candidate cause as a stressor, ++ the available evidence *strongly supports* the case for the candidate cause as a stressor, + the available evidence *somewhat supports* the case for the candidate cause as a stressor, **0** *neither supports nor weakens* the case for the candidate cause as a stressor, **NE** *no evidence* is available to support the case for the candidate cause as a stressor, and **NA** *not applicable.*

4.2 Recommendations

The recommended actions listed below, as well as included in *The Aquatic Biota Stressor and Best Management Practice Selection Guide*, will help to reduce the influence of or better understand the stressors that are limiting the fish and macroinvertebrate communities of the watershed.

Loss of longitudinal connectivity

- Remove/modify barriers (e.g., dams, perched culverts and private road crossings) that are impeding fish passage.
- Evaluate the potential impact of culverts as velocity barriers to fish passage.

Flow regime instability

- Increase runoff detention/retention efforts throughout the watershed to attenuate peak flows and augment base flows.
- Mitigate activities that will further alter the hydrology of the watershed.

Insufficient physical habitat

- Increase runoff detention/retention efforts throughout the watershed to attenuate peak flows and augment base flows.
- Establish and/or protect riparian corridors along all waterways, including ditches, using native vegetation whenever possible.
- Reduce soil erosion through the strategic implementation of best management practices (BMPs).
- Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities.

High suspended sediment

- Increase runoff detention/retention efforts throughout the watershed to attenuate peak flows and augment base flows.
- Establish and/or protect riparian corridors along all waterways, including ditches, using native vegetation whenever possible.
- Reduce soil erosion through the strategic implementation of BMPs.
- Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities.

Low dissolved oxygen

- Increase runoff detention/retention efforts throughout the watershed to attenuate peak flows and augment base flows.
- Reduce soil erosion through the strategic implementation of BMPs.
- Improve agricultural nutrient management.
- Collect additional eutrophication-related data (i.e., TP, Chl-a, and DO flux) for each of the reaches to better understand the relationship, if any, to low DO.

High temperature

- Increase shading by increasing the amount of riparian trees and brush.
- Remove beaver dams and other barriers that impound water.

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Appendix A: Individual F-IBI metric and related data

Relative abundance (%) of individuals per selected F-IBI metric

AUID Suffix	Station	Visit Date	F-IBI Class[1] (Use[2])	Metrics											
				BenInsect-TolPct	DarterPct	DarterSculpPct	DetNWQPct	DomThreePct	DomTwoPct	GeneralPct	Hdw-TolPct	InsectCypPct	Insect-TolPct	LLvdPct	MA<1Pct
579	14RD037	11-Jun-14	NH(M)	0	0	0	30	92	83	30	8	0	0	0	92
646	95RD005	31-Jul-14	NS(G)	20	19	19	7	78	71	22	0	0	20	2	71
650	05RD114	04-Aug-14	NH(G)	27	27	27	8	80	72	61	0	5	27	0	33
	14RD014(1	16-Jul-14	NS(G)	19	19	19	6	68	50	67	0	10	20	0	22
	14RD014(2	14-Jul-15	NS(G)	21	21	21	11	74	63	70	0	5	21	0	24
	14RD034	24-Jun-14	NH(G)	4	4	4	17	54	40	54	18	5	8	0	40
654	10RD080(1	20-Jul-10	NC(G)	5	2	2	7	70	57	20	57	47	49	0	21
	10RD080(2	15-Jun-15	NC(G)	5	4	4	2	65	49	20	26	12	15	0	53
	10RD080(3	08-Sep-15	NC(G)	5	5	5	6	72	63	53	33	29	35	0	14
	14RD046(1	17-Jul-14	SC(G)	1	0	0	6	82	76	87	5	9	5	0	1
	14RD046(2	08-Jul-15	SC(G)	2	2	2	3	86	82	86	7	7	7	0	5
	15RD012	15-Jun-15	NC(G)	16	4	4	3	63	51	55	13	19	23	0	21
	15RD035	08-Jul-15	SC(G)	1	1	1	0	95	90	90	6	6	6	0	2
661	07RD028(1	06-Aug-07	NS(M)	15	15	15	19	54	41	62	1	17	23	0	27
	07RD028(2	08-Jul-15	NS(M)	0	0	0	69	83	77	76	19	6	6	0	68
	14RD081	15-Jun-15	NS(M)	0	0	0	62	80	68	80	18	6	6	0	57
Class NS(G) State MTS Average				**29**	**16**	**18**	**10**	**64**	**51**	**34**	**2**	**16**	**45**	**19**	**19**
Class NS(M) State MTS Average				**22**	**14**	**15**	**17**	**75**	**61**	**39**	**4**	**7**	**32**	**10**	**36**
Class NH(G) State MTS Average				**17**	**9**	**12**	**12**	**71**	**58**	**47**	**14**	**14**	**28**	**5**	**28**
Class NH(M) State MTS Average				**7**	**6**	**7**	**17**	**72**	**59**	**35**	**23**	**14**	**22**	**2**	**46**
Class SC(G) State MTS Average				**21**	**3**	**18**	**15**	**92**	**83**	**21**	**16**	**3**	**22**	**54**	**7**
Class NC(G) State MTS Average				**22**	**2**	**9**	**5**	**84**	**73**	**43**	**13**	**20**	**30**	**16**	**8**

[1] F-IBI Classes: Northern Coldwater (NC), Northern Headwaters (NH), Northern Streams (NS), Southern Coldwater (SC)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Relative abundance (%) of individuals per selected F-IBI metric (continued)

AUID Suffix	Station	Visit Date	F-IBI Class[1] (Use[2])	Metrics											
				MA<2Pct	MA>3-TolPct	MgrPct	MinnowPct	Minnows-TolPct	OmnivorePct	PioneerPct	RifflePct	SLithopPct	SLvdPct	SSpnPct	WetlandPct
579	14RD037	11-Jun-14	NH(M)	100	0	0	38	8	30	30	0	0	47	38	100
646	95RD005	31-Jul-14	NS(G)	91	0	11	15	5	8	20	7	22	6	0	58
650	05RD114	04-Aug-14	NH(G)	92	0	9	58	2	8	72	8	16	17	5	6
	14RD014(1	16-Jul-14	NS(G)	95	0	5	74	14	5	49	5	38	33	10	4
	14RD014(2	14-Jul-15	NS(G)	88	0	12	64	10	11	64	12	27	14	5	5
	14RD034	24-Jun-14	NH(G)	97	0	3	72	21	17	41	3	17	60	33	54
654	10RD080(1	20-Jul-10	NC(G)	91	0	5	76	61	7	11	9	15	35	15	76
	10RD080(2	15-Jun-15	NC(G)	96	0	2	45	27	2	14	4	11	45	15	75
	10RD080(3	08-Sep-15	NC(G)	94	0	6	80	37	6	39	6	19	18	4	42
	14RD046(1	17-Jul-14	SC(G)	92	1	8	91	10	6	33	6	56	51	6	6
	14RD046(2	08-Jul-15	SC(G)	97	0	3	91	8	3	43	3	45	45	4	10
	15RD012	15-Jun-15	NC(G)	85	0	3	76	27	3	14	15	57	50	6	29
	15RD035	08-Jul-15	SC(G)	100	0	0	98	6	0	34	0	57	60	2	7
661	07RD028(1	06-Aug-07	NS(M)	92	0	7	74	22	15	49	10	29	31	26	14
	07RD028(2	08-Jul-15	NS(M)	94	0	6	89	20	69	68	6	7	79	77	88
	14RD081	15-Jun-15	NS(M)	93	0	7	91	22	62	57	7	23	81	68	75
Class NS(G) State MTS Average				62	18	17	42	31	10	15	24	45	9	13	17
Class NS(M) State MTS Average				75	7	19	34	20	16	18	19	38	15	11	33
Class NH(G) State MTS Average				82	4	10	58	31	11	24	17	36	25	13	32
Class NH(M) State MTS Average				91	1	8	54	32	16	20	9	19	42	24	62
Class SC(G) State MTS Average				21	60	68	9	4	15	5	35	21	6	2	4
Class NC(G) State MTS Average				59	21	22	60	27	5	16	29	45	25	4	14

[1] F-IBI Classes: Northern Coldwater (NC), Northern Headwaters (NH), Northern Streams (NS), Southern Coldwater (SC)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Relative abundance (%) of taxa per selected F-IBI metric

AUID Suffix	Station	Visit Date	F-IBI Class[1] (Use[2])	BenInsect-TolTxPct	DarterSculpTxPct	DarterTxPct	DetNWQTxPct	GeneralTxPct	Hdw-TolTxPct	HerbvTxPct	InsectCypTxPct	Insect-TolTxPct	LLvdTxPct	MA<1TxPct	MA<2TxPct
				Metrics											
579	14RD037	11-Jun-14	NH(M)	0	0	0	25	25	25	25	0	0	0	75	100
646	95RD005	31-Jul-14	NS(G)	25	17	17	8	42	0	0	0	33	25	17	67
650	05RD114	04-Aug-14	NH(G)	25	25	25	13	50	0	0	13	25	0	25	88
	14RD014(1	16-Jul-14	NS(G)	21	14	14	29	36	7	14	21	29	0	36	86
	14RD014(2	14-Jul-15	NS(G)	30	20	20	20	50	0	0	20	30	0	30	80
	14RD034	24-Jun-14	NH(G)	8	8	8	25	42	17	17	17	17	0	42	92
654	10RD080(1	20-Jul-10	NC(G)	20	10	10	20	40	20	10	20	30	0	40	80
	10RD080(2	15-Jun-15	NC(G)	22	11	11	11	33	22	11	22	33	0	33	78
	10RD080(3	08-Sep-15	NC(G)	11	11	11	11	44	22	11	11	22	0	33	89
	14RD046(1	17-Jul-14	SC(G)	11	0	0	11	44	22	11	22	22	0	11	78
	14RD046(2	08-Jul-15	SC(G)	11	11	11	11	44	22	11	22	22	0	22	89
	15RD012	15-Jun-15	NC(G)	20	10	10	10	40	20	10	20	30	0	30	80
	15RD035	08-Jul-15	SC(G)	14	14	14	0	29	29	14	29	29	0	29	100
661	07RD028(1	06-Aug-07	NS(M)	22	11	11	22	33	11	6	33	44	0	22	78
	07RD028(2	08-Jul-15	NS(M)	0	0	0	25	50	25	13	13	13	0	38	88
	14RD081	15-Jun-15	NS(M)	8	8	8	17	42	25	8	25	25	0	25	92
Class NS(G) State MTS Average				27	14	12	10	24	4	2	13	43	26	21	58
Class NS(M) State MTS Average				27	18	15	13	25	7	3	11	41	19	29	67
Class NH(G) State MTS Average				19	14	11	14	35	14	8	15	33	11	32	78
Class NH(M) State MTS Average				11	10	9	18	35	21	12	16	27	5	41	87
Class SC(G) State MTS Average				21	16	7	12	23	13	1	4	22	41	19	37
Class NC(G) State MTS Average				20	12	4	8	34	17	4	16	30	19	18	62

[1] F-IBI Classes: Northern Coldwater (NC), Northern Headwaters (NH), Northern Streams (NS), Southern Coldwater (SC)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Relative abundance (%) of taxa per selected F-IBI metric (continued)

AUID Suffix	Station	Visit Date	F-IBI Class[1] (Use[2])	Metrics											
				MA>3-TolTxPct	MgrTxPct	Minnows-TolTxPct	MinnowTxPct	OmnivoreTxPct	PioneerTxPct	RiffleTxPct	SLithopTxPct	SLvdTxPct	SSpnTxPct	ColdCoolTxPct	ColdTxPct
579	14RD037	11-Jun-14	NH(M)	0	0	25	50	25	25	0	0	75	50	NA	NA
646	95RD005	31-Jul-14	NS(G)	8	17	8	25	17	17	8	33	8	8	NA	NA
650	05RD114	04-Aug-14	NH(G)	0	25	13	50	13	25	13	50	38	13	NA	NA
	14RD014(	16-Jul-14	NS(G)	0	14	29	64	14	21	14	43	50	21	NA	NA
	14RD014(	14-Jul-15	NS(G)	0	20	20	60	20	30	20	50	40	20	NA	NA
	14RD034	24-Jun-14	NH(G)	0	8	25	67	17	25	8	25	50	33	NA	NA
654	10RD080(	20-Jul-10	NC(G)	0	10	30	60	20	30	20	30	40	20	30	0
	10RD080(	15-Jun-15	NC(G)	0	11	33	56	11	22	22	33	33	11	33	0
	10RD080(	08-Sep-15	NC(G)	0	11	33	56	11	22	11	33	33	11	22	0
	14RD046(	17-Jul-14	SC(G)	11	22	33	67	11	11	11	44	44	22	22	0
	14RD046(	08-Jul-15	SC(G)	0	11	33	67	11	22	11	33	33	22	11	0
	15RD012	15-Jun-15	NC(G)	0	10	40	60	10	20	20	40	30	10	30	0
	15RD035	08-Jul-15	SC(G)	0	0	29	71	0	29	0	14	43	29	14	0
661	07RD028(	06-Aug-07	NS(M)	0	11	39	61	17	17	17	39	33	33	NA	NA
	07RD028(	08-Jul-15	NS(M)	0	13	38	63	25	25	13	25	38	25	NA	NA
	14RD081	15-Jun-15	NS(M)	0	17	33	67	17	17	8	33	42	33	NA	NA
Class NS(G) State MTS Average				**24**	**18**	**19**	**31**	**10**	**12**	**20**	**35**	**13**	**17**	**NA**	**NA**
Class NS(M) State MTS Average				**17**	**20**	**19**	**30**	**12**	**15**	**18**	**32**	**18**	**14**	**NA**	**NA**
Class NH(G) State MTS Average				**8**	**13**	**26**	**48**	**13**	**19**	**17**	**29**	**27**	**19**	**NA**	**NA**
Class NH(M) State MTS Average				**2**	**12**	**29**	**53**	**17**	**19**	**9**	**20**	**40**	**25**	**NA**	**NA**
Class SC(G) State MTS Average				**47**	**52**	**5**	**15**	**12**	**12**	**30**	**21**	**14**	**5**	**64**	**47**
Class NC(G) State MTS Average				**21**	**23**	**24**	**47**	**8**	**16**	**25**	**33**	**22**	**8**	**43**	**22**

[1] F-IBI Classes: Northern Coldwater (NC), Northern Headwaters (NH), Northern Streams (NS), Southern Coldwater (SC)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Catch-Per-Unit-Effort (CPUE) F-IBI metric

AUID Suffix	Station	Visit Date	F-IBI Class[1] (Use[2])	Metrics											
				NumPerMeter-Tolerant											
579	14RD037	11-Jun-14	NH(M)	0.03											
646	95RD005	31-Jul-14	NS(G)	0.62											
650	05RD114	04-Aug-14	NH(G)	0.80											
	14RD014(1)	16-Jul-14	NS(G)	0.85											
	14RD014(2)	14-Jul-15	NS(G)	0.70											
	14RD034	24-Jun-14	NH(G)	0.25											
654	10RD080(1)	20-Jul-10	NC(G)	1.29											
	10RD080(2)	15-Jun-15	NC(G)	0.19											
	10RD080(3)	08-Sep-15	NC(G)	2.05											
	14RD046(1)	17-Jul-14	SC(G)	0.06											
	14RD046(2)	08-Jul-15	SC(G)	0.05											
	15RD012	15-Jun-15	NC(G)	0.25											
	15RD035	08-Jul-15	SC(G)	0.05											
661	07RD028(1)	06-Aug-07	NS(M)	1.91											
	07RD028(2)	08-Jul-15	NS(M)	0.10											
	14RD081	15-Jun-15	NS(M)	1.36											
Class NS(G) State MTS Average				0.97											
Class NS(M) State MTS Average				0.86											
Class NH(G) State MTS Average				0.88											
Class NH(M) State MTS Average				1.18											
Class SC(G) State MTS Average				0.76											
Class NC(G) State MTS Average				0.47											

[1] F-IBI Classes: Northern Coldwater (NC), Northern Headwaters (NH), Northern Streams (NS), Southern Coldwater (SC)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Fish TIVs and standard probability data

AUID Suffix	Station	Visit Date	F-IBI Class[1] (Use[2])	Metrics											
				Mean TSS TIV (mg/L)	Probability of Meeting TSS Standard (%)	Mean DO TIV (mg/L)	Probability of Meeting DO Standard (%)	Mean Temperature TIV (°C)							
579	14RD037	11-Jun-14	NH(M)	16	70	5.6	7	NA							
646	95RD005	31-Jul-14	NS(G)	12	84	6.1	16	NA							
650	05RD114	04-Aug-14	NH(G)	15	75	7.2	55	NA							
	14RD014(1)	16-Jul-14	NS(G)	14	78	7.3	62	NA							
	14RD014(2)	14-Jul-15	NS(G)	15	76	7.2	57	NA							
	14RD034	24-Jun-14	NH(G)	15	75	6.5	27	NA							
654	10RD080(1)	20-Jul-10	NC(G)	11	59	6.4	8	20.0							
	10RD080(2)	15-Jun-15	NC(G)	12	57	6.1	3	20.1							
	10RD080(3)	08-Sep-15	NC(G)	13	56	6.8	24	20.3							
	14RD046(1)	17-Jul-14	SC(G)	13	55	7.5	72	20.4							
	14RD046(2)	08-Jul-15	SC(G)	13	56	7.4	66	20.4							
	15RD012	15-Jun-15	NC(G)	11	59	7.2	49	20.2							
	15RD035	08-Jul-15	SC(G)	13	57	7.6	77	20.3							
661	07RD028(1)	06-Aug-07	NS(M)	16	69	7.1	54	NA							
	07RD028(2)	08-Jul-15	NS(M)	19	45	6.2	19	NA							
	14RD081	15-Jun-15	NS(M)	18	54	6.5	26	NA							
Class NS(G) State MTS Average				12	83	7.2	55	NA							
Class NS(M) State MTS Average				14	76	6.7	38	NA							
Class NH(G) State MTS Average				13	83	6.9	45	NA							
Class NH(M) State MTS Average				14	75	6.3	25	NA							
Class SC(G) State MTS Average				10	60	8.8	90	17.3							
Class NC(G) State MTS Average				10	60	7.8	80	19.4							

[1] F-IBI Classes: Northern Coldwater (NC), Northern Headwaters (NH), Northern Streams (NS), Southern Coldwater (SC)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Appendix B: Individual M-IBI metric and related data (attached)

Relative abundance (%) of individuals per selected M-IBI metric

AUID Suffix	Station	Visit Date	M-IBI Class[1] (Use[2])	Metrics												
				BurrowerPct	ClimberPct	ClingerPct	Collector-filtererPct	CrustMollPct	EPTPct	HBI_MN	LeglessPct	LongLivedPct	ScraperPct	SprawlerPct	SwimmerPct	TrichwoHydroPct
647	14RD022	31-Jul-14	PGP(M)	11	12	61	3	8	1	8	98	0	8	15	0	0
650	14RD014	04-Aug-15	SRR(G)	12	26	37	25	8	25	7	71	0	10	14	4	3
654	10RD080(1	22-Sep-10	NC(G)	2	6	53	30	3	67	6	17	11	13	12	27	8
	10RD080(2	22-Sep-10	NC(G)	3	5	56	27	2	69	6	14	11	18	12	24	11
	10RD080(3	04-Aug-15	NC(G)	2	26	45	14	1	33	7	56	6	6	22	1	1
	14RD046(1	05-Aug-14	NC(G)	9	27	27	14	6	52	7	42	4	6	9	28	13
	14RD046(2	04-Aug-15	NC(G)	12	17	52	27	8	43	7	29	26	17	12	5	20
	15RD012	04-Aug-15	NC(G)	2	17	59	33	1	51	7	41	3	4	19	0	1
	15RD035	04-Aug-15	NC(G)	3	7	76	56	3	74	6	9	15	14	3	10	55
662	14RD012	04-Aug-14	SRR(G)	0	33	60	46	0	28	7	68	3	3	3	3	1
	94RD012	04-Aug-14	SRR(G)	3	7	85	63	0	64	7	21	9	10	4	2	4
SRR(G) State MTS Average				**8**	**15**	**50**	**27**	**9**	**44**	**7**	**36**	**9**	**16**	**17**	**11**	**6**
PGP(M) State MTS Average				**14**	**27**	**23**	**10**	**23**	**21**	**8**	**56**	**6**	**18**	**27**	**8**	**2**
NC(G) State MTS Average				**7**	**16**	**54**	**30**	**8**	**52**	**5**	**33**	**9**	**15**	**14**	**6**	**16**

[1] M-IBI Class: Northern Coldwater (NC), Prairie Streams-Glide/Pool Habitats (PGP), Southern Streams-Riffle/Run Habitats (SRR)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Taxa richness (#) per selected M-IBI metric

AUID Suffix	Station	Visit Date	M-IBI Class[1] (Use[2])	Metrics												
				EPT	LongLived	ScraperCh	TaxaCountAllChir									
647	14RD022	31-Jul-14	PGP(M)	3	1	5	24									
650	14RD014	04-Aug-15	SRR(G)	8	2	6	42									
654	10RD080(1	22-Sep-10	NC(G)	15	6	6	46									
	10RD080(2	22-Sep-10	NC(G)	19	5	7	47									
	10RD080(3	04-Aug-15	NC(G)	10	4	5	39									
	14RD046(1	05-Aug-14	NC(G)	7	6	3	36									
	14RD046(2	04-Aug-15	NC(G)	9	8	5	39									
	15RD012	04-Aug-15	NC(G)	6	3	3	30									
	15RD035	04-Aug-15	NC(G)	10	7	5	32									
662	14RD012	04-Aug-14	SRR(G)	4	1	1	20									
	94RD012	04-Aug-14	SRR(G)	8	3	3	23									
SRR(G) State MTS Average				**11**	**6**	**6**	**42**									
PGP(M) State MTS Average				**5**	**3**	**4**	**34**									
NC(G) State MTS Average				**16**	**6**	**5**	**43**									

[1] M-IBI Class: Northern Coldwater (NC), Prairie Streams-Glide/Pool Habitats (PGP), Southern Streams-Riffle/Run Habitats (SRR)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Relative abundance (%) of taxa per selected M-IBI metric

AUID Suffix	Station	Visit Date	M-IBI Class[1] (Use[2])	Metrics												
				ClingerChTxPct	Tolerant2ChTxPct	TrichopteraChTxPct										
647	14RD022	31-Jul-14	PGP(M)	17	83	4										
650	14RD014	04-Aug-15	SRR(G)	38	81	12										
654	10RD080(1	22-Sep-10	NC(G)	48	63	20										
	10RD080(2	22-Sep-10	NC(G)	53	55	28										
	10RD080(3	04-Aug-15	NC(G)	46	74	10										
	14RD046(1	05-Aug-14	NC(G)	33	72	6										
	14RD046(2	04-Aug-15	NC(G)	31	77	5										
	15RD012	04-Aug-15	NC(G)	40	73	13										
	15RD035	04-Aug-15	NC(G)	34	81	9										
662	14RD012	04-Aug-14	SRR(G)	50	75	15										
	94RD012	04-Aug-14	SRR(G)	52	61	22										
SRR(G) State MTS Average				**38**	**72**	**14**										
PGP(M) State MTS Average				**24**	**87**	**6**										
NC(G) State MTS Average				**43**	**47**	**20**										

[1] M-IBI Class: Northern Coldwater (NC), Prairie Streams-Glide/Pool Habitats (PGP), Southern Streams-Riffle/Run Habitats (SRR)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Macroinvertebrate TIVs and tolerance-related data

AUID Suffix	Station	Visit Date	M-IBI Class[1] (Use[2])	Metrics												
				Mean TSS TIV (mg/L)	TSS Very Tolerant Taxa (%)	TSS Tolerant Taxa (%)	TSS Intolerant Taxa (%)	TSS Very Intolerant Taxa (%)	Mean DO TIV (mg/L)	DO Very Tolerant Taxa (%)	DO Tolerant Taxa (%)	DO Intolerant Taxa (%)	DO Very Intolerant Taxa (%)	Mean Temperature TIV (°C)		
647	14RD022	31-Jul-14	PGP(M)	15	6	10	0	0	6.8	2	34	11	1	NA		
650	14RD014	04-Aug-15	SRR(G)	15	3	29	1	0	6.7	0	19	5	4	NA		
654	10RD080(1	22-Sep-10	NC(G)	14	1	12	5	2	7.7	0	1	68	47	19.1		
	10RD080(2	22-Sep-10	NC(G)	13	4	14	9	5	7.5	0	1	65	32	18.7		
	10RD080(3	04-Aug-15	NC(G)	15	3	31	2	0	7.5	0	1	47	34	19.1		
	14RD046(1	05-Aug-14	NC(G)	19	13	59	1	0	7.4	0	5	18	15	20.6		
	14RD046(2	04-Aug-15	NC(G)	19	31	41	0	0	7.4	0	6	27	19	20.4		
	15RD012	04-Aug-15	NC(G)	15	3	39	1	0	7.7	0	0	49	42	19.4		
	15RD035	04-Aug-15	NC(G)	17	20	29	0	0	8.0	0	1	65	57	19.5		
662	14RD012	04-Aug-14	SRR(G)	17	3	53	0	0	7.4	0	0	11	10	NA		
	94RD012	04-Aug-14	SRR(G)	15	5	23	6	1	7.7	0	2	57	52	NA		
SRR(G) State MTS Average				**16**	**12**	**35**	**5**	**1**	**7.1**	**1**	**9**	**25**	**18**	**NA**		
PGP(M) State MTS Average				**16**	**11**	**36**	**1**	**0**	**6.2**	**7**	**31**	**3**	**2**	**NA**		
NC(G) State MTS Average				**12**	**3**	**14**	**23**	**15**	**7.4**	**1**	**5**	**46**	**34**	**19.0**		

[1] M-IBI Class: Northern Coldwater (NC), Prairie Streams-Glide/Pool Habitats (PGP), Southern Streams-Riffle/Run Habitats (SRR)
[2] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

Appendix C: Tulaby Lake Stressor Identification Report

Tulaby Lake

Stressor Identification Report

A study of local stressors limiting the fish biotic community in Tulaby Lake.

CLEAN WATER LAND & LEGACY AMENDMENT

DEPARTMENT OF NATURAL RESOURCES

September 2017

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Key Terms & Abbreviations

EPA	Environmental Protection Agency of the United States
FIBI	Fish Index of Biotic Integrity developed by MNDNR
IBI	Index of Biotic Integrity
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
TP	Total Phosphorus
TSI	Trophic State Index

1. Monitoring and Assessment Overview and Summary of Biological Impairments on Lakes

The approach used to identify biological impairments on lakes includes assessment of fish and aquatic plant communities and habitat conditions throughout a watershed. Information collected can be used to calculate an index of biotic integrity (IBI) score. The IBI scores can then be compared to a range of thresholds as a measurement tool used to assess the health of the aquatic communities.

This report summarizes data collected for assessment of lakes using the Fish IBI tool (FIBI) in the Wild Rice River Watershed.

Metrics developed for the FIBI tools for lakes were selected based on correlations with changes in watershed land use, dock density, and/or floristic quality index. For the FIBI Tool 2, which was used to assess Tulaby Lake, a total of 15 metrics (total numbers of native, intolerant, tolerant, insectivorous, omnivorous, cyprinid, small benthic-dwelling, and vegetation-dwelling species caught collectively in nearshore gears, standard trap nets, and standard gill nets; proportions of intolerant and small benthic-dwelling individuals caught in nearshore gears, proportion of insectivores, omnivores, and tolerant species by biomass in standard trap nets, and proportion of top carnivores by biomass and presence or absence of intolerant species in gill nets) either increased or decreased with changes in trophic state, floristic quality, land use, and/or dock density among a set of Minnesota lakes (Drake and Pereira, 2002; Drake and Valley, 2005; J. Bacigalupi, MNDNR unpublished data). Furthermore, the probability of sampling select fish species in lakes increased or decreased with total phosphorus (TP) concentration, trophic state, or land-use among Minnesota lakes (J. Bacigalupi, MNDNR unpublished data).

FIBI scores are compared to thresholds and confidence intervals that have been developed for similar lakes and determined through a weight of evidence approach using a Biological Condition Gradient Model (Gerritsen and Stamp, 2014). FIBI scores that are higher than the impairment threshold indicate that the lake supports a fish community that has not been substantially altered. Conversely, scores below the impairment threshold indicate that the fish community has been altered. Confidence limits around the impairment threshold help to ascertain where additional information may be considered to help inform the impairment decision. When IBI scores fall within the confidence interval, interpretation and assessment of the waterbody condition involves consideration of potential stressors, and draws upon additional information regarding water chemistry, physical habitat, land use, and other pertinent information.

Eleven lakes were surveyed for use with the FIBI in the Wild Rice River Watershed, listed in Table 1.3. None were determined to be impaired based on the FIBI. However, the Tulaby Lake FIBI score was just one point above the impairment threshold and, thus is considered vulnerable to future aquatic life use impairment. Water quality and shoreline habitat condition were evaluated and excess nutrients and shoreline habitat development appear likely to be contributing to the current status of the fish community and FIBI score on Tulaby Lake. There is concern that additional stress from one or more of these variables may result in a designation of non-supporting (i.e., impaired) for aquatic life use based on the fish community in future assessments on Tulaby Lake. Note that Tulaby Lake is wholly located within White Earth Indian Reservation. See further discussion in sections 2 and 3.

Table 1.1. Biologically vulnerable AUIDs in the Wild Rice River Watershed.

		Impairments	
Lake Name	AUID (DOW #)	Biological*	Water Quality**
Tulaby	44-0003-00	Aquatic Life Use-Vulnerable-FIBI	Aquatic Recreation Use- nutrient/eutrophication biological indicators.

* Data indicates that Tulaby Lake is very nearly impaired for aquatic life use based on the FIBI, but it is not listed on the Impaired Waters List.

** This impairment has been listed on the Impaired Waters List since 2010.

Table 1.2. Fish classes with respective IBI thresholds and upper/lower confidence limits (CL) found in the Wild Rice River Watershed.

Class (FIBI Tool)	Description of Lakes in FIBI Tool	FIBI Impairment Threshold	Upper CL	Lower CL
2	Deep, Complex shoreline (LC 22-25, 27)	45	36	54
4	Deep, Rounder shoreline, central and northern MN (LC 28-32)	38	30	46
5	Moderate depth, central and northern MN (LC 33-37, 39)	24	9	39

The purpose of stressor identification is to interpret the data collected during the biological monitoring and assessment process. Trends in the IBI scores can help to identify causal factors for biological impairments. The FIBI scores and plant IBI summary information in the Wild Rice River Watershed are shown in Table 1.3. All FIBI scores on lakes within the watershed are at or above thresholds with the exception of a score from an older survey (2007) on South Twin and a 2014 survey on Rockstad Lake. Evidence from the fish species age structure suggests that the fish communities on South Twin in 2007 and Rockstad in 2014 were likely highly impacted by recent winterkill events related to low oxygen caused by weather conditions. The FIBI data will be discussed in more detail in Section 3.

Table 1.3. Fish and Aquatic Plant IBI scores by lake, organized by Fish Class and DOW. Key to color coding is in Table 1.4.

AUID (DOW #)	Lake Name	FIBI Sampling Year	Fish IBI Score	Fish IBI Class	Fish IBI Assessment	Aquatic Plant IBI Summary (* indicates survey ≥10 years old)
03-0323-00	Strawberry	2012	55	2	Full Support	Above threshold*
03-0328-00	White Earth	2012	58	2	Full Support	Above threshold*

AUID (DOW #)	Lake Name	FIBI Sampling Year	Fish IBI Score	Fish IBI Class	Fish IBI Assessment	Aquatic Plant IBI Summary (* indicates survey ≥10 years old)
44-0003-00	Tulaby	2015	46	2	Vulnerable	Above threshold
44-0014-00	South Twin	2007, 2008, 2009, 2010, 2011, 2014	41, 48, 65, 60, 55, 63	2	Full Support	Above threshold
44-0038-00	Island	2010, 2015	57, 58	2	Full Support	Above threshold*
44-0006-00	Bass	2013	50	4	Full Support	Above threshold*
44-0045-00	Snider	2015	45	4	Full Support	No data
15-0075-00	Rockstad	2014	15	5	Insufficient Information	Above threshold
44-0001-00	Roy	2007, 2015	25, 24	5	Full Support	Above threshold
44-0023-00	North Twin	2014	53	5	Full Support	Above threshold*
44-0108-00	Sargent	2015	67	5	Full Support	No data

Table 1.4. Key to color coded IBI scores.

≤ lower CL	> lower CL & ≤ Threshold	> threshold & ≤ upper CL	> upper CL	NA = Not available

2. Possible Stressors to Biological Communities

A comprehensive list of potential stressors to aquatic biological communities compiled by the Environmental Protection Agency (EPA; primarily for streams) can be found here (http://www.epa.gov/caddis/si_step2_stressorlist_popup.html).

This section of the report is designed to quantify known or potential environmental stressors responses of FIBI metrics or fish communities in lakes. The stressors selected for consideration for Tulaby Lake include: excess nutrients, shoreline development and physical nearshore habitat alteration, toxic chemicals, sedimentation, non-native species, angling pressure and fisheries management, connectivity, sedimentation, and global climate change or local weather conditions.

2.1. Eliminated Causes

Eliminated causes are in bold.

Introductions of **non-native, aquatic species** have affected fish populations in Minnesota lakes, but no non-native species are confirmed in Tulaby Lake.

A number of **toxic chemicals** can directly or indirectly affect fish populations. Impacts to fish communities range from direct lethal effects on individuals, altered food web from impacts to forage organisms, and reduced fitness from chronic exposure. Hazardous chemicals such as herbicides, pesticides, fertilizers, and petroleum-based products typically enter the aquatic environment as a result of an unintentional discharge or spill.

Chloride is a naturally occurring chemical that, at high concentration, can be toxic to fish and aquatic plant life. Lakes with exposure to road salt run-off can have elevated chloride levels. Tulaby Lake is located in a forested area with few roads.

Mercury is another naturally occurring chemical that can be toxic to fish and other aquatic life. Currently, mercury levels in fish tissue are used to assess lakes for aquatic consumption use. Minnesota Pollution Control Agency (MPCA) and local partners have developed a statewide mercury reduction plan approved by EPA to address these impairments (MPCA, 2007). Mercury concentrations that are toxic to fish and other aquatic organisms would need to far exceed the current aquatic consumption standards. Therefore current standards and actions intended to address aquatic consumption impairment should provide adequate protection to eliminate mercury as a likely candidate cause for the impaired fish community.

Tulaby Lake has a contributing watershed of only 3% disturbed land use with almost no agriculture or other sources of toxic chemicals. Based on this information, toxic chemicals were eliminated as a candidate cause for the impairment and will not be discussed further.

2.2. Inconclusive Causes

Inconclusive causes are in bold.

Although **connectivity** was not significantly related to the FIBI scores in the IBI Tool development, connectivity influences the number of species available to inhabit lakes and can impact the abundance of certain species (Bouvier et al., 2009). Tulaby Lake is a headwaters lake, and likely has limited immigration or emigration of fish. There are four intermittent inlets. The outlet, Tulaby Creek, is also intermittent and often blocked by beaver dams along its path to McCraney Lake (MNDNR Fisheries LMP, 2013). Connection to other surface waters may be important to determine the number of species available to inhabit a given lake, but once established, these species should persist if the lake has enough appropriate habitat. Availability of reliably accurate historical species lists is limited and makes substantiating claims of loss of species in an individual lake difficult; there are no recorded extirpations from Tulaby Lake based on a review of historical fish surveys. Sampling on Tulaby Lake yielded similar total species richness to other similar lakes in the watershed, but a lower number of small benthic dwelling and intolerant species and higher number of omnivorous species than similar lakes (see discussion and table in Section 3.1).

Fish regulations, management, and angling pressure impact fish communities in a multitude of ways. As the numbers of licensed anglers and overall fishing pressure have increased in Minnesota, declines in catches of quality-sized fish, size structure, and age at maturity occurred in many game fishes in Minnesota (Olson and Cunningham, 1989; Cook and Younk, 1998). Despite this, no creel data are available on Tulaby Lake from which to quantify fishing effort or harvest. Harvest of several nongame species and Yellow Perch by the White Earth Tribe have been recorded; however, recent harvest has excluded Yellow Perch and is unlikely to be contributing to changes in the fish population. A review of gill net and trap net records from surveys completed in 1959 through 2016 indicate consistently low numbers of Bluegill, fairly consistently high numbers and biomass of Yellow Perch, an increasing trend in the number of Northern Pike (but a decrease in size), a decreasing trend in Bullhead species abundance, and fluctuations in Cisco, Bass, Walleye, and White Sucker numbers and biomass.

Fish stocking may increase angling opportunities, but stocking may also affect fish species abundance or diversity by increasing predator abundance. Most research in the region has focused on the impact of predator stocking to other gamefish populations (Fayram, et al., 2005; Knapp, et al., 2008). Studies have shown a negative relationship between predator stocking and Yellow Perch abundance, an important forage fish in many Minnesota lakes (Anderson and Schupp, 1986; Pierce, et al., 2006). Strong Yellow Perch year-classes are thought to buffer small-bodied fishes like minnows and darters to the impact of Walleye predation (Forney, 1974; Lyons and Magnuson, 1987). In Tulaby Lake, records of fish stocking date to 1921 and have included Bluegill, Black Crappie, Largemouth Bass, Northern Pike, and Walleye. Since 1977, only Walleye have been stocked. According to the DNR Fisheries 2013 Tulaby Lake Management Plan, a Walleye fingerling stocking rate of 1.5 to 2.0 pounds per littoral acre has sustained the fishery without adversely impacting the abundance of Yellow Perch, Cisco, and White Suckers. Research by the MNDNR FIBI Program has found no relationships between predator abundance, Walleye abundance, or stocking rates with a reduction in FIBI score or reduction in overall richness or numbers of cyprinid or intolerant species (J. Bacigalupi, MNDNR unpublished data).

Sedimentation can be caused by a variety of activities and can change available fish habitat. Development along lakeshores can result in significant changes to the sediment characteristics in a lake (Francis, et al., 2007). Destruction of nearshore aquatic vegetation and removal of woody material, which help to stabilize substrates, can lead to resuspension and redistribution of sediments. Excess erosion upstream can carry sediments to lakes via inlets. Limited substrate survey information exists on Tulaby Lake, but the DNR Fisheries 2013 LMP does indicate concern about sedimentation on historical Walleye spawning reefs degrading the quality of substrates. MNDNR Fisheries researchers are currently investigating the spatial relationship between a variety of habitat measurements and their associated fish communities. Completion of this study is pending and may provide a more clear understanding of the importance of different habitats to the overall fish community living in a lake. Although sedimentation may be contributing to the impaired fish community in some lakes, the lack of high quality quantitative data and scientific research makes it impossible to say conclusively.

Global climate change is expected to affect fish populations in Minnesota lakes because of expected increases in water temperature, shorter ice cover periods and longer growing seasons, and reduced quantities of oxythermal habitat caused by longer periods of summer thermal stratification, especially in northern Minnesota. Global climate change and other global or regional stochastic events such as large volcanic eruptions, drought/wet periods, and annual weather are not discussed in this report.

2.3. Summary and Evaluation of Candidate Causes for Tulaby Lake

Two candidate causes were selected as possible drivers of biological impairments in Tulaby Lake for final analysis in this report: 1) excess nutrients and 2) shoreline development and physical nearshore habitat alteration.

2.3.1. Candidate Cause: Excess Nutrients

MPCA has developed water quality standards to assess nutrient impairment for lakes using measurements of TP and the two TP-response variables, chlorophyll-a and transparency. Data for TP and at least one response variable are needed to determine whether a lake meets the standard. Based on these criteria, Tulaby Lake has been listed as impaired for aquatic recreation use since 2010.

Poor water quality caused by excess nutrients is a driving factor influencing (i.e., stressing) fish communities and the FIBI scores. All 15 FIBI metrics in the FIBI Tool 2 which were used to assess Tulaby Lake, are correlated with TP and Trophic State Index (TSI).

Research has shown that elevated TP levels significantly affect fish community structure and function in Minnesota lakes (Schupp and Wilson, 1993; Heiskary and Willson, 2008). Negative effects of eutrophication include increased plant growth, shifts in phytoplankton and zooplankton composition, and decreases in water transparency, which lead to changes in the fish community that are detected by FIBI tools. Modeling by Cross and Jacobson (2013) in Minnesota lakes suggests that TP concentrations increase significantly over natural concentrations when land use disturbances occur in greater than around 40% of the watershed area.

Watershed and water quality effects on fish communities are strongly documented (Jeppesen et al., 2000; Drake and Pereira, 2002). During FIBI development, increases in urbanization and agriculture were strongly associated with water quality degradation and changes in fish communities (Drake and Pereira 2002; J. Bacigalupi, MNDNR unpublished data).

There are several mechanisms by which eutrophication contributes to impaired fish communities. Excess nutrients impact plankton communities that make up the foundation of aquatic food webs. Increased primary production leads to more phytoplankton, reduced light penetration, and fewer rooted aquatic macrophytes. Loss of aquatic plants represents a physical alteration to available habitat, which can alter fish community composition over time. Reduced plant cover can impact the success of vegetation-dwelling species from a variety of feeding guilds. Decreased light penetration can also reduce the efficiency of sight-feeding predators like Largemouth Bass and Northern Pike and can result in lower biomass of habitat-dependent, top carnivores in the community.

Increased phytoplankton can also lead to an unbalanced community with few large-bodied zooplankton that are preferred food for forage fish and important to the diet of many young game fish. These conditions favor undesirable planktivorous fish species over predatory game fish, which are expressed over several generations of individual fish.

Sedimentation can be caused by a variety of activities and can change available fish habitat. Excess erosion upstream can carry sediments to lakes via inlets, especially in a landscape with extensive cultivation. Development along lakeshores can also result in significant changes to the sediment characteristics in a lake (Francis et al., 2007). Destruction of nearshore aquatic vegetation and removal of woody material, both of which help to stabilize substrates, can lead to resuspension and redistribution of sediments. MNDNR Fisheries researchers are currently investigating the spatial relationship between a variety of habitat measurements and their associated fish communities. Completion of this study is pending and may provide a more clear understanding of the importance of different habitats to the overall fish community living in a lake.

Tulaby Lake was listed as impaired for aquatic recreation use due to excess nutrients in 2010. It remains listed based on TP and chlorophyll-a readings. There has been no obvious trend in transparency during the period of record (1990-2015). Additional information about the water quality and impairment can be found at: https://cf.pca.state.mn.us//water/watershedweb/wdip/waterunit.cfm?wid=44-0003-00

Given that Tulaby Lake is impaired for aquatic recreation use due to nutrients, it is likely that ecological changes resulting from eutrophication are a stressor contributing to the FIBI aquatic life use impairment. Excess nutrients in Tulaby Lake will be further discussed in Section 3.

2.3.2. Candidate Cause: Shoreline Development and Physical Nearshore Habitat Alteration

Changes in fish populations are oftentimes linked to changes in nearshore habitat. Healthy aquatic plant communities, woody or other complex habitat, and diverse substrates provide important benefits to fish communities including providing spawning habitat for some species, protection or refuge areas for juvenile fish, and foraging opportunities. The number of seasonal cabins and homes along lakeshores increased six-fold from the 1950's through the 1990's in class 23 lakes in Minnesota, and about two-thirds of nearshore emergent and floating leaf vegetation was lost as a result of development in these lakes (Radomski and Goeman, 2001). Density of coarse woody debris, emergent vegetation, and floating vegetation increased as shoreline development decreased among Wisconsin lakes (Christensen et al., 1996; Jennings et al., 2003). Among lakes in northern Wisconsin, several fish species were linked to specific nearshore habitats during spring, summer, and fall, and residential development altered spatial distribution patterns of fishes in Washington lakes (Jennings et al., 1999; Scheuerell and Schindler, 2004). MNDNR fisheries research on a broader set of lakes, primarily in Central and Northern Minnesota, has found the likelihood of sampling intolerant species is diminished at dock densities exceeding approximately 16 docks/mile of shoreline (J. Bacigalupi, MNDNR unpublished data).

MNDNR-Ecological and Water Resources has designed a protocol for assessing the habitat conditions of lakeshore and nearshore aquatic areas using a Score the Shore (STS) survey (http://files.dnr.state.mn.us/eco/lake-habitat/lake-plant-survey-manual.pdf). Current MNDNR research is focusing on understanding the relationships between fish species and communities with shoreline disturbance variables measured by STS surveys. Preliminary results indicate a correlation fewer intolerant species and more omnivorous and tolerant species in lakes with lower STS scores (indicating higher disturbance). The results of the STS survey on Tulaby Lake suggest that the condition of riparian habitat may be a stressor to the fish community.

Based on available data, the alteration of fish habitat caused by shoreline development and habitat alteration may be contributing to the impairment of aquatic life use on Tulaby Lake and will be discussed further.

3. Evaluation of Candidate Causes

3.1. Tulaby Lake

3.1.1. Biological Communities

A FIBI survey was conducted on Tulaby Lake in 2015. Tulaby Lake is 832 acres, has a maximum depth of 43 feet, and is in Lake Class 27. The FIBI score for Tulaby Lake was 46 with FIBI Tool 2, which is one point above the impairment threshold (45) and within the 90% confidence interval for the threshold (36-54). Most of the FIBI metrics were near the average values for similar lakes used in FIBI tool development. The FIBI score was most positively influenced by a high number of cyprinids sampled (6), the absence of tolerant species in the trap nets, and the presence of intolerant species in the gill net catch (Cisco and Rock Bass). The score was most negatively influenced by a low number of small benthic species, a high proportion of omnivores in the trap nets (41%, White Sucker and Bullheads), and a low proportion of top carnivores in the gill nets. White Sucker were the most abundant species by biomass in the trap nets, followed by Yellow Perch, Bluegill, and Rock Bass. Yellow Perch were the most abundant species by biomass in gill nets, followed by Walleye, White Sucker, and Northern Pike. The nearshore catch included 19 species, with Yellow Perch, Bluntnose Minnow, and Banded Killifish most common.

The 2015 FIBI was the first FIBI survey on Tulaby lake, but trap net and gill net gears have been used to sample portions of the fish community during 10 summer surveys from 1959-2016. The trap net composition has generally been dominated by omnivorous species, and the highest biomass of White Suckers were sampled in the two most recent surveys (2011 and 2016). Bluegills and other insectivores have not made up a large proportion of the biomass during the historical sampling period on Tulaby Lake.

Four lakes were surveyed in the Wild Rice River Watershed that were scored with FIBI tool 2 for lakes over 40 feet deep: Strawberry, White Earth, Island, and Tulaby. These lakes will be referred to as comparable lakes. Tulaby had the lowest FIBI score of comparable lakes in the Wild Rice River Watershed (46, compared to 55, 58, and 58 respectively). Note that this is a small number of lakes, so some caution is advised in using average values. The majority of the FIBI metrics score similar to comparable lakes. Most species richness FIBI metric scores in FIBI Tool 2 are adjusted for lake size using a mixed model as designated in Table 3.1. A high number of omnivorous species, relatively high proportion of Yellow Perch and White Sucker in the gill net catch, and a high abundance of omnivores in the trap net catches are the most notable differences from comparable lakes. A low FIBI score associated with high number and proportion of omnivores and high TP values is consistent with patterns observed in FIBI Tool 2 development (Bacigalupi, MNDNR unpublished data).

Table 3.1. Fish IBI metric raw values and scores for Tulaby Lake, and difference from comparable lakes within the Wild Rice River Watershed (lakes >40 feet deep score with FIBI Tool 2).

Metric (Spp. = species, Ppn. = Proportion, * indicates scored metric is adjusted for lake size)	Tulaby Lake – Raw Value	Tulaby Lake – Metric Score	Avg. Metric Score for comparable lakes	Difference From average of comparable lakes (difference>±1)
# Native Spp.*	23	0.09	-0.02	0.11
# Intolerant Spp.*	6	0.05	0.15	-0.10
# Tolerant Spp.	2	-0.15	-0.15	0
# Insectivore Spp.*	13	0.18	0.11	0.07
# Omnivore Spp.*	5	-0.44	0.30	-0.74
# Cyprinid Spp.*	6	0.92	0.50	0.43
# Small Benthic Dwelling Spp.*	2	-0.81	-0.28	-0.53
# Vegetation Dwelling Spp.*	6	-0.07	-0.17	0.10
Ppn. Intolerant Individuals in Nearshore	0.17	0.56	0.54	0.02
Ppn. Small Benthic Individuals in Nearshore	0.04	0.22	0.21	0.01
Ppn. Insectivore Biomass in Trap nets	0.34	-0.26	0.61	-0.87
Ppn. Omnivore Biomass in Trap nets	0.41	-1.31	0.15	-1.46
Ppn. Tolerant Biomass in Trap nets	0	0.91	0.42	0.50

Metric (Spp. = species, Ppn. = Proportion, * indicates scored metric is adjusted for lake size)	Tulaby Lake – Raw Value	Tulaby Lake – Metric Score	Avg. Metric Score for comparable lakes	Difference From average of comparable lakes (difference>±1)
Ppn. Top Carnivore Biomass in Gill nets	0.60	-2.29	-0.71	-1.58
Presence/Absence Intolerant Spp. in Gill nets	P	2	2	0

3.1.2. Data Evaluation for each Candidate Cause

Candidate Cause: Excess Nutrients

Water quality is a driving factor influencing fish communities and the FIBI scores. All 15 FIBI metrics in the FIBI Tool 2, used to assess Tulaby Lake, and the overall Fish IBI Score were correlated with TP and TSI in the set of lakes used for tool development. Average TP and TSI values for Tulaby lake are 32 ug/L and 54 respectively, levels that correspond with depressed FIBI scores as shown in Figure 3.1.

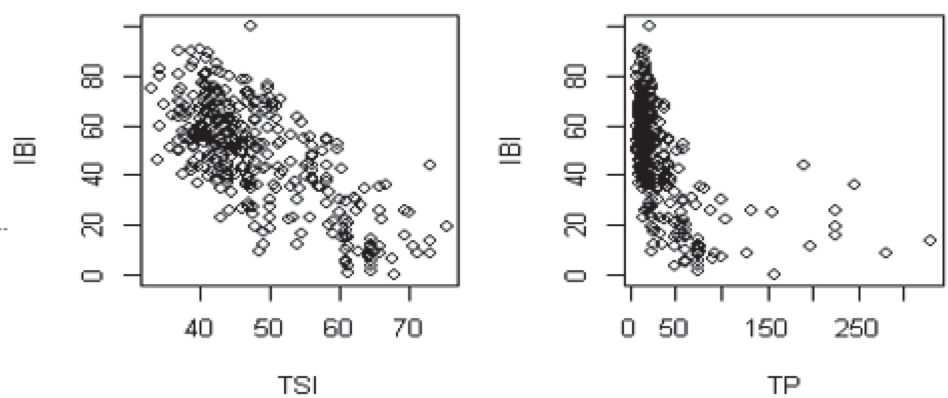

Figure 3.1. Relationships with FIBI Score and TSI and TP in FIBI Tool 2 tool development lakes, 2014.

The specific sources of excess nutrients that may be impacting the fish community and contributing to a low FIBI score will be explored in the Total Maximum Daily Load report for Tulaby Lake will explore the source(s) of excess nutrients.

Often we observe changes to the fish community from land use practices in the upstream contributing watershed away from the lake, but this appears to be unlikely as a major contributor to the impairment on Tulaby Lake. Tulaby is a headwater lake with only about 3% of contributing land use classified as disturbed. The contributing watershed has a watershed to lake size ratio of about 8:1. Watershed land cover remained stable between 2001 and 2011 based on National Land Cover Datasets (WHAF, 2016). Land cover within the watershed is primarily forest (73%). The remaining undeveloped land is a combination of open water (14%), wetlands (6%), and shrub or grassland (4%). Residential and commercial development (3%), including paved and unpaved roads, account for the remaining land cover within the watershed and is primarily located directly on the lakeshore. Less than 1% of land is in cultivation, including a small amount of grains and corn in recent years. This low level of disturbance within the contributing watershed is significantly lower than where we typically observe impacts to the FIBI.

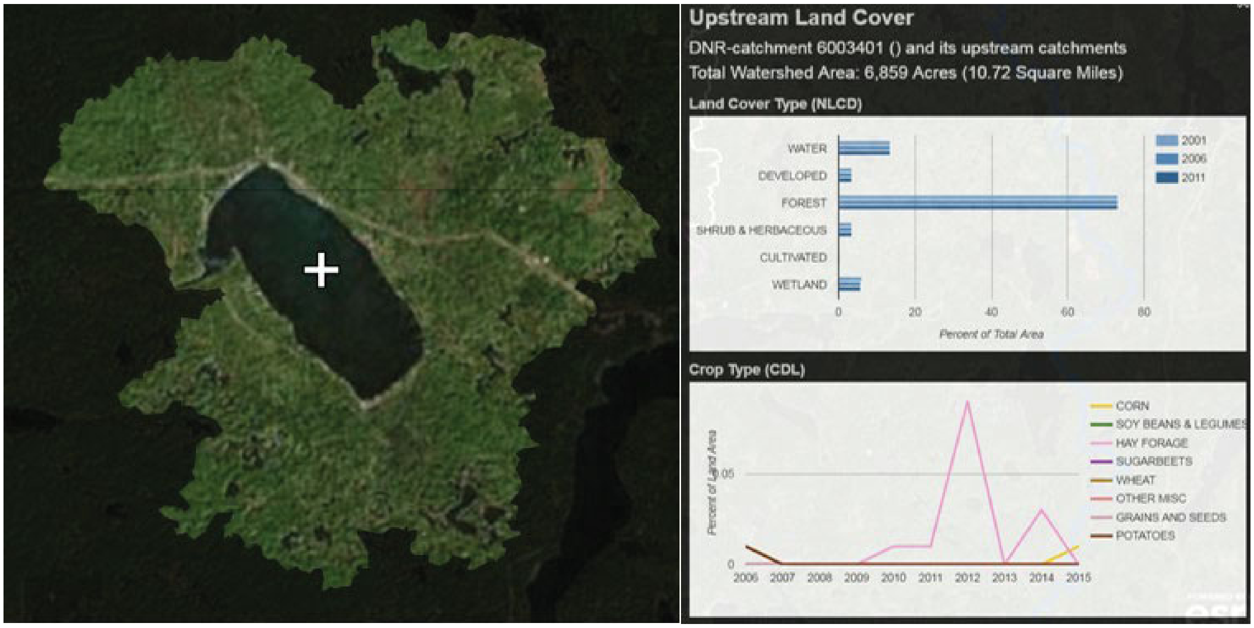

Figure 3.2. Contributing watershed for Tulaby Lake and land cover within the upstream catchments (WHAF, 2016).

Candidate Cause: Shoreline Development and Physical Nearshore Habitat Alteration

Several methods have been developed to quantify the status of riparian lakeshore habitat and to index the amount of human development in these areas. Dock density can be obtained easily from aerial photography (Radomski et al., 2010) and computer analysis can be applied to quantify docks in many lakes quickly (Beck et al., 2013). The dock density index is a surrogate for the measurement of physical habitat (i.e., the amount of tree cover near the lake, the amount of overhanging woody cover at the shoreline, or presence of emergent or floating-leaf vegetation). Dock density was considered in selecting FIBI metrics. Ongoing research projects by MNDNR-Fisheries have found changes to fish species sampled detectable at about 10 docks per kilometer of shoreline.

"Score the Shore" (STS) survey protocols were developed by MNDNR–Ecological and Water Resources in 2013 as a rapid assessment of riparian lake habitat (Perleberg et al., 2015) and adopted for use by MNDNR–Fisheries beginning in 2015. Aquatic, upland (Shoreland), and transition zone (Shoreline) habitats are assessed and the lake-wide score (ranging for 0 to 100) is the sum of three habitat scores, which are equally weighted. STS surveys provide a lake-wide lakeshore habitat score that can be used to monitor changes in a lake over time and to compare lakes within and between watersheds. STS scores are summed from three component scores: shoreland, shoreline, and aquatic.

The shoreline of Tulaby Lake has a range of residential development density with about 221 homes and cabins (DNR Fisheries Lake Management Plan, 2013), and about 127 docks, 22 per mile of shoreline, based on analysis using aerial imagery (described in Beck et al., 2013). An assessment of riparian development was conducted in July 2015 following Score the Shore survey protocols and resulted in a mean score of 61 (range is 0 to 100), indicating overall poor lakeshore condition (see Table 3.2). There was a marked difference between shoreline habitat observed at developed sites (mean score 51) and undeveloped sites (mean score 95), suggesting much of the shoreland and shoreline vegetation was manicured and removed at survey site locations. Emergent and/or floating leaf vegetation was observed at about 60% of survey sites, but the majority of survey sites with emergent and/or floating leaf vegetation present had at least some removal noted as man-made openings or channels. Aquatic woody habitat was only noted at 17% of survey sites. The DNR Fisheries 2013 Tulaby Lake Management Plan noted significant stands of bulrush along the northeast and southwest shores, but noted some removal of vegetation.

Table 3.2. Summary of Score the Shore Survey results.

Land Use Observed	Number of survey sites	Shoreland Zone Score (0-33.3)	Shoreline Zone Score (0-33.3)	Aquatic Zone Score (0-33.3)	Lakewide Mean Score (0-100)	Qualitative Rating
Developed sites	32	19.9	14.8	16.0	51	Poor
Undeveloped sites	10	33.3	32.7	28.7	95	Excellent
Total (all sites)	42	23.1	19.0	19.0	61	Poor

4. Conclusions and Recommendations

This report has presented information summarizing the potential stressors impacting the FIBI on Tulaby Lake in the Wild Rice River Watershed. Tulaby is very near the FIBI impairment threshold and considered vulnerable to future aquatic life use impairment. The primary stressors on Tulaby Lake are poor water quality and alterations of nearshore habitat associated with shoreline development practices. The main methods for improving fish community composition and resulting FIBI scores would be to improve water quality, restore altered shoreline, and protect undeveloped shoreline and vegetation stands (such as bulrush stands) within the lake.

Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted. Lakeshore restoration should include reestablishment of trees, shrubs, and natural ground cover in an attempt to restore the habitat complexity around the perimeter of the lake to natural levels. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Removal of woody habitat from the lake should be discouraged because natural woody structures add to the nearshore habitat complexity important to a variety of organisms including fish. Trees that provide habitat for wildlife while living can provide habitat in aquatic environments for a much greater period of time because submerged wood decomposes slowly. Removing dead trees from the water has the effect of reducing overall aquatic habitat in a lake for decades or longer.

The current assessment of aquatic recreation found nutrient levels exceeded water quality standards. More study is needed, as part of a Total Maximum Daily Load Report to explore the source(s) of excess nutrients and identify appropriate mitigation techniques. Best management practices to reduce nutrient loading into lakes should be promoted because these efforts will benefit human (aquatic recreation use) and aquatic ecosystem (aquatic life use) health. It is important to note though that a full response of lake ecology may take decades after external nutrient loads are reduced (Schindler, 2006).

Protection and restoration efforts that reduce the impact of any of the candidate stressors presented in this report will have a positive influence on the fish community.

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