Snake River Watershed Stressor Identification Report

A study of the local stressors that are limiting the impaired fish and macroinvertebrate communities in the Snake River Watershed.

Middle River

CLEAN WATER LAND & LEGACY AMENDMENT

MINNESOTA POLLUTION CONTROL AGENCY

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Cover Photo

Middle River at County Road 128 on July 15, 2015

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Contents

List of tables

List of figures

Acronyms

AUID – Assessment Unit Identification

BMP – Best Management Practice

CADDIS – Causal Analysis/Diagnosis Decision Information System

CD – County Ditch

Chl-a – Chlorophyll-a

CR – County Road

CSAH – County State Aid Highway

DO – Dissolved Oxygen

FIBI – Fish Index of Biological Integrity

HSPF – Hydrological Simulation Program - FORTRAN

IBI – Index of Biological Integrity

IWM – Intensive Watershed Monitoring

MDNR – Minnesota Department of Natural Resources

MIBI – Macroinvertebrate Index of Biological Integrity

MPCA – Minnesota Pollution Control Agency

MSHA – MPCA Stream Habitat Assessment

MSTRWD – Middle-Snake-Tamarac Rivers Watershed District

NAIP – National Agriculture Imagery Program

NLCD – National Land Cover Database

SID – Stressor Identification

SRW – Snake River Watershed

TALU – Tiered Aquatic Life Use

TIV – Tolerance Indicator Value

TMDL – Total Maximum Daily Load

TSS – Total Suspended Solids

USEPA – United States Environmental Protection Agency

USGS – United States Geological Survey

WHAF – Watershed Health Assessment Framework

Executive summary

The Minnesota Pollution Control Agency (MPCA) follows a watershed approach to systematically monitor and assess the quality of surface waters 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 2013 and 2014, the MPCA conducted biological monitoring at several stations throughout the Snake River Watershed (SRW). An Index of Biological Integrity (IBI) score was then calculated for the fish (FIBI) and macroinvertebrate (MIBI) communities of each station using the IWM and previously collected data. 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 11 reaches were determined to have an FIBI and/or MIBI impairment in the SRW, including segments of the Snake River, Middle River, South Branch of the Snake River, Judicial Ditch 28, and Judicial Ditch 29.

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

Several potential longitudinal connectivity barriers (e.g., dams and private road crossings) were identified along the reaches; however, there is no conclusive evidence that these barriers are limiting the associated biotic communities. Additional investigation of these barriers, particularly culverts, is needed to further understand their effects, if any, on fish passage, as well as flow. All 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., ditching and channelization) are the primary anthropogenic factors contributing to this flow regime instability. Additional runoff detention/retention is needed throughout the watershed to attenuate peak flows and augment base flows. The central and eastern portions of the watershed generally offer the most diverse instream habitat, including coarse substrate and riffles. However, the effects of altered hydrology have degraded the habitat of several reaches in these areas. The habitat of the western portion of the watershed is inherently limited by the predominance of fine lacustrine sediment. Excess suspended sediment appears to be having a substantial effect on the biological communities of several impaired reaches. Soil and instream erosion are the primary sources of this sediment. The implementation of additional soil conservation practices and the attenuation of peak flows would reduce sediment loads. Lastly, low DO is a stressor for each of the impaired reaches. While the severity of low DO conditions varies amongst the reaches, the lowest concentrations generally coincide with low flow and stagnant conditions that occur during the late summer (i.e., July, August, and September). Base flow augmentation and nutrient reductions are the primary means of alleviating this stressor.

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 (USEPA, 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.

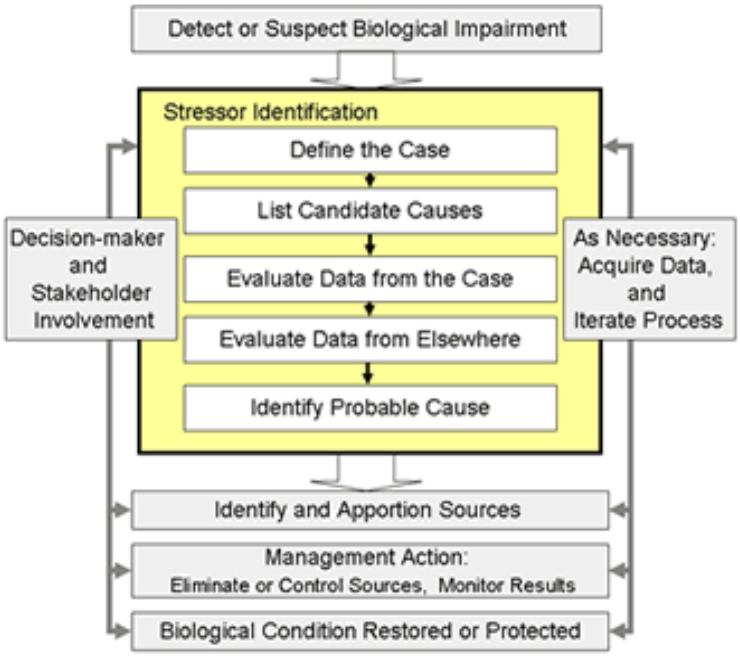


Figure 1. Conceptual model of the SID process (USEPA 2012b).

Section 1: Watershed overview

1.1 Physical setting

The Snake River Watershed (SRW), United States Geological Survey (USGS) Hydrologic Unit Code 09020309, is situated in northwestern Minnesota and is part of the larger Red River of the North Basin. The SRW has a drainage area of 779 square miles and encompasses portions of the following counties, listed in order of the percentage of watershed area: Marshall (92%), Polk (6%), and Pennington (2%). Cities within the watershed include Alvarado, Argyle, Holt, Middle River, Newfolden, Viking, and Warren.

1.2 Surface water resources

The Snake River and the Middle River are the prominent water features in the SRW. The Snake River outlets to the Red River of the North approximately 11 miles west of the City of Stephen, while the Middle River outlets to the Snake River roughly 12 miles northwest of the City of Argyle. The SRW contains 434 miles of intermittent drainage ditch, 352 miles of intermittent stream, 188 miles of perennial stream and river, and 32 miles of perennial drainage ditch (MDNR, 2003). According to the MPCA (2013), at least 52% of the watercourses in the SRW have been physically altered (i.e., channelized, ditched, or impounded). There are no notable lakes in the watershed.

1.3 Geology and soils

Two distinct physiographic regions are represented in the SRW. The drift plain/beach ridges region, which includes glacial drift deposits that were modified by glacial Lake Agassiz, as well as the ancient shorelines of glacial Lake Agassiz, encompasses approximately the eastern two-thirds of the watershed. This region is characterized by an undulating topography (1-8% slope) and soils of varying textures (sand to clay loam). There are also large inclusions of organic soils scattered throughout the region. 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 (e.g., silty clay) derived from lacustrine sediments deposited in glacial Lake Agassiz.

1.4 Land use and ecoregion

The predominant land use in the SRW is agricultural crop production. According to the National Land Cover Database (NLCD) 2011 (USGS, 2011), cultivated crops comprised 79% of the watershed. Other notable land cover groups in the watershed included wetlands (7%), forest (6%), developed (5%), and hay/pasture (3%). The entire watershed is located within the Red River Valley Level III Ecoregion (USEPA, 2012a).

1.5 Ecological health

The Minnesota Department of Natural Resources (MDNR) 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"). Statewide mean health scores ranged from 40 (Marsh River Watershed) to 84 (Rapid River Watershed).

Figure 2 presents the watershed health scorecard for the SRW. The mean health score for the watershed was 46. The overall score was limited by the individual mean component scores for connectivity (18) and biology (36). Specifically, the watershed scored poorly for the following component indices: terrestrial habitat quality (4), terrestrial habitat connectivity (5), altered streams (8), climate vulnerability (16), perennial cover (16), at-risk species richness (28), riparian connectivity (29), surface storage (42), and phosphorus risk (43).

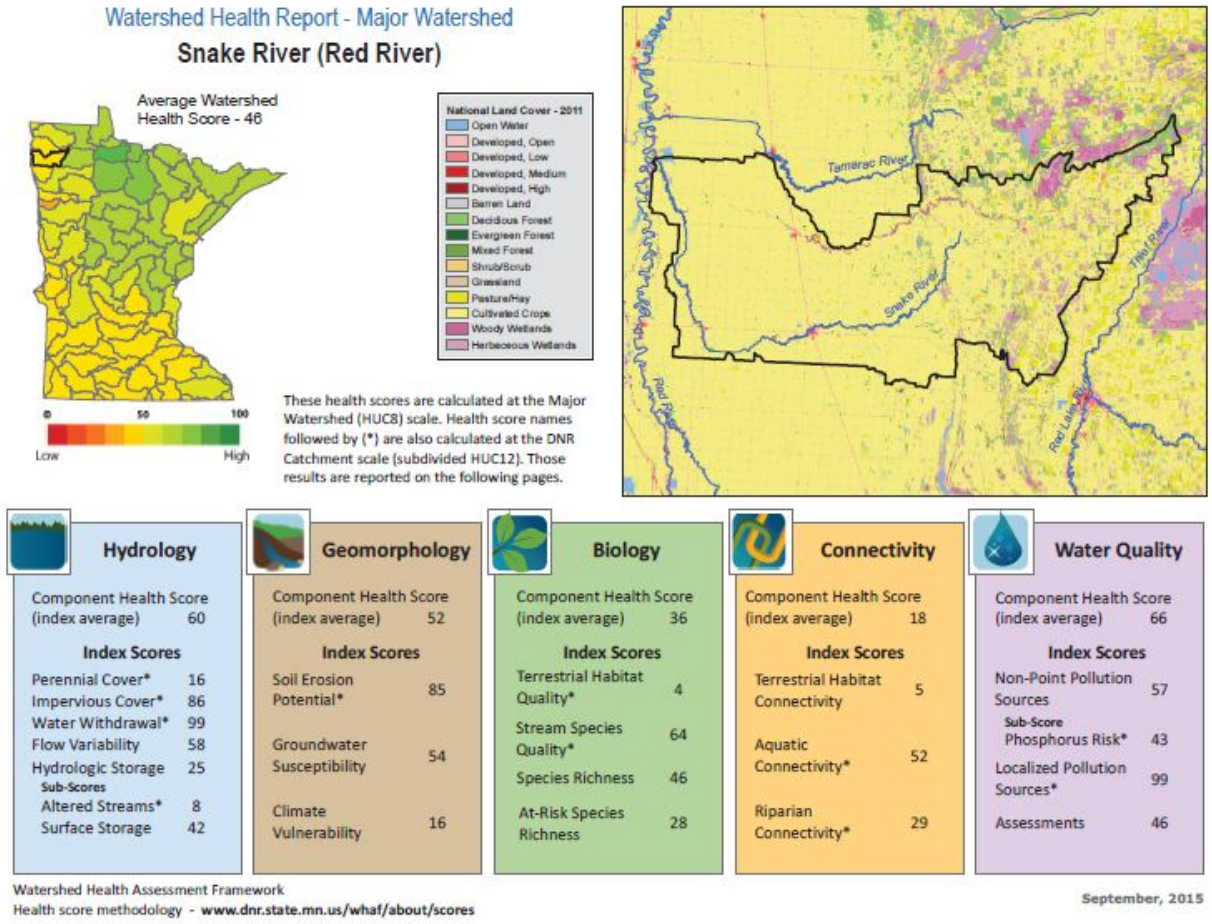


Figure 2. Watershed health assessment scores for the SRW.

1.6 Hydrological Simulation Program – FORTRAN (HSPF) Model

A Hydrological Simulation Program – FORTRAN (HSPF) model was developed for the SRW 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 watershed-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 instream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient concentrations, along with a time history of water quantity and quality at the outlet of each subwatershed. The HSPF model outputs were used to evaluate several of the candidate causes outlined in this report.

Section 2: Biological monitoring and impairments

2.1 Watershed approach

The Minnesota Pollution Control Agency (MPCA) utilizes a watershed approach (Figure 3) to systematically monitor and assess the quality of surface waters 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 2013 and 2014, the MPCA conducted biological monitoring at several stations throughout the SRW. An Index of Biological Integrity (IBI) score was then calculated for the fish (FIBI) and macroinvertebrate (MIBI) communities of each station using the IWM and previously collected data. 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 SRW 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 (TMDL) study.

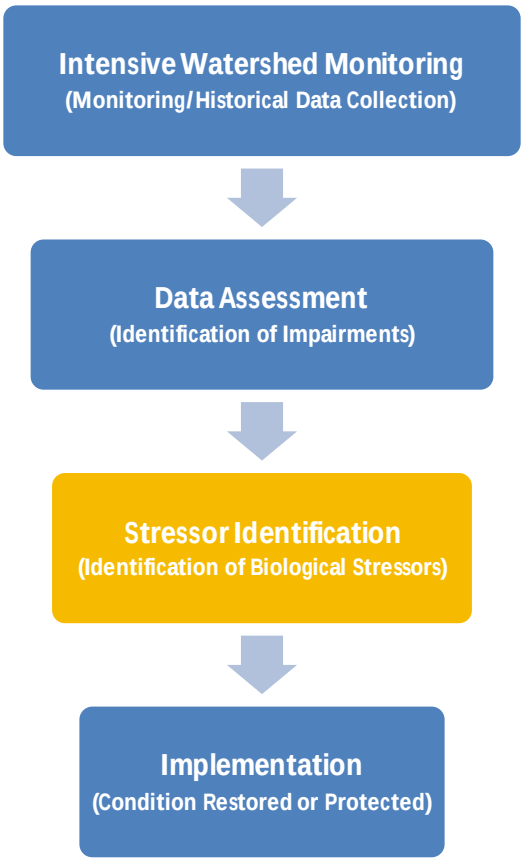


Figure 3. Conceptual model of the watershed approach processes.

2.2 Monitoring stations

Table 1 lists the 34 biological monitoring stations that were sampled for fish and/or macroinvertebrates in the SRW. The stations are situated along 17 separate reaches. For the purpose of this report, 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 SRW.

AUID suffix	AUID	Name	Monitoring station(s)
501	09020309-501	Snake River	13RD009
502	09020309-502	Snake River	13RD007
504	09020309-504	Snake River	04RD002, 05RD175, 13RD004, 13RD108, 93RD416
515	09020309-515	Unnamed Ditch	05RD020
518	09020309-518	Unnamed Ditch	05RD011
519	09020309-519	Judicial Ditch 29	13RD010
529	09020309-529	Unnamed Ditch	13RD027
530	09020309-530	Judicial Ditch 21	13RD023
534	09020309-534	Unnamed Creek	13RD025
537	09020309-537	Snake River	13RD006, 13RD080, 94RD511
538	09020309-538	Middle River	13RD026
539	09020309-539	Middle River	05RD095, 13RD002, 13RD100, 13RD103
540	09020309-540	Middle River	05RD014, 13RD022, 13RD079, 13RD098, 93RD417
541	09020309-541	Middle River	13RD008
543	09020309-543	Snake River	13RD036, 13RD104
544	09020309-544	South Branch of the Snake River	13RD035
546	09020309-546	South Branch of the Snake River	13RD034, 13RD099, 13RD105, 13RD106

2.3 Monitoring results

Table 2 provides the FIBI and MIBI scores for each of the biological monitoring stations in the SRW. A total of 17 stations (55%) scored below their FIBI impairment threshold, while 15 stations (54%) scored below their MIBI impairment threshold; these stations are highlighted red.

Table 2. Summary of FIBI and MIBI scores for biological monitoring stations in the SRW.

Fish					Macroinvertebrate				
AUID suffix	Station	FIBI Class[1] (Use[3])	FIBI impairment threshold	FIBI score (mean)	AUID suffix	Station	MIBI Class[2] (Use[3])	MIBI impairment threshold	MIBI score (mean)
501	**13RD009**	**SR(G)**	**49**	**46**	501	13RD009	Not Sampled		
502	**13RD007**	**SR(G)**	**49**	**20**	**502**	**13RD007**	**PGP(G)**	**41**	**30**
504	04RD002	Not Sampled			**504**	**04RD002**	**PGP(G)**	**41**	**30**
504	**05RD175**	**SS(G)**	**50**	**48**	**504**	**05RD175**	**PGP(G)**	**41**	**17**
504	**13RD004**	**SS(G)**	**50**	**1**	504	13RD004	PGP(G)	41	59
504	**13RD108**	**SS(G)**	**50**	**33**	**504**	**13RD108**	**SRR(G)**	**37**	**21**
504	**93RD416**	**SS(G)**	**50**	**28**	**504**	**93RD416**	**PGP(G)**	**41**	**38**
515	05RD020	NH(M)	23	38	515	05RD020	PGP(M)	22	29
518	05RD011	Not Sampled			518	05RD011	PGP(M)	22	24
519	**13RD010**	**SH(G)**	**55**	**0**	519	13RD010	Not Sampled		
529	13RD027	NH(M)	23	59	**529**	**13RD027**	**SRR(M)**	**24**	**13**
530	**13RD023**	**NH(G)**	**42**	**30**	**530**	**13RD023**	**SRR(G)**	**37**	**36**
534	13RD025	NH(G)	42	66	534	13RD025	SRR(G)	37	43
537	**13RD006**	**SS(G)**	**50**	**27**	**537**	**13RD006**	**PGP(G)**	**41**	**8**
537	**13RD080**	**SR(G)**	**49**	**47**	**537**	**13RD080**	**PGP(G)**	**41**	**19**
537	**94RD511**	**SS(G)**	**50**	**27**	537	94RD511	PGP(G)	41	57
538	13RD026	LG(M)	15	39	538	13RD026	Not Sampled		
539	05RD095	Not Sampled			539	05RD095	PGP(G)	41	46
539	13RD002	NS(G)	47	52	539	13RD002	SRR(G)	37	41
539	13RD100	NS(G)	47	51	539	13RD100	SRR(G)	37	42
539	13RD103	NH(G)	42	65	539	13RD103	Not Sampled		
540	05RD014	NS(G)	47	55	540	05RD014	PGP(G)	41	60
540	13RD022	NS(G)	47	51	**540**	**13RD022**	**SRR(G)**	**37**	**27**
540	13RD079	SS(G)	50	56	**540**	**13RD079**	**SRR(G)**	**37**	**27**
540	13RD098	SS(G)	50	62	**540**	**13RD098**	**SRR(G)**	**37**	**36**
540	93RD417	SS(G)	50	50	540	93RD417	PGP(G)	41	56
541	13RD008	SS(M)	35	54	541	13RD008	Not Sampled		
543	**13RD036**	**NS(G)**	**47**	**29**	543	13RD036	SRR(G)	37	42
543	**13RD104**	**NS(G)**	**47**	**24**	**543**	**13RD104**	**SRR(G)**	**37**	**14**
544	**13RD035**	**NH(G)**	**42**	**28**	**544**	**13RD035**	**SRR(G)**	**37**	**15**
546	**13RD034**	**NH(G)**	**42**	**37**	546	13RD034	SRR(G)	37	51
546	**13RD099**	**NS(G)**	**47**	**35**	**546**	**13RD099**	**SRR(G)**	**37**	**32**
546	**13RD105**	**NH(G)**	**42**	**24**	546	13RD105	Not Sampled		
546	13RD106	NH(G)	42	43	546	13RD106	SRR(G)	37	48

[1] FIBI Classes: Low Gradient Streams (LGS), Northern Headwaters (NH), Northern Streams (NS), Southern Headwaters (SH), Southern Rivers (SR), Southern Streams (SS)
[2] MIBI Class: Prairie Streams-Glide/Pool Habitats (PGP), 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 SRW were formally assessed as part of the development of the *Snake River Watershed Monitoring and Assessment Report* (MPCA, 2016) to determine if individual stream reaches met applicable aquatic life standards. As shown in Table 3, 11 reaches were determined to be biologically impaired; these reaches are highlighted red. The relative location of these reaches is shown in Figure 4.

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

AUID suffix	Name	Description of extent	Length (mi)	Biological impairment(s)
501	Snake River	Middle River to Red River of the North	10	FIBI
502	Snake River	County Ditch 3 to Middle River	11	FIBI, MIBI
504	Snake River	S. Branch of the Snake River to County Ditch 7	23	FIBI, MIBI
515	Unnamed Ditch	Headwaters to County Ditch 15	2	None
518	Unnamed Ditch	Unnamed Ditch to Unnamed Ditch	2	None
519	Judicial Ditch 29	Headwaters to Snake River	11	FIBI
529	Judicial Ditch 28	Unnamed Ditch to Middle River	8	MIBI
530	Judicial Ditch 21	380th Street crossing to Middle River	5	None
534	Unnamed Creek	Unnamed Ditch to Middle River	2	None
537	Snake River	AUID 536 to County Ditch 3	17	FIBI, MIBI
538	Middle River	Headwaters to AUID 539	7	FIBI
539	Middle River	AUID 538 to County Road 114 crossing	38	None
540	Middle River	County Road 114 crossing to AUID 541	46	MIBI
541	Middle River	AUID 540 to Snake River	6	None
543	Snake River	Unnamed Creek to S. Branch of the Snake River	29	FIBI, MIBI
544	South Branch of the Snake River	Judicial Ditch 25-1 to Snake River	3	FIBI, MIBI
546	South Branch of the Snake River	Headwaters to Snake River	14	FIBI

In addition to the abovementioned biological impairments, six reaches in the SRW were included on the 2012 Impaired Waters List for a water quality impairment that affects aquatic life (Table 4).

Table 4. Water quality impairments (2012 Impaired Waters List) associated with reaches in the SRW.

AUID suffix	Name	Description of extent	Water Quality impairment(s)
501	Snake River	Middle River to Red River of the North	Dissolved Oxygen, Turbidity[4]
502	Snake River	County Ditch 3 to Middle River	Dissolved Oxygen, Turbidity[4]
503[1]	Snake River	County Ditch 7 to County Ditch 3	Dissolved Oxygen
504	Snake River	S. Branch of the Snake River to County Ditch 7	Turbidity[4]
505[2]	Middle River	Headwaters to Snake River	Dissolved Oxygen, Turbidity[4]
506[3]	Snake River	Headwaters to S. Branch of the Snake River	Dissolved Oxygen

[1] AUID 503 was split into AUIDs 536 and 537 for the purposes of biological monitoring.
[2] AUID 505 was split into AUIDs 538, 539, 540, and 541 for the purposes of biological monitoring.
[3] AUID 506 was split into AUIDs 542 and 543 for the purposes of biological monitoring.
[4] The MPCA has since replaced the turbidity standard with a total suspended solids standard.

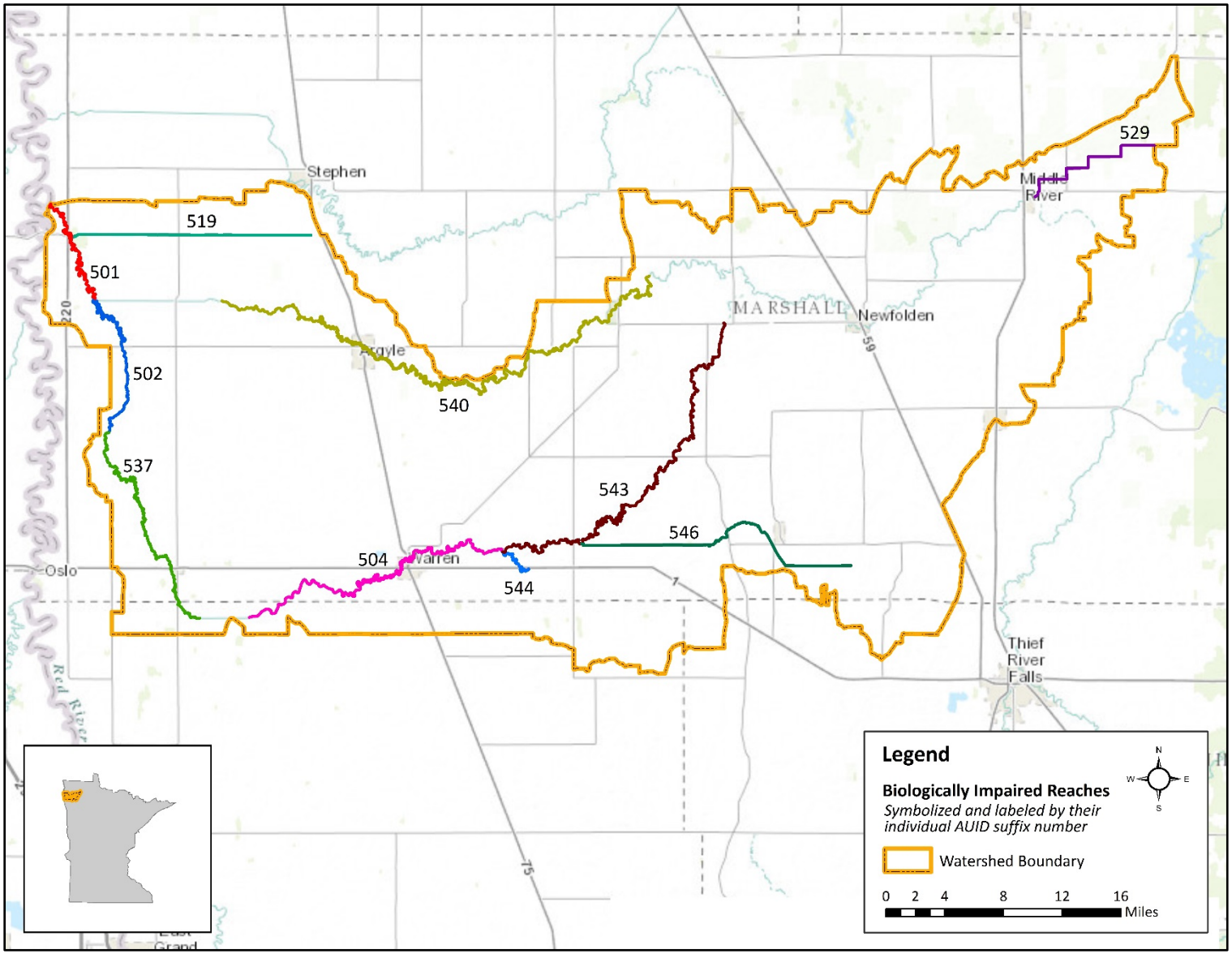


Figure 4. Map of the SRW and associated biologically impaired reaches.

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" (USEPA, 2012b). 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 SRW. 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 *Snake River Watershed Monitoring and Assessment Report* (MPCA, 2016), the *Middle-Snake-Tamarac Rivers Watershed District's (MSTRWD) Watershed Management Plan* (MSTRWD, 2011), and the *Red River Basin Stream Survey Report: Snake River and Tamarac River Watersheds 2006* (Groshens, 2007). Based upon the results of this evaluation, five candidate causes were identified to undergo causal analysis (Section 3.3).

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

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 values that exceed the applicable state standard (>30/65 mg/L).	Yes
Low dissolved oxygen	Several of the biologically impaired reaches have discrete dissolved oxygen values that are below the state standard (<5.0 mg/L). Three of the reaches have an existing dissolved oxygen impairment.	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
Temperature regime alteration	Nearly all of the temperature values associated with the biologically impaired reaches were below the state standard (<30°C).	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 Overview of candidate causes

3.2.1 Loss of longitudinal connectivity

Background

Connectivity in aquatic ecosystems refers to how waterbodies and waterways are linked to each other on the landscape and how matter, energy, and organisms move throughout the system (Pringle, 2003). Dams and other water control structures on river systems alter hydrologic (longitudinal) connectivity, often obstructing the movement of migratory fish and causing a change in the population and community structure (Brooker, 1981; Tiemann et al., 2004). These structures also alter stream flow, water temperature regime, and sediment transport processes; each of which can cause changes in fish and macroinvertebrate assemblages (Cummins, 1979; Waters, 1995). According to the MDNR (2014), there are more than 1,200 dams in the state that serve a variety of purposes, including flood control, lake level control, wildlife habitat, and hydroelectric power generation. Culverts at road crossings can also interfere with fish passage if they are installed (e.g., perched) or sized incorrectly. A similar phenomenon can occur naturally with beaver dams acting as barriers to fish migration.

Applicable standards

There are no applicable standards for connectivity. However, the Minnesota Department of Transportation has developed design guidelines for culverts to ensure fish passage.

3.2.2 Flow regime instability

Background

Flow is considered a "maestro" (Walker et al., 1995) or "master variable" (Power et al., 1995) that affects many fundamental characteristics of stream ecosystems, including biodiversity (Bunn and Arthington, 2002; Hart and Finelli, 1999; Poff et al., 1997). According to Poff and Zimmerman (2010), the flow regime of a stream is largely a function of climate (i.e., precipitation and temperature) and runoff-related controls (e.g., land cover and topography). The natural flow regime of most waterways in the Red River of the North Basin has been anthropogenically altered by the conversion of native vegetation to cropland, as well as intensive agricultural drainage. Examples of drainage-related hydrologic alterations include ditching, channelization of natural streams, modification/cultivation of headwater streams, subsurface tiling, and wetland drainage. These practices are known to cause increased discharges following rain events and/or reduced base flows during dry periods (EOR, 2009; Franke and McClymonds, 1972; Miller, 1999; Mitsch and Gosselink, 2007; Moore and Larson, 1979; Verry, 1988).

Intense peak flows can directly result in the displacement of fish and macroinvertebrates downstream if they are unable to move into refuges, or if refuges are not available. The high channel shear stresses associated with peak flows can also cause the mobilization of sediment, woody debris, and plant materials, as well as increased channel scouring and bank destabilization. These effects often negatively impact instream habitat and turbidity. Diminished base flows result in decreased wetted width, cross sectional area, and water volume. Aquatic organisms require adequate living space, and when flows are reduced beyond normal base flow, habitat can be scarce and the competition for resources increases. Additionally, low flow and stagnant conditions often result in a decrease in dissolved oxygen levels.

The United States Environmental Protection Agency's (USEPA) Causal Analysis/Diagnosis Decision Information System (CADDIS) webpage contains a conceptual diagram of the sources and pathways for flow alteration as a candidate cause for impairment.

Applicable standards

There are limited standards for the protection of base flow. The MDNR regulates the appropriation of water resources and may restrict the withdrawal of surface water when flows are below protected levels.

3.2.3 Insufficient physical habitat

Background

Physical habitat is primarily a function of channel geomorphology (Rosgen, 1996) and flow (Bovee, 1986). Geomorphology is determined naturally by geology and climate (Leopold et al., 1994), but may be altered directly by channelization and indirectly by land use changes affecting runoff and the removal of riparian vegetation (Aadland et al., 2005). A high frequency of bankfull flows often results in a subsequent increase in channel cross-sectional area (Verry, 2000) and a decrease in sinuosity (Verry and Dolloff, 2000). These geomorphic changes can result in reduced habitat quality and diversity, loss of interstitial space due to embeddedness, loss of pool depth due to sedimentation, and loss of instream cover (Aadland et al., 2005). Biotic population changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (USEPA, 2012b).

The MPCA Stream Habitat Assessment (MSHA) was used to evaluate the quality of habitat present at each of the biological monitoring stations in the SRW. The MSHA is comprised of five scoring subcategories, including land use, riparian zone, instream zone substrate, instream zone cover, and channel morphology, which are summed for a total possible score of 100 points.

The USEPA's CADDIS webpage contains a conceptual diagram of the sources and pathways for physical habitat as a candidate cause for impairment.

Applicable standards

There are no applicable standards for physical habitat.

3.2.4 High suspended sediment

Background

Total suspended solids (TSS) is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water. Klimetz and Simon (2008) indicated that streams in the Red River of the North Basin had the highest median suspended sediment concentration of any region in Minnesota, with the exception of the Western Corn Belt Plains ecoregion (e.g., the Minnesota River Basin). Soil erosion from agricultural fields and streambanks are the primary sources of sediment in the basin (EOR, 2009). The majority of the annual suspended sediment load associated with the streams in the basin is discharged between the months of March and May (EOR, 2009).

According to Waters (1995), high suspended sediment can cause harm to fish and macroinvertebrates through two major pathways: 1) direct, physical effects (e.g., abrasion of gills and avoidance behavior) and 2) indirect effects (e.g., loss of visibility and increase in sediment oxygen demand). High suspended sediment can also reduce the penetration of sunlight and thus limit primary production (Munavar et al., 1991; Murphy et al., 1981).

The USEPA's CADDIS webpage contains a conceptual diagram of the sources and pathways sediment as a candidate cause for impairment.

Applicable standards

The state TSS standard for waters in the Central River TSS Region is 30 mg/L. The state TSS standard for waters in the Southern River TSS Region is 65 mg/L. With the exception of AUIDs 529 and 546, which are located in the Central River TSS Region, all of the biologically impaired reaches in the SRW are situated in the Southern River TSS Region.

3.2.5 Low dissolved oxygen

Background

Dissolved oxygen (DO) refers to the concentration of oxygen gas within the water column. Oxygen diffuses into water from the atmosphere (turbulent flow enhances this diffusion) and from aquatic plants during photosynthesis. The concentration of DO changes seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column. Low or highly fluctuating DO concentrations can cause adverse effects (e.g., avoidance behavior, reduced growth rate, and fatality) for many fish and macroinvertebrate species (Allan, 1995; Davis, 1975; Marcy, 2007; Nebeker et al., 1992; USEPA, 2012b). Many species of fish avoid areas where DO concentrations are below 5.0 mg/L (Raleigh et al., 1986). According to Heiskary et al. (2010), DO flux of between 2.0 to 4.0 mg/L is typical in a 24-hour period.

Low DO can be an issue in streams with slow currents, excessive temperatures, high biological oxygen demand, and/or high groundwater seepage (Hansen, 1975). The critical conditions for DO usually occur during the late summer, when the water temperature is high and stream flow is low. The critical daily period for DO is early morning (i.e., prior to 9:00 a.m.), as respiration continues during the evening, but photosynthesis does not. Additionally, eutrophication (due to increased phosphorus) can cause excessive aquatic plant and algal growth, which can ultimately result in a decline in daily minimum DO concentrations and an increase in the magnitude of daily DO concentration fluctuations.

The USEPA's CADDIS webpage contains a conceptual diagram of the sources and pathways for DO as a candidate cause for impairment.

Applicable standards

The state DO standard for Class 2B waters is 5.0 mg/L as a daily minimum; this includes all of the biologically impaired reaches in the SRW.

3.3 Causal analysis – Profile of individual biologically impaired reaches

3.3.1 Snake River (AUID 543)

Physical setting

AUID 543 represents the segment of the Snake River from its confluence with an unnamed creek, to its confluence with the South Branch of the Snake River (Figure 5); a total length of 29 miles. The reach has a subwatershed area of 132 square miles (84,200 acres). The subwatershed contains 86 miles of intermittent drainage ditch, 80 miles of intermittent stream, 32 miles of river (which includes AUID 543), one mile of perennial drainage ditch, and one mile of perennial stream (MDNR, 2003). According to the MPCA (2013), 47% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 5% of AUID 543. The NLCD 2011 (USGS, 2011) lists cultivated crops (75%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (8%), forest (7%), hay/pasture (5%), and developed (4%).

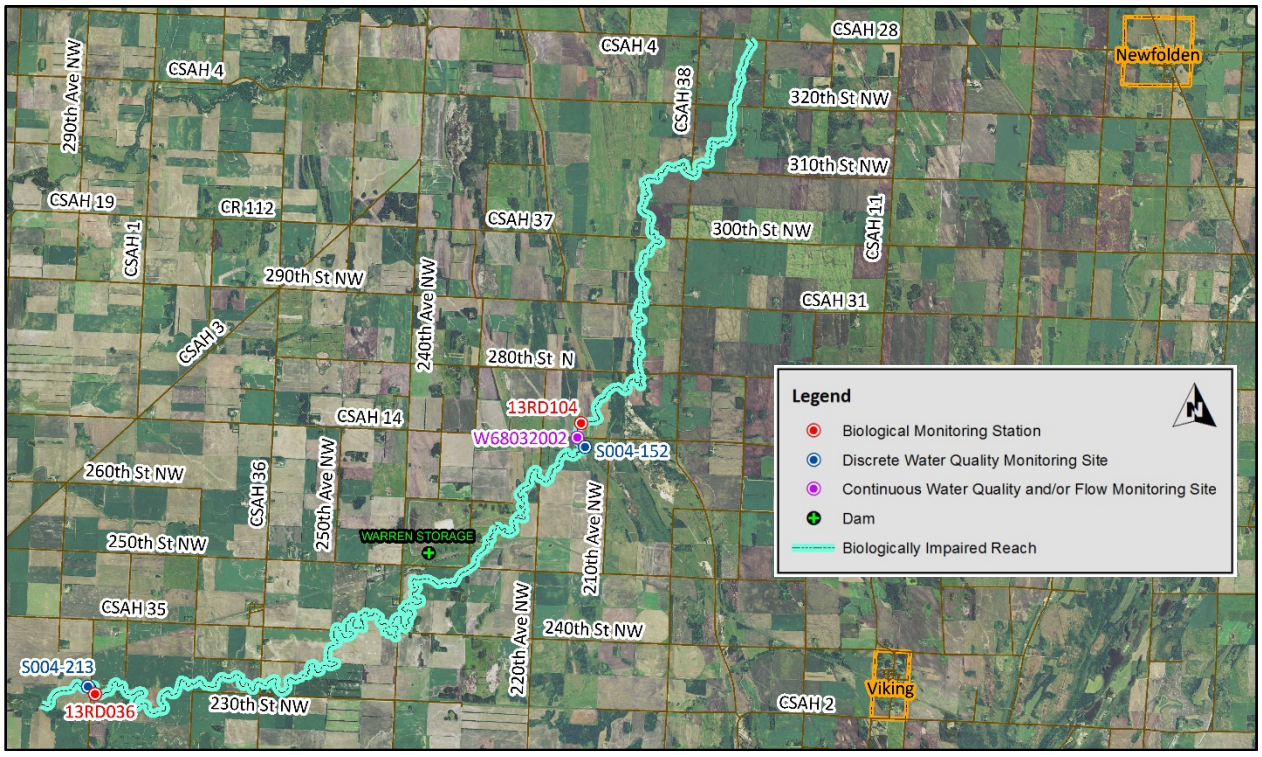


Figure 5. Map of AUID 543 and associated biological monitoring stations and water quality monitoring sites (2013 National Agriculture Imagery Program (NAIP) aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 543 was monitored at Station 13RD036 (0.1 mile upstream of the 285th Avenue NW crossing) on August 5, 2013(1) and June 9, 2014(2); and Station 13RD104 (0.1 mile upstream of the County State Aid Highway (CSAH) 14 crossing) on June 11, 2013(1) and June 10, 2014(2). The location of each station is shown in Figure 5. The stations were designated as General Use within the Northern Streams FIBI Class. Accordingly, the impairment threshold for the stations is an FIBI score of 47. Stations 13RD036 (FIBI=29 and 27) and 13RD104 (FIBI=24 and 25) each had scores that were below the impairment threshold. Overall, the fish assemblage of the stations was largely dominated by tolerant taxa, specifically brook stickleback, fathead minnow, and white sucker.

Macroinvertebrate (MIBI)

The macroinvertebrate community of AUID 543 was monitored at Station 13RD036 on August 1, 2013; and Station 13RD104 on August 6, 2013. Both stations were designated as General Use within the Southern Streams-Riffle/Run Habitats MIBI Class. Accordingly, the impairment threshold for the stations is an MIBI score of 37. Station 13RD036 (MIBI=42) scored above the impairment threshold, while Station 13RD104 (MIBI=14) scored substantially below the threshold. The macroinvertebrate assemblage of the stations was dominated by tolerant taxa, specifically, *Physa* (snails) and *Tanytarsus* (midges).

Candidate causes

Loss of longitudinal connectivity

Available data

According to J. Vinje, MDNR (personal communication, 2017), a local landowner reported that there were beaver dams near the 240th Avenue NW crossing in 2014. The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 13RD036 and 13RD104

along AUID 543. According to the MDNR (2014), there are no man-made dams on the reach. However, the Warren Storage Dam is located adjacent to the channel and is part of the Off Channel Storage Site (OCSS) that is owned and operated by the MSTRWD. The OCSS, which became operational in 2004, was constructed to mitigate the downstream effects of the Warren Diversion on the Snake River (MSTRWD, 2016). The OCSS functions by diverting water from the Snake River via a side inlet into an approximately 550-acre impoundment that is controlled by the Warren Storage Dam (Figure 6). According to D. Omdahl, MSTRWD (personal communication, 2017), water is only diverted into the OCSS during periods of high flow; therefore, it should not impede longitudinal connectivity. The Warren Diversion, which will be further discussed in Subsection 3.3.2 (AUID 504), is located downstream of this reach and includes a dam. The Warren Diversion Dam was completed in 2003 and is also owned and operated by the MSTRWD. The dam includes a fish passage structure that is designed to maintain connectivity at a wide range of flow conditions (MSTRWD, 2016). On September 21, 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 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 29, 2016, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo. In summary, beaver dams, the OCSS, and the Warren Storage Dam are the only known potential obstructions to connectivity that may have been affecting the reach at the time of biological monitoring.

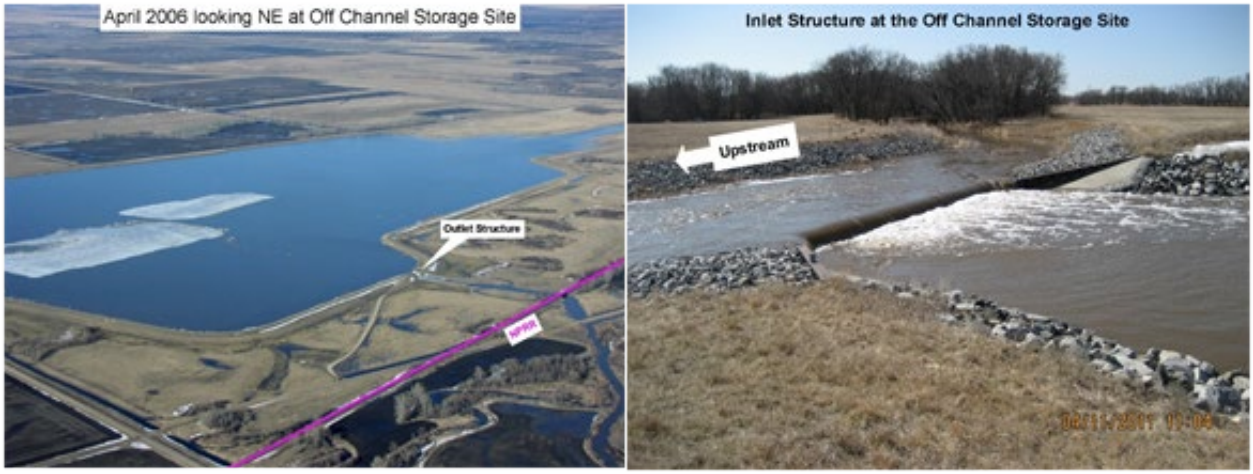


Figure 6. Images of the Off Channel Floodwater Storage Area, including the impoundment in April 2006 (left), courtesy of the MSTRWD; and the inlet structure on April 11, 2011 (right), courtesy of the MSTRWD.

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 543:

- Below average (<24%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Stations 13RD036(1) (0%), 13RD036(2) (13%), 13RD104(1) (0%), and 13RD104(2) (0%)
- Below average (<18%) relative abundance of taxa that are migratory (MgrTxPct) at Stations 13RD036(1) (10%), 13RD036(2) (13%), 13RD104(1) (17%), and 13RD104(2) (13%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Table 6 shows the collective fish assemblage for the reach. A total of 13 species were sampled between Stations 13RD036 and 13RD104. Of these species, eight were present at both stations. The fish community of Station 13RD036, which is located downstream of the OCSS, included one channel catfish. According to Aadland (2015), channel

catfish are considered "vulnerable" to extirpation by connectivity barriers. However, given the fact that the fish assemblage of Station 13RD104, which is located upstream of the OCSS, was largely the same as Station 13RD036, there is no evidence that the OCSS is interfering with longitudinal connectivity and so it's unlikely to be responsible for the abovementioned metric responses. Also, there is no compelling evidence to suggest that the Warren Storage Dam (refer to Subsection 3.3.2) is limiting connectivity. Additionally, there is insufficient information to determine if beaver dams and the culverts associated with road crossings (i.e., creating a velocity barrier during high flow conditions) are impeding fish passage.

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the MIBI impairment associated with AUID 543. Aquatic macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Table 6. Summary of fish species sampled downstream and upstream of the OCSS along the Snake River (AUID 543).

Fish Species[1]	Present Downstream of the Off Channel Storage Site[2]	Present Upstream of the Off Channel Storage Site[3]
brassy minnow	X	
brook stickleback	X	X
central mudminnow	X	X
channel catfish	**X**	
common carp	X	
common shiner	X	X
creek chub	X	X
fathead minnow	X	X
johnny darter	X	
northern pike		X
northern redbelly dace	X	X
pearl dace	X	X
white sucker	X	X

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

[2] Station 13RD036 along AUID 543

[3] Station 13RD104 along AUID 543

Flow regime instability

Available data

The Snake River has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge (MSTRWD, 2011). Local water resource managers indicated that AUID 543 is prone to periods of intermittency (MPCA, 2015). Groshens (2007) attributed the river's flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. According to the MPCA (2013), 47% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 5% of AUID 543. The MPCA biological monitoring staff did not encounter any flow-related issues at Stations 13RD036 and 13RD104 along

AUID 543. 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 3.0 (Q25) to 0.1 (Q75) cubic feet per second (cfs). Additionally, the estimated median flow (Q50) was 0.4 cfs, while the projected Q5 flow was 71.9 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 40:1, 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 three separate dates (i.e., July 1, 2015, July 15, 2015, and September 21, 2016) and documented flow conditions. Stagnant conditions were noted along the upstream extent of the reach (i.e., starting at the CSAH 37 crossing) on September 21, 2016. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

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 543:

- Above average (>52%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 13RD036(1) (85%), 13RD036(2) (75%), 13RD104(1) (65%), and 13RD104(2) (74%)
- Above average (>34%) relative abundance of individuals that are generalists (GeneralPct) at Stations 13RD036(1) (62%), 13RD036(2) (59%), 13RD104(1) (69%), and 13RD104(2) (69%)
- Above average (>58%) relative abundance of taxa with a female mature age equal to or less than two years (MA<2TxPct) at Stations 13RD036(1) (90%), 13RD036(2) (75%), 13RD104(1) (83%), and 13RD104(2) (88%)
- Below average (<0.96) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD036(1) (0.20), 13RD036(2) (0.03), 13RD104(1) (0.01), and 13RD104(2) (0.04)
- Above average (>12%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 13RD036(1) (30%), 13RD036(2) (25%), 13RD104(1) (33%), and 13RD104(2) (25%)
- Above average (>10%) relative abundance of individuals that are short-lived (SLvdPct) at Stations 13RD036(1) (42%), 13RD036(2) (84%), 13RD104(1) (67%), and 13RD104(2) (75%)

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) *strongly supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 543:

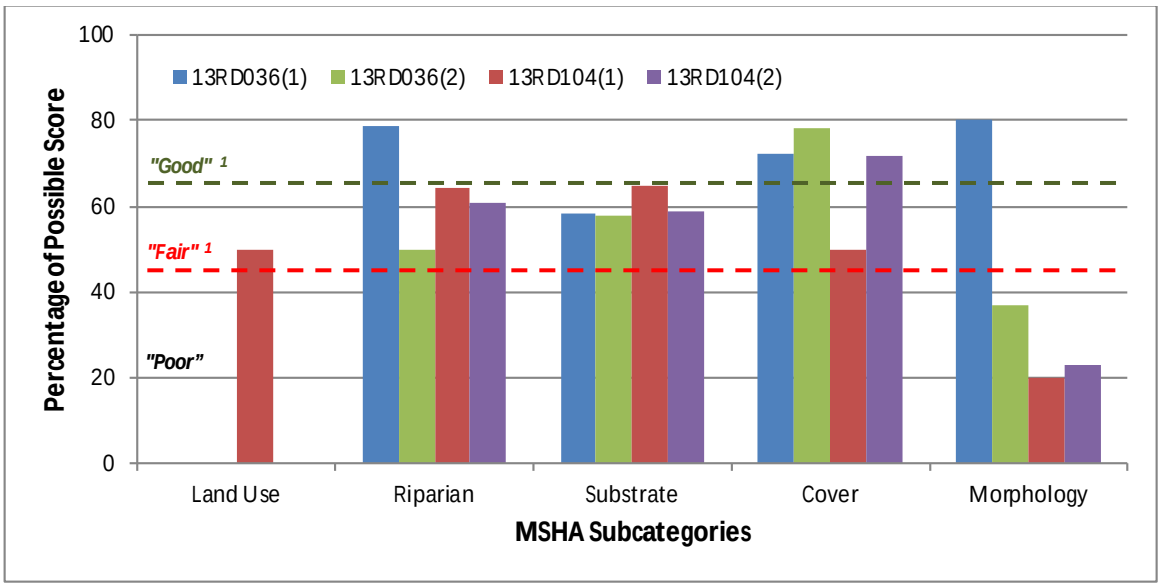
- Below average (<43%) relative abundance of Ephemeroptera, Plecoptera, and Trichoptera individuals (EPTPct) at Stations 13RD036 (9%) and 13RD104 (1%)
- Below average (<9%) relative abundance of long-lived individuals (LongLivedPct) at Stations 13RD036 (2%) and 13RD104 (0%)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD104 (29)
- Above average (>72%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Stations 13RD036 (87%) and 13RD104 (90%)
- Below average (<6%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Stations 13RD036 (1%) and 13RD104 (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; USEPA, 2012b). Additionally, the macroinvertebrate assemblage of the stations had a large composition of taxa that are adapted to lentic environments (e.g., *Dicrotendipes, Gyraulus*, *Hyalella*, and *Physa*).

Insufficient physical habitat

Available data

The physical habitat of AUID 543 was evaluated at Stations 13RD036 and 13RD104 using the MSHA. The stations are located along natural segments of the reach (MPCA, 2013). Station 13RD036 (68/"good" and 50/"fair") yielded slightly higher MSHA scores than Station 13RD104 (46/"fair" and 46/"fair"). Figure 7 displays the MSHA subcategory results for the stations. Both stations scored poorly in the land use subcategory due to the predominance of agricultural row crops immediately surrounding the stations. The riparian subcategory scores were positively influenced by a "moderate" to "wide" zone width, although a "heavy" amount of bank erosion was noted at each of the stations. The stations scored well in the substrate subcategory, offering both riffle habitat and coarse substrate (i.e., boulders, cobble, and gravel). However, the substrate of the stations was degraded by a "moderate" amount of embeddedness. The stations also scored well in the cover subcategory due to the amount of cover present. Cover types noted included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, rootwads, undercut banks, and woody debris. Lastly, the morphology subcategory scores for the stations were adversely affected by "moderate" channel stability and "poor" channel development.



[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 Stations 13RD036 and 13RD104 along AUID 543.

Clark and Vinje (2017) conducted fluvial geomorphology assessments near Stations 13RD036 and 13RD104 along AUID 543 in 2014. The results of these assessments are provided in Appendix C, as well as summarized below:

> *"A Level II survey was done approximately 700 feet upstream of [Station 13RD036], and a reconnaissance visit was also made to the [station] prior to the geomorph survey. The stream type through this reach was a borderline E5/C5 (low to moderate width-to-depth ratio, sand bed stream). The river at this location was slightly incised and slightly entrenched, but it did have access to a*

narrow floodplain (approx. 100') at 2x the maximum bankfull riffle depth. However, if the river becomes much more incised, it will become completely cut off from its floodplain and become an F channel. Because of the incision, there was some mass erosion in the upper banks and cutting in the lower banks, but the most apparent issue through this reach was the sand deposition, primarily in the channel bottom. As a result of the sand deposition, habitat was generally lacking, although there was some scouring occurring in the pools."

"A Pfankuch and Level II survey were completed approximately 1200 feet downstream of [Station 13RD104]. The river at this location was classified as an F4 stream type (high width-to-depth ratio, entrenched, gravel bed stream). The Pfankuch rating for this site was 112, which is fair for an F4 stream type. However, F stream types located in this valley type are considered unstable. The stable channel type in this location would likely be a C. A C4 stream type with a Pfankuch score of 112 would be considered poor (unstable). Most Pfankuch categories rated as fair, reflecting the relatively unstable nature of this reach. There were some bankfull benches present, but for the most part this reach was both incised and entrenched, with virtually no access to a floodplain throughout. Excess stress on the banks due to the incision and entrenchment were leading to some mass erosion issues on the upper banks, as well as cutting on the lower banks. Overall, the stream bed was composed of course substrate, but at the upstream and downstream ends of the reach, the channel bed was much flatter, with almost stagnant water, and at these locations fine particles (silt and sand) were more abundant. Even though this reach was mainly composed of coarse substrate, holding cover was likely an issue as pool depth was lacking."

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by bank erosion, embeddedness, and inadequate channel development. Additionally, Clark and Vinje (2017) noted that excessive sand deposition and inadequate pool depth were adversely affecting the habitat of the reach.

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 543:

- Below average (<27%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Stations 13RD036(1) (10%), 13RD036(2) (0%), 13RD104(1) (0%), and 13RD104(2) (0%)
- Below average (<14%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Stations 13RD036(1) (10%), 13RD036(2) (0%), 13RD104(1) (0%), and 13RD104(2) (0%)
- Above average (>11%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 13RD036(1) (30%), 13RD036(2) (38%), 13RD104(1) (33%), and 13RD104(2) (25%)
- Below average (<15%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 13RD036(1) (0%), 13RD036(2) (2%), 13RD104(1) (0%), and 13RD104(2) (3%)
- Below average (<44%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 13RD036(1) (4%), 13RD036(2) (2%), 13RD104(1) (0%), and 13RD104(2) (3%)
- Below average (<20%) relative abundance of taxa that predominately utilize riffle habitats (RiffleTxPct) at Stations 13RD036(1) (10%), 13RD036(2) (13%), 13RD104(1) (17%), and 13RD104(2) (13%)

- Below average (<35%) relative abundance of taxa that are simple lithophilic spawning species (SLithopTxPct) at Stations 13RD036(1) (20%), 13RD036(2) (13%), 13RD104(1) (17%), and 13RD104(2) (25%)

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 543:

- Above average (>8%) relative abundance of burrower individuals (BurrowerPct) at Stations 13RD036 (13%) and 13RD104 (28%)
- Below average (<48%) relative percentage of clinger individuals (ClingerPct) at Station 13RD104 (5%)
- Above average (>38%) relative abundance of legless individuals (LeglessPct) at Stations 13RD036 (65%) and 13RD104 (92%)
- Above average (>16%) relative abundance of sprawler individuals (SprawlerPct) at Station 13RD036 (21%)

Clinger taxa require clean, coarse substrate or other objects to attach themselves to, while burrower, legless, and sprawler macroinvertebrates are tolerant of degraded benthic habitat (i.e., excess fine sediment).

High suspended sediment

Available data

According to the MSTRWD (2011), the Snake River is prone to high sediment loads. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 13RD036 and 13RD104 along AUID 543 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. Table 7 summarizes all available discrete TSS data for Sites S004-152 (CR 14 crossing) and S004-213 (285th Avenue NW crossing); the location of each site is shown in Figure 5. Both sites had at least one TSS value that exceeded the 65 mg/L standard, as well as a very high maximum value (231 and 610 mg/L). Site S004-213 had a high proportion of values that exceeded the standard (25%). The SRW HSPF model estimates that the reach had a TSS concentration in excess of the standard approximately 26% 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 13RD036 and 13RD104. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment. Clark and Vinje (2017) documented both in-channel and off-channel sources of sediment to the reach (Figure 8). Channel incision and entrenchment caused by flow regime alteration are resulting in mass erosion along segments of the reach.

Table 7. Discrete TSS data for Sites S004-152 (1998-2010; *n*=37) and S004-213 (1998-2000; *n*=16) along AUID 543.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S004-152	1998-2010	37	1	610	24	1
S004-213	1998-2000	16	1	231	52	4

Figure 8. Images of sediment sources to AUID 543, including bank slumping along an unnamed ditch at the 200th Avenue NW and CSAH 14 intersection on May 28, 2014 (left), courtesy of Clark and Vinje (2017); and bank erosion near Station 13RD104 on May 29, 2014 (right), courtesy of Clark and Vinje (2017).

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for high suspended sediment as a stressor to the fish community of AUID 543:

- Above average (>13 mg/L) mean TSS Tolerance Indicator Value (TIV) at Stations 13RD036(1) (16 mg/L), 13RD036(2) (21 mg/L), 13RD104(1) (20 mg/L), and 13RD104(2) (20 mg/L)
- Below average (<83%) probability of meeting the TSS standard at Stations 13RD036(1) (69%), 13RD036(2) (38%), 13RD104(1) (45%), and 13RD104(2) (42%)

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 543:

- Below average (<26%) relative abundance of collector-filterer individuals (Collector-FiltererPct) at Stations 13RD036 (25%) and 13RD104 (1%)
- Above average (>16 mg/L) mean TSS TIV at Station 13RD104 (19 mg/L)
- Above average (>35%) relative abundance of high TSS tolerant taxa at Station 13RD104 (52%)
- Below average (<5%) relative abundance of high TSS intolerant taxa at Stations 13RD036 (0%) and 13RD104 (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 reach has an existing DO impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a combined six discrete DO measurements at Stations 13RD036 and 13RD104 along AUID 543 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 7.3 to 15.3 mg/L. While none of the values were below the 5.0 mg/L standard, Station 13RD104 had an extremely high DO concentration (15.3 mg/L) and saturation percentage (166%) at the time of the August 6, 2013, macroinvertebrate monitoring visit. Such elevated DO conditions are commonly caused by excessive aquatic plant (i.e., algae and submergent macrophyte) growth. Figure 9 displays all available discrete DO data for Sites S004-152 (1998-2010; *n*=53) and S004-213 (1998-2000; *n*=16). Collectively, 14% of the DO values for the sites were below the standard; however, only two of the measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. During this period, stream flow is usually low and water temperature is high. The MPCA conducted continuous DO monitoring at Site W68032002 (CSAH 14 crossing) from July 1, 2015, to July 5, 2015; the location of the site is shown in Figure 5. The monitoring results are provided in Table 8, as well as displayed in Figure 10. While 9% of the total values were below the standard, 33% of the daily minimum values were below the standard. Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

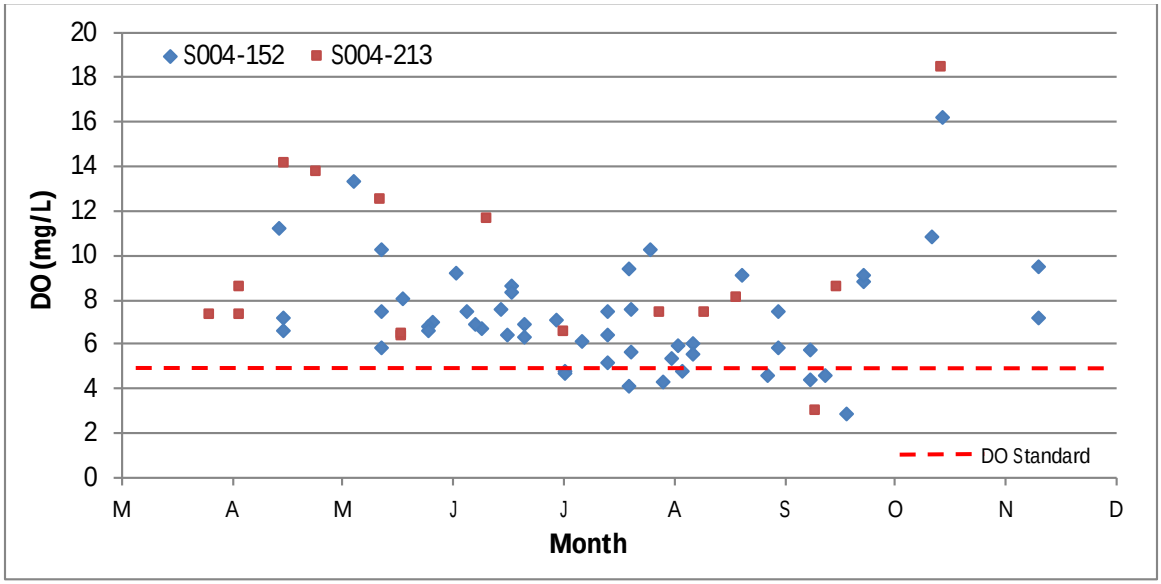


Figure 9. Discrete DO data for Sites S004-152 (1998-2010; *n*=53) and S004-213 (1998-2000; *n*=16) along AUID 543.

Table 8. Continuous DO data for Site W68032002 (2015; *n*=388) along AUID 543.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 1, 2015 - July 5, 2015	388	3.4	9.5	9	33	3.2

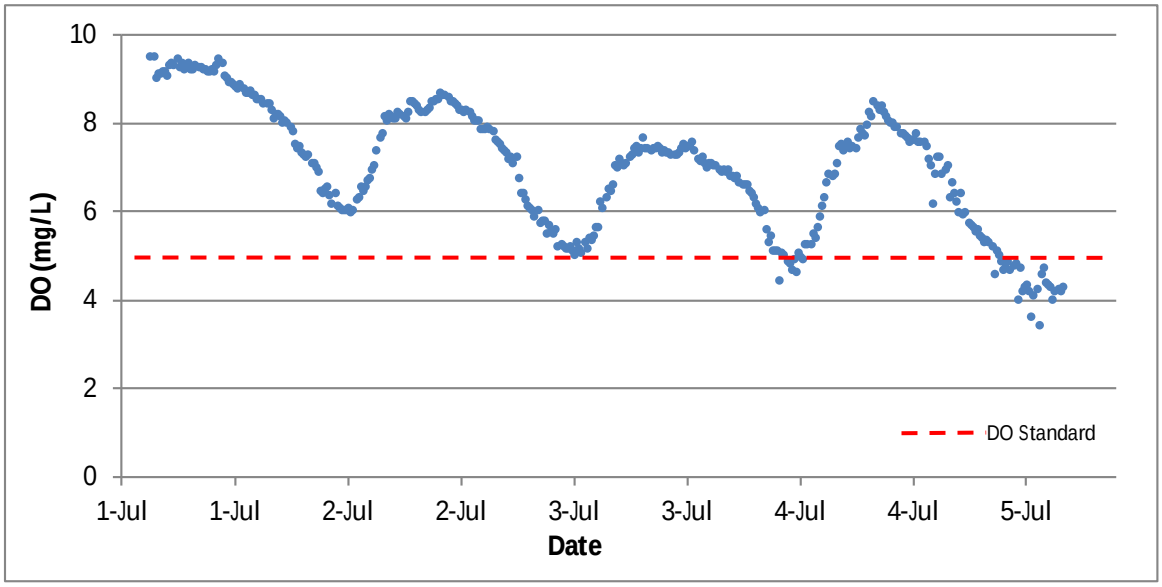


Figure 10. Continuous DO data for Site W68032002 (2015; *n*=388) along AUID 543.

Eutrophication-related data for AUID 543 includes the following parameters: total phosphorus (TP), chlorophyll-a (Chl-a), and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 13RD036 and 13RD104 along AUID 543 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TP. The stations had TP concentrations ranging from 26 to 174 µg/L. Only one of the values exceeded the 150 µg/L South River Nutrient Region TP standard; Station 13RD104 had a concentration of 174 µg/L on June 10, 2014. Discrete TP data are available for Sites S004-152 (1998-2009, *n*=48) and S004-213 (1998-2000, *n*=16). Collectively, the mean TP concentration for the sites was 114 µg/L, while the highest concentration was 700 µg/L and the lowest concentration was 10 µg/L. Approximately 17% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S004-152 (2009; *n*=8). The mean Chl-a concentration for the site was 4 µg/L, while the highest concentration was 9 µg/L and the lowest concentration was 3 µg/L. There were no exceedances of the 35 µg/L South River Nutrient Region Chl-a standard. The mean daily DO flux documented during continuous DO monitoring at Site W68032002 (Table 8) was 3.2 mg/L, which is 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 three separate reconnaissance visits along the reach (i.e., July 1, 2015, July 15, 2015, and September 21, 2016). While the reach is prone to high TP concentrations, the limited response variable (i.e., Chl-a and DO flux) 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) *convincingly supports* the case for low DO as a stressor to the fish community of AUID 543:

- Below average (<7.1 mg/L) mean DO TIV at Stations 13RD036(1) (6.6 mg/L), 13RD036(2) (6.1 mg/L), 13RD104(1) (6.2 mg/L), and 13RD104(2) (6.2 mg/L)
- Below average (<53%) probability of meeting the DO standard at Stations 13RD036(1) (30%), 13RD036(2) (16%), 13RD104(1) (16%), and 13RD104(2) (18%)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *convincingly supports* the case for low DO as a stressor to the macroinvertebrate community of AUID 543:

- Above average (>7) Hilsenhoff's Biotic Index value (HBI_MN) at Stations 13RD036 (8) and 13RD104 (9)
- Below average (<11) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Stations 13RD036 (6) and 13RD104 (2)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD104 (29)
- Below average (<7.1 mg/L) mean DO TIV at Stations 13RD036 (6.4 mg/L) and 13RD104 (6.3 mg/L)
- Above average (>9%) relative abundance of low DO tolerant taxa at Stations 13RD036 (26%) and 13RD104 (44%)
- Below average (<24%) relative abundance of low DO intolerant taxa at Stations 13RD036 (1%) and 13RD104 (0%)

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; USEPA, 2012b).

Summary of stressors

The evidence suggests that the FIBI impairment associated with AUID 543 is attributed to flow regime instability, insufficient physical habitat, high suspended sediment, and low DO. Additionally, the evidence indicates that the MIBI impairment is likely the result of flow regime instability, insufficient physical habitat, low DO, and, to a lesser extent, high suspended sediment. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.2 Snake River (AUID 504)

Physical setting

AUID 504 represents the segment of the Snake River from its confluence with the South Branch of the Snake River, to its confluence with County Ditch (CD) 7 (Figure 11); a total length of 23 miles. The reach has a subwatershed area of 215 square miles (137,864 acres). The subwatershed contains 127 miles of intermittent stream, 113 miles of intermittent drainage ditch, 61 miles of river (which includes AUID 504), one mile of perennial drainage ditch, and one mile of perennial stream (MDNR, 2003). According to the MPCA (2013), 44% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 15% of AUID 504. The NLCD 2011 (USGS, 2011) lists cultivated crops (81%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (6%), forest (5%), developed (5%), and hay/pasture (3%).

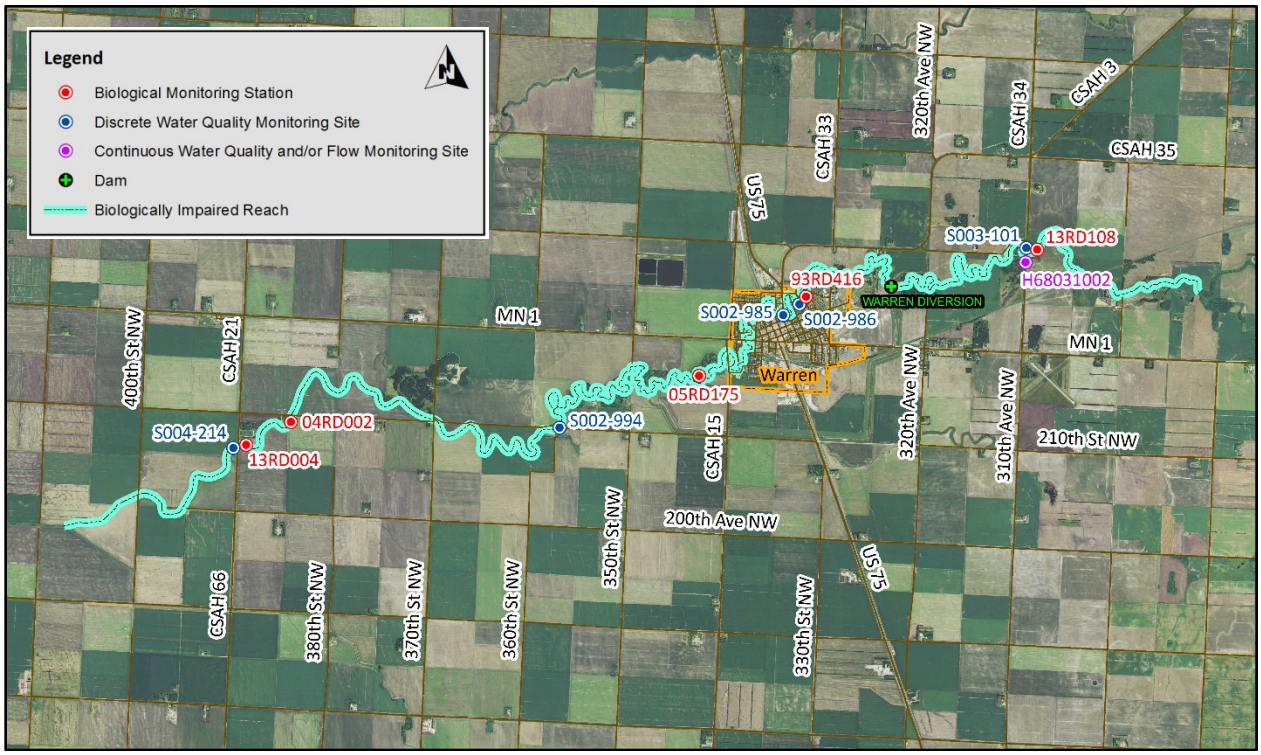


Figure 11. Map of AUID 504 and associated biological monitoring stations and flow/water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 504 was monitored at Station 05RD175 (0.7 mile downstream of the CSAH 15 crossing) on July 24, 2006; Station 13RD004 (0.1 mile upstream of the CSAH 21 crossing) on June 25, 2013; Station 13RD108 (0.1 mile upstream of the CSAH 34 crossing) on June 24, 2013; and Station 93RD416 (0.6 mile upstream of the US Highway 75 crossing) on June 27, 2013. The location of each station is shown in Figure 11. The stations were designated as General Use within the Southern Streams FIBI Class. The impairment threshold for these stations is an FIBI score of 50. Stations 05RD175 (FIBI=48), 13RD004 (FIBI=1), 13RD108 (FIBI=33), and 93RD416 (FIBI=28) each scored below the impairment threshold. Overall, the fish assemblage of the stations was largely dominated by tolerant taxa, specifically creek chub, fathead minnow, and white sucker.

Macroinvertebrate (MIBI)

The macroinvertebrate community of AUID 504 was monitored at Station 04RD002 (0.1 mile downstream of the 210th Street NW crossing) on September 12, 2004; Station 05RD175 on August 15, 2006; Station 13RD004 on August 7, 2013; Station 13RD108 on August 7, 2013; and Station 93RD416 on August 6, 2013. Station 13RD108 was designated as General Use within the Southern Streams-Riffle/Run Habitats MIBI Class. The impairment threshold for the station is an MIBI score of 37. Stations 04RD002, 05RD175, 13RD004, and 93RD416 were designated as General Use within the Prairie Streams-Glide/Pool Habitats MIBI Class. Accordingly, the impairment threshold for this station is an MIBI score of 41. Stations 04RD002 (MIBI=30), 05RD175 (MIBI=17), 13RD108 (MIBI=21), and 93RD416 (MIBI=38) each scored below their respective impairment threshold, while Station 13RD004 (MIBI=59) scored above its threshold. The macroinvertebrate assemblage of the stations was dominated by tolerant taxa, specifically, *Caenis* (mayflies), Oligochaeta (worms), *Physa* (snails), *Polypedilum* (midges), and *Simulium* (black flies).

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 04RD002, 05RD175, 13RD108, and 93RD416 along AUID 504. According to the MSTRWD (2016), the Warren Diversion (Figure 12) is located along the upstream end of the reach, immediately east of the City of Warren. The diversion, which is owned and operated by the MSTRWD, consists of a dam and an associated diversion channel that is used during high flow events to prevent flooding within the city. The Warren Diversion Dam (Figure 12) was completed in 2003 and includes a fish passage structure that is designed to maintain connectivity at most flow conditions. However, according to D. Omdahl, MSTRWD (personal communication, 2017), during low flow conditions, the water level of the Snake River can drop below the fish passage structure, thereby inhibiting connectivity. On September 21, 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 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 29, 2016, aerial photo (courtesy of Google Earth) of the reach. Two private road crossings were identified; one near 290th Avenue NW and the other near 300th Avenue NW. According to D. Omdahl, MSTRWD (personal communication, 2017), the crossings were permitted and installed as part of the Agassiz Valley Water Resource Management Impoundment project. Based upon the aerial photo, the crossing do not appear to be limiting connectivity. In addition, staff noted the remnants (i.e., large pieces of concrete) of another private road crossing located downstream of the CSAH 15 crossing. The concrete debris in the channel appears to alter stream flow, as well as potentially impede connectivity during periods of low flow. In summary, the Warren Storage Dam and the remnants of the private road crossing are the only known potential obstructions to connectivity that may have been affecting the reach at the time of biological monitoring.

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 504:

- Below average (<21%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Stations 05RD175 (10%), 13RD004 (0%), 13RD108 (0%), and 93RD416 (11%)
- Below average (<24%) relative abundance of taxa that are migratory (MgrTxPct) at Stations 13RD004 (20%), 13RD108 (17%), and 93RD416 (11%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Table 9 shows the collective fish assemblage for AUID 504, as well as AUIDs 543, 544, and 546, which are all located upstream of the Warren Diversion Dam. A total of 20 species were sampled between the reaches, of which 10 were present at stations above and below the dam. The fish community of Station 13RD036, which is located upstream of the dam, included one channel catfish. According to Aadland (2015), channel catfish are considered "vulnerable" to extirpation by connectivity barriers. The presence of this species is likely an indication that fish are able to migrate upstream of the dam. Based upon fish assemblage data, there is no compelling evidence that the Warren Diversion Dam is interfering with longitudinal connectivity and so it is unlikely to be responsible for the abovementioned metric responses. Additionally, there is insufficient information to determine if the remnants of the private road crossing and the culverts associated with road crossings (i.e., creating a velocity barrier during high flow conditions) are impeding fish passage.

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the MIBI impairment associated with AUID 504. Aquatic macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Figure 12. Images of the Warren Diversion Dam and associated diversion channel on an unspecified date (left), courtesy of the MSTRWD; and the upstream side of the Warren Diversion Dam on an unspecified date (right), courtesy of the MSTRWD.

Table 9. Summary of fish species sampled downstream and upstream of the Warren Diversion Dam along the Snake River (AUID 504).

Fish Species[1]	Present Downstream of the Warren Diversion Dam[2]	Present Upstream of the Warren Diversion Dam[3]
black bullhead		X
blacknose dace	X	X
brassy minnow		X
brook stickleback	X	X
central mudminnow	X	X
channel catfish		X
common carp	X	X
common shiner	X	X
creek chub	X	X
fathead minnow	X	X
hornyhead chub		X
johnny darter	X	X
northern pike	X	X
northern redbelly		X
pearl dace		X
rock bass	X	
shorthead redhorse	X	
spotfin shiner	X	
tadpole madtom	X	
white sucker	X	X

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

[2] Stations 93RD416, 05RD175, and 13RD004 along AUID 504

[3] Station 13RD108 along AUID 504; Stations 13RD036 and 13RD104 along AUID 543; Station 13RD035 along AUID 544; and Stations 13RD034, 13RD099, 13RD105, and 13RD106 along AUID 546

Flow regime instability

Available data

The Snake River has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge (MSTRWD, 2011). Groshens (2007) attributed the river's flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching) that have altered the natural hydrology of the watershed. According to the MPCA (2013), 44% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 15% of AUID 504. The MPCA biological monitoring staff did not encounter any flow-related issues at Stations 04RD002, 05RD175, 13RD004, 13RD108, and 93RD416 along AUID 504. The MPCA and USGS have cooperatively conducted continuous flow monitoring at Site E68031002 (CSAH 34 crossing) since 2008; the location of the site is shown in Figure 11. Table 10 presents the percentile flow values for the site. The highest mean daily peak flow recorded at the site was 1740.0 cfs, while the lowest flow was 0.0 cfs. Approximately 38% of the total mean daily flow values were less than 1.0 cfs. Figure 13 provides the 2013 and 2014 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 5.5 (Q25) to 0.1 (Q75) cfs. Additionally, the estimated median flow (Q50) was 0.8 cfs, while the projected Q5 flow was 120.0 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 39:1, 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 three separate dates (i.e., July 1, 2015, July 15, 2015, and September 21, 2016) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

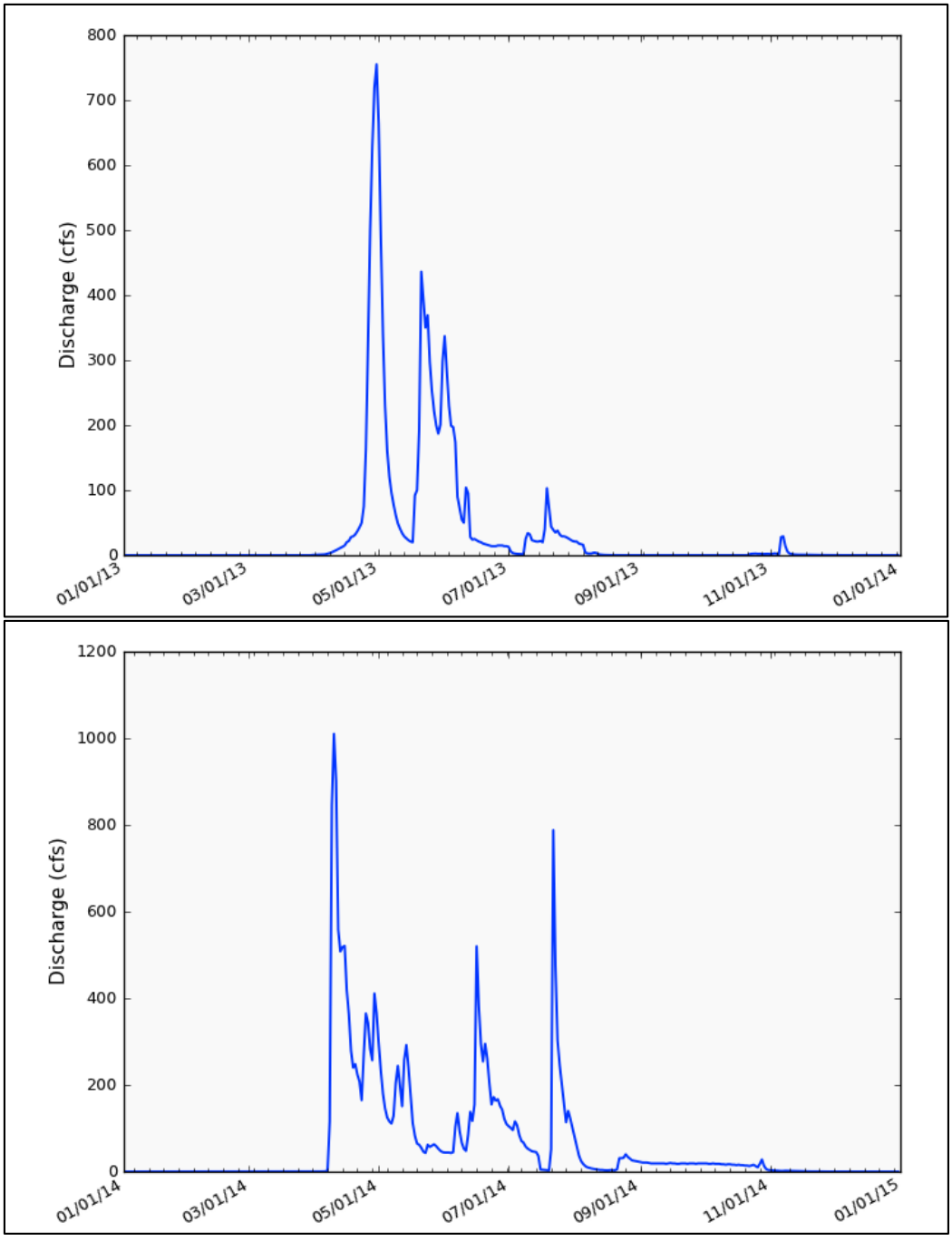


Figure 13. Annual (2013 and 2014) hydrographs for Site E68031002 along AUID 504.

Table 10. Percentile flow values for Site E68031002 (2008-2016; *n*=2659) along AUID 504.

Date range	*n*	Percentile values – Mean daily discharge (cfs)						
		5th	10th	20th	40th	60th	80th	100th
2008-2016	2659	0.0	0.0	0.1	1.3	7.8	55.4	1740.0

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 504:

- Above average (>49%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 05RD175 (56%), 13RD004 (90%), 13RD108 (90%), and 93RD416 (96%)
- Above average (>43%) relative abundance of individuals that are generalists (GeneralPct) at Stations 05RD175 (84%), 13RD004 (100%), 13RD108 (91%), and 93RD416 (97%)
- Above average (>63%) relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct) at Stations 05RD175 (83%), 13RD004 (91%), 13RD108 (66%), and 93RD416 (66%)
- Below average (<1.00) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 05RD175 (0.33), 13RD004 (0.01), 13RD108 (0.01), and 93RD416 (0.01)
- Above average (>20%) relative abundance of individuals that are pioneers (PioneerPct) at Stations 05RD175 (63%), 13RD004 (90%), 13RD108 (57%), and 93RD416 (63%)
- Above average (>16%) relative abundance of individuals that are short-lived (SLvdPct) at Stations 05RD175 (39%), 13RD004 (49%), 13RD108 (65%), and 93RD416 (64%)

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) *strongly supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 504:

- Below average (<43/37%) relative abundance of Ephemeroptera, Plecoptera, and Trichoptera individuals (EPTPct) at Stations 04RD002 (15%), 13RD004 (25%), 13RD108 (5%), and 93RD416 (4%)
- Below average (<9/8%) relative abundance of long-lived individuals (LongLivedPct) at Stations 04RD002 (1%), 05RD175 (3%), 13RD004 (0%), 13RD108 (0%), and 93RD416 (0%)
- Below average (<43/38) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 05RD175 (34), 13RD004 (34), 13RD108 (33), and 93RD416 (31)
- Above average (>72/81%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Stations 04RD002 (93%), 05RD175 (94%), 13RD108 (88%), and 93RD416 (90%)
- Below average (<6/5%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Stations 04RD002 (0%), 05RD175 (0%), 13RD108 (1%), and 93RD416 (2%)

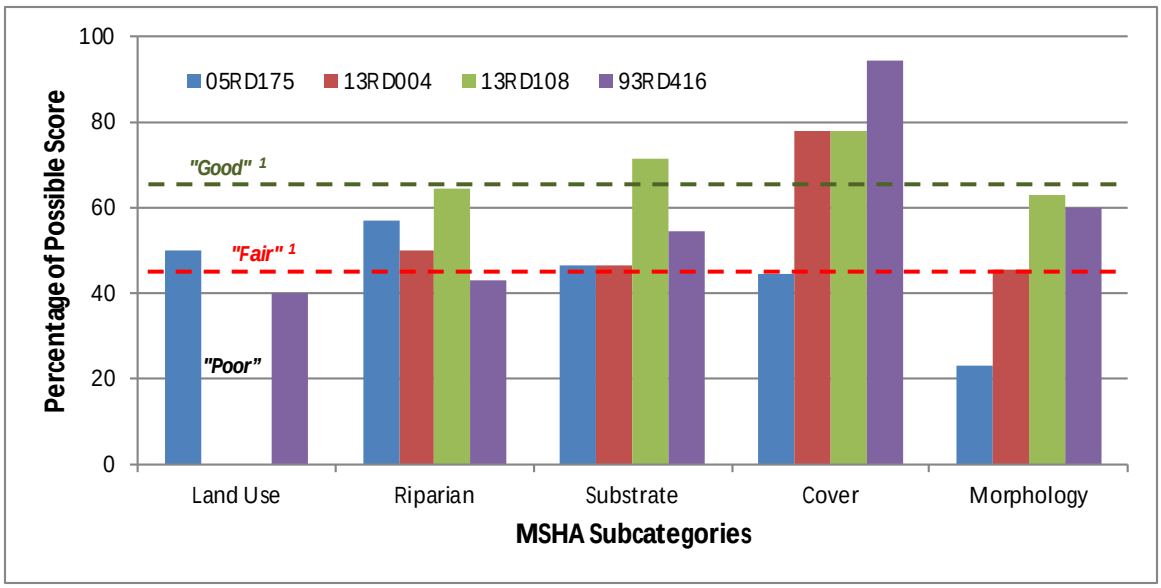
Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of Ephemeroptera, Plecoptera, and Trichoptera, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; USEPA, 2012b).

Additionally, the macroinvertebrate assemblage of the stations had a large composition of taxa that are adapted to lentic environments (e.g., *Physa*).

Insufficient physical habitat

Available data

The physical habitat of AUID 504 was evaluated at Stations 05RD175, 13RD004, 13RD108, and 93RD416 using the MSHA. With the exception of Station 13RD004, all of the stations are located along natural segments of the reach (MPCA, 2013). Stations 13RD108 (MSHA=65/"fair") and 93RD416 (MSHA=61/"fair"), which are located along the upstream extent of the reach, scored markedly higher than Stations 05RD175 (MSHA=39/"poor") and 13RD004 (MSHA=50/"fair"), which are found further downstream. Figure 14 displays the MSHA subcategory results for the stations. Stations 13RD004 and 13RD108 had a score of zero in the land use subcategory due to the predominance of agricultural row crops immediately surrounding the stations. Station 93RD416 scored lower in the riparian subcategory than the other stations due to a "very narrow" zone width. Substantial bank erosion was noted at each of the stations. Station 13RD108 yielded the highest substrate subcategory score along the reach, offering riffle habitat and coarse substrate (i.e., cobble and gravel) with only "light" embeddedness. The other stations had no riffle habitat and only limited coarse substrate with a "moderate" to "severe" amount of embeddedness. Stations 13RD004, 13RD108, and 93RD416 scored exceptionally well in the cover subcategory due to the diversity and "moderate" to "extensive" amount of cover present. Conversely, Station 05RD175 scored substantially lower, offering only a "sparse" amount of cover. Common cover types noted along the reach included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, rootwads, undercut banks, and woody debris. Lastly, the morphology subcategory scores for the Stations 05RD175 and 13RD004 were adversely affected by "low" channel stability and "poor" to "fair" channel development.



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

Figure 14. MSHA subcategory results for Stations 05RD175, 13RD004, 13RD108, and 93RD416 along AUID 504.

Clark and Vinje (2017) conducted fluvial geomorphology assessments near Stations 13RD004 and 13RD108 along AUID 504 between 2014 and 2015. The results of these assessments are provided in Appendix C, as well as summarized below:

"A Rosgen Level II survey and a Pfankuch stability assessment were conducted just downstream of the County Road 21 (390th Ave NW) crossing, which is approximately 500 feet downstream of [Station 13RD004]. The river through this reach was classified as an E6 stream type (low width-to-depth ratio, clay/silt bed stream). The Pfankuch rating for this site was 87, which is poor (unstable) for an E6 stream type. Based on the survey data, the riffle cross-sections had bankfull benches, so the stream was not incised, and it was only slightly entrenched – at 2x the maximum bankfull depth at the riffles, the river had access to a narrow (approx. 100' wide) floodplain. There was evidence of mass erosion and slumping in the upper banks, but some of it had healed over. Bank slumping and cutting in the lower banks was also observed through this reach. Even though the debris jam potential was low throughout the reach overall, there was a large debris jam at the lower end of the reach that could be a barrier to fish passage if it is not mobilized/cleared with higher flows. The debris jam was also causing excessive deposition of fine sediment on the upstream side. There was sufficient flow at the time of the survey, but the maximum pool depth observed during the survey was approximately 3 feet, and lateral scour pools were lacking throughout the reach. On the day of the survey (September 17, 2014), the suspended sediment load in the water appeared to be very high. Pebble counts were not completed at this site due to the high percentage of silt/clay, however, notes from the riffle cross indicate that the substrate (on the active bed) was mostly clay with some gravel mixed in)."

"A Rosgen Level II survey and a Pfankuch stability assessment were conducted at [Station 13RD108]. The river at this location was classified as a borderline E4/C4 stream type (low to moderate width-to-depth ratio, gravel bed stream), with the upper portion of the survey reach being an E and the lower portion being a C, but the entire reach was close to being an entrenched F. Throughout the reach, the river is mostly incised, but there are a few places where bankfull benches were present. And at 2x the maximum bankfull depth it had access to a floodplain; however, it was close to being cut-off from its floodplain. There was some mass erosion in the upper banks, but it was infrequent and mostly healed over. Most noticeable was the amount of cutting on the lower banks, which was indicative of the incision that was observed. The bottom was predominantly small gravel with areas of sand and silt and there was an overall general lack of pool depth/holding cover, except for in the upper end of the reach where the river was narrower and deeper (E channel). When seeking permission to access this site the homeowner (east of CR 34) was working with a contractor to install a new septic system and indicated it was being installed because of what agency staff found the last time they were assessing the river."

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by bank erosion, limited riffle habitat, embeddedness, and inadequate channel development. Additionally, Clark and Vinje (2017) noted that the lack of lateral scour pools and inadequate pool depth were adversely affecting the habitat of the reach.

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 504:

- Below average (<20%) relative abundance of individuals that are benthic insectivores, excluding tolerant species (BenInsect-TolPct) at Stations 05RD175 (13%), 13RD004 (0%), 13RD108 (1%), and 93RD416 (0%)
- Below average (<12%) relative abundance of individuals that are darters and sculpins (DarterSculpPct) at Stations 05RD175 (9%), 13RD004 (0%), 13RD108 (1%), and 93RD416 (0%)
- Above average (>29%) relative abundance of individuals that are detritivorous (DetNWQPct) at Stations 05RD175 (54%), 13RD004 (58%), 13RD108 (90%), and 93RD416 (96%)

- Below average (<17%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 05RD175 (4%), 13RD004 (0%), 13RD108 (0%), and 93RD416 (0%)
- Below average (<35%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 05RD175 (16%), 13RD004 (0%), 13RD108 (1%), and 93RD416 (0%)
- Below average (<25%) relative abundance of taxa that predominately utilize riffle habitats (RiffleTxPct) at Stations 05RD175 (20%), 13RD004 (20%), 13RD108 (17%), and 93RD416 (11%)
- Below average (<37%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Stations 05RD175 (33%), 13RD004 (10%), 13RD108 (34%), and 93RD416 (34%)

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 504:

- Above average (>9%) relative abundance of burrower individuals (BurrowerPct) at Stations 04RD002 (25%), 05RD175 (12%), and 93RD416 (23%)
- Below average (<22%) relative percentage of climber individuals (ClimberPct) at Stations 04RD002 (21%) and 05RD175 (16%)
- Below average (<36%) relative percentage of clinger individuals (ClingerPct) at Stations 04RD002 (26%), 05RD175 (9%), and 93RD416 (10%)
- Above average (>42%) relative abundance of legless individuals (LeglessPct) at Stations 04RD002 (68%) and 93RD416 (91%)
- Above average (>19%) relative abundance of sprawler individuals (SprawlerPct) at Station 05RD175 (61%)

Climber and clinger taxa require clean, coarse substrate or other objects to attach themselves to, while burrower, legless, and sprawler macroinvertebrates are tolerant of degraded benthic habitat (i.e., excess fine sediment).

High suspended sediment

Available data

According to the MSTRWD (2011), the Snake River is prone to high sediment loads. The reach has an existing turbidity impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD175, 13RD108, and 93RD416 along AUID 504 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The stations had TSS concentrations ranging from 8 to 27 mg/L. Table 11 summarizes all available discrete TSS data for Sites S002-986 (North 5th Street crossing), S002-994 (210th Street NW crossing), S003-101 (CSAH 34 crossing), and S004-214 (CSAH 21 crossing); the location of each site is shown in Figure 11. Each of the sites had multiple TSS values that exceeded the 65 mg/L standard, as well as a high maximum value (≥151 mg/L). Sites S002-994 and S004-214, which are located along the downstream extent of the reach, had the highest standard exceedance rates (37 and 31%). The SRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 55 and 82% 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 05RD175, 13RD004, and 93RD416. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment. According to Clark and Vinje (2017), mass erosion caused by incision is a contributing source of excess sediment to the reach. Figure 15 shows images of streambank instability along the reach.

Table 11. Discrete TSS data for Sites S002-986 (2002; *n*=6), S002-994 (2002-2006; *n*=24), S003-101 (2006-2015; *n*=62), and S004-214 (1998-2013; *n*=26) along AUID 504.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S002-986	2002	6	10	172	66	2
S002-994	2002-2006	24	1	312	71	9
S003-101	2006-2015	62	1	336	28	5
S004-214	1998-2013	26	5	151	48	8

Figure 15. Images of sediment sources along AUID 504, including bank slumping near Station 13RD004 on September 17, 2014 (upper left), courtesy of Clark and Vinje (2017); bank cutting at Station 13RD108 on September 17, 2015 (upper right), courtesy of Clark and Vinje (2017); streambank erosion near 400th Avenue NW on April 29, 2016 (lower left), courtesy of Google Earth; and streambank erosion near 230th Street NW on April 29, 2016 (lower right), courtesy of Google Earth.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for high suspended sediment as a stressor to the fish community of AUID 504:

Above average (>18 mg/L) mean TSS TIV at Stations 05RD175 (20 mg/L), 13RD004 (21 mg/L), 13RD108 (21 mg/L), and 93RD416 (22 mg/L)

- Below average (<56%) probability of meeting the TSS standard at Stations 05RD175 (45%), 13RD004 (36%), 13RD108 (36%), and 93RD416 (31%)

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 504:

- Below average (<26/18%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Stations 04RD002 (10%), 05RD175 (3%), and 93RD416 (6%)
- Above average (17 mg/L) mean TSS TIV at Station 93RD416 (19 mg/L)
- Above average (>44%) relative abundance of high TSS tolerant taxa at Station 93RD416 (65%)
- Below average (<5/3%) relative abundance of high TSS intolerant taxa at Stations 04RD002 (1%), 05RD175 (0%), 13RD004 (2%), 13RD108 (0%), and 93RD416 (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 five discrete DO measurements at Stations 05RD175, 13RD108, and 93RD416 along AUID 504 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 6.6 to 11.0 mg/L. Figure 16 displays all available discrete DO data for Sites S002-985 (North 2nd Street crossing; 1999-2001; *n*=9), S002-986 (1999-2015; *n*=58), S002-994 (2002-2015; *n*=54), S003-101 (2003-2015; *n*=118), and S004-214 (1998-2014; *n*=38); the location of each site is shown in Figure 11. Collectively, 6% of the DO values for the sites were below the standard; however, only 23 of the measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of June, July, and August. During this period, stream flow is usually low and water temperature is high. The MPCA conducted continuous DO monitoring at Site H68031002 (CSAH 34 crossing) from July 1, 2015, to July 15, 2015; the location of the site is shown in Figure 11. The monitoring results are provided in Table 12, as well as displayed in Figure 17. None of the DO measurements within the monitoring period were below the standard. A large rain event (≈2-3") interrupted the diurnal pattern on and after July 5, 2015. Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences occasional periods of low DO.

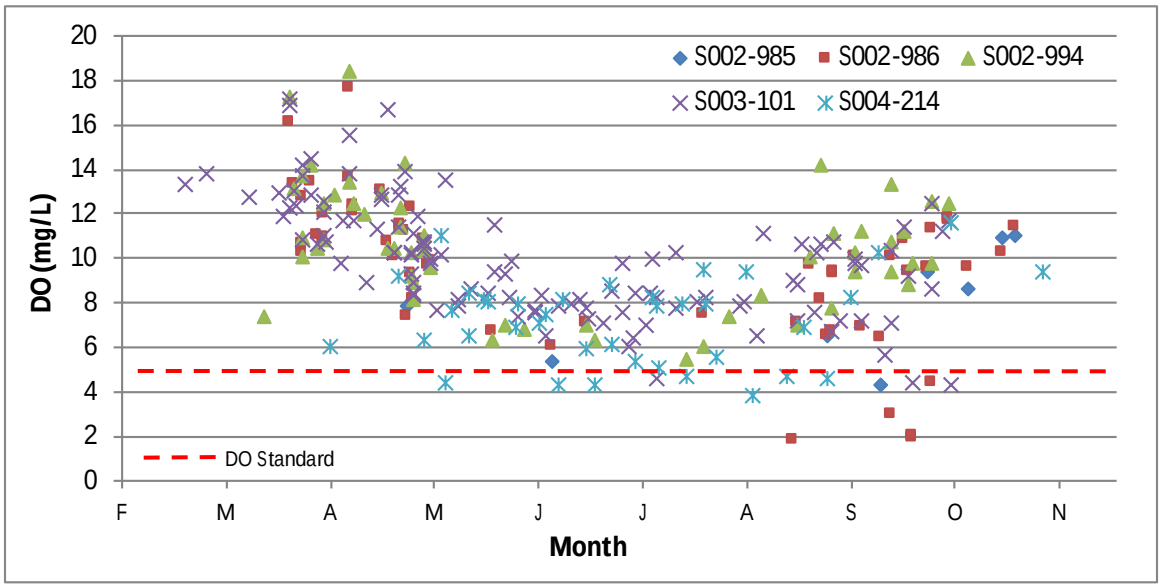


Figure 16. Discrete DO data for Sites S002-985 (1999-2001; *n*=9), S002-986 (1999-2015; *n*=58), S002-994 (2002-2015; *n*=54), S003-101 (2003-2015; *n*=118), and S004-214 (1998-2014; *n*=38) along AUID 504.

Table 12. Continuous DO data for Site H68031002 (2015; *n*=1348) along AUID 504.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 1, 2015 - July 15, 2015	1348	5.9	13.3	0	0	2.1

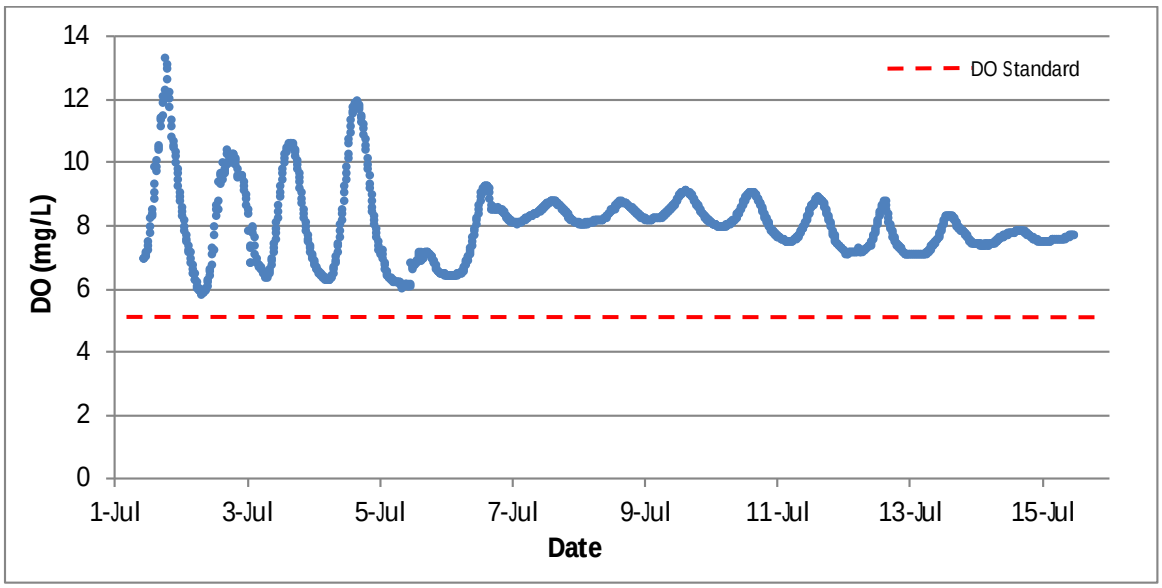


Figure 17. Continuous DO data for Site H68031002 (2015; *n*=1348) along AUID 504.

Eutrophication-related data for AUID 504 includes the following parameters: TP, Chl-a, and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD175, 13RD108, and 93RD416 along AUID 504 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TP. The stations had TP concentrations ranging from 89 to

108 µg/L. Discrete TP data are available for Sites S002-985 (1999-2001; *n*=8), S002-986 (1999-2002; *n*=15), S002-994 (2002-2006; *n*=25), S003-101 (2008-2015; *n*=58), and S004-214 (1998-2013; *n*=26). Collectively, the mean TP concentration for the sites was 162 µg/L, while the highest concentration was 990 µg/L and the lowest concentration was 10 µg/L. Approximately 45% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S003-101 (2009; *n*=8). The mean Chl-a concentration for the site was 15 µg/L, while the highest concentration was 64 µg/L and the lowest concentration was 3 µg/L. There was one exceedance of the 35 µg/L South River Nutrient Region Chl-a standard. The mean daily DO flux documented during continuous DO monitoring at Site W68031002 (Table 12) was 2.1 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 three separate reconnaissance visits along the reach (i.e., July 1, 2015, July 15, 2015, and September 21, 2016). While the reach is prone to high TP concentrations, the limited response variable (i.e., Chl-a and DO flux) 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 504:

- Below average (<7.2 mg/L) mean DO TIV at Stations 05RD175 (6.9 mg/L), 13RD004 (6.7 mg/L), 13RD108 (6.5 mg/L), and 93RD416 (6.5 mg/L)
- Below average (<56%) probability of meeting the DO standard at Stations 05RD175 (41%), 13RD004 (34%), 13RD108 (26%), and 93RD416 (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 504:

- Above average (>8) Hilsenhoff's Biotic Index value (HBI_MN) at Station 05RD175 (9)
- Below average (<11/9) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Stations 04RD002 (7), 05RD175 (3), 13RD004 (7), 13RD108 (5), and 93RD416 (7)
- Below average (<43/38) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 05RD175 (34), 13RD004 (34), 13RD108 (33), and 93RD416 (31)
- Below average (<7.1/6.8 mg/L) mean DO TIV at Stations 04RD002 (5.8 mg/L), 05RD175 (6.2 mg/L), and 93RD416 (6.4 mg/L)
- Above average (>16%) relative abundance of low DO tolerant taxa at Stations 05RD175 (67%) and 93RD416 (23%)
- Below average (<24/9%) relative abundance of low DO intolerant taxa at Stations 04RD002 (4%), 05RD175 (0%), 13RD004 (3%), 13RD108 (3%), and 93RD416 (1%)

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; USEPA, 2012b).

Summary of stressors

The evidence suggests that the FIBI impairment associated with AUID 504 is attributed to flow regime instability, insufficient physical habitat, high suspended sediment, and, to a lesser extent, low DO. Additionally, the evidence indicates that the MIBI impairment is likely the result of flow regime instability, insufficient physical habitat, and, to a lesser extent, high suspended sediment and low DO. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.3 Snake River (AUID 537)

Physical setting

AUID 537 represents the segment of the Snake River from the downstream end of AUID 536, to its confluence with CD 3 (Figure 18); a total length of 15 miles. The reach has a subwatershed area of 328 square miles (209,844 acres). The subwatershed contains 197 mile of intermittent drainage ditch, 173 miles of intermittent stream, 77 miles of river (which includes AUID 537), 14 miles of perennial drainage ditch, and two miles of perennial stream (MDNR, 2003). According to the MPCA (2013), 49% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 3% of AUID 537. The NLCD 2011 (USGS, 2011) lists cultivated crops (85%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included developed (5%), wetlands (4%), forest (3%), and hay/pasture (2%).

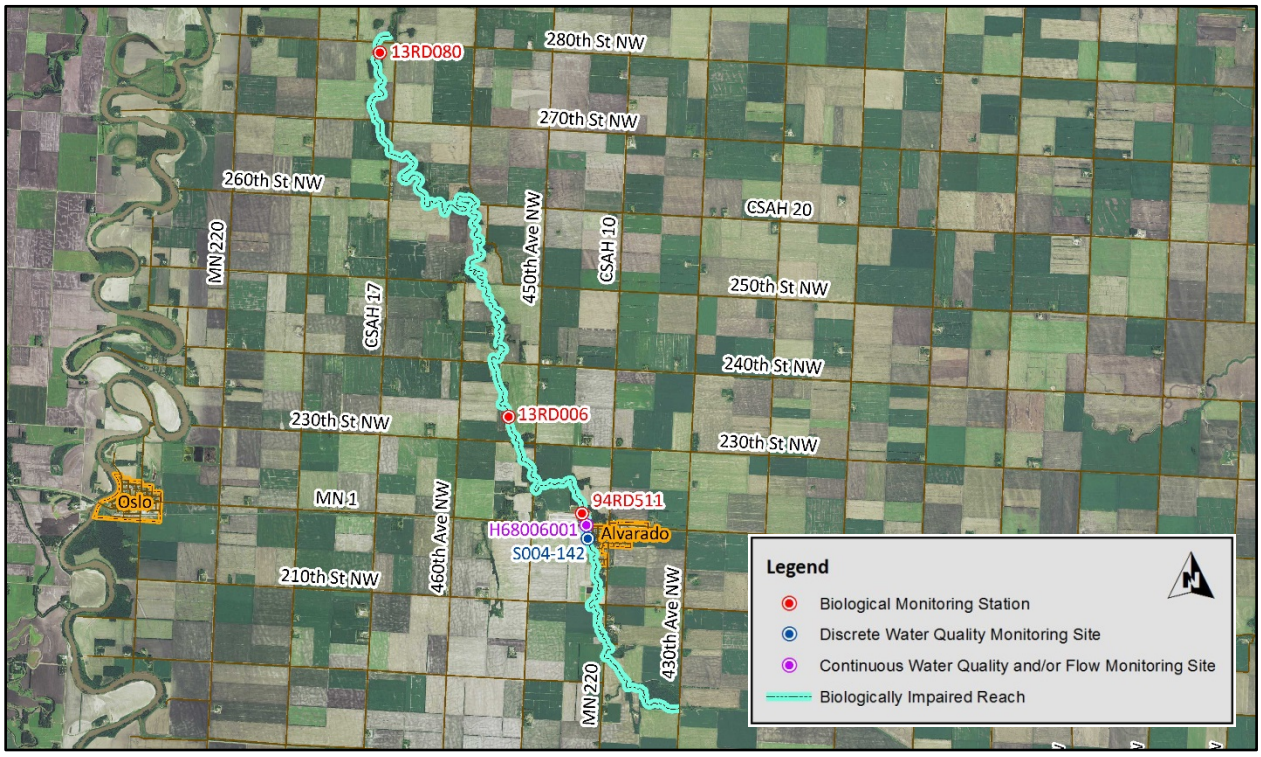


Figure 18. Map of AUID 537 and associated biological monitoring stations and flow monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 537 was monitored at Station 13RD006 (0.4 mile downstream of the 230th Street NW crossing) on June 25, 2013; Station 13RD080 (0.2 mile upstream of the CSAH 17 crossing) on June 25, 2013; and Station 94RD511 (0.2 mile downstream of the State Highway 1 crossing) on September 2, 2014. The location of each station is shown in Figure 18. Station 13RD080 was designated as General Use within the Southern Rivers FIBI Class. The impairment threshold for the station is an FIBI score of 49. Stations 13RD006 and 94RD511 were designated as General Use within the Southern Streams FIBI Class. Accordingly, the impairment threshold for this station is an FIBI score of 50. Stations 13RD006 (FIBI=27), 13RD080 (FIBI=47), and 94RD511 (FIBI=27) each scored below their respective impairment threshold. Overall, the fish assemblage of the stations was dominated by fathead minnow. However, several longer-lived, riverine species (e.g., channel catfish, goldeye, sauger, and walleye) were

sampled at the stations, which is likely the result of the close proximity and unimpeded connectivity to the Red River of the North.

Macroinvertebrate (MIBI)

The macroinvertebrate community of AUID 537 was monitored at Station 13RD006 on August 6, 2013; Station 13RD080 on August 6, 2013; and Station 94RD511 on August 6, 2013. The stations were designated as General Use within the Prairie Streams-Glide/Pool Habitats MIBI Class. Accordingly, the impairment threshold for the stations is an MIBI score of 41. Stations 13RD006 (MIBI=8) and 13RD080 (MIBI=19) each scored below the impairment threshold, while Station 94RD511 (MIBI=57) scored above the threshold. The macroinvertebrate assemblage of the stations was dominated by tolerant taxa, specifically, *Hyalella* (amphipods), Oligochaeta (worms), and *Simulium* (black flies).

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 13RD006, 13RD080, and 94RD511 along AUID 537. According to the MDNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. On September 21, 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 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 29, 2016, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo. In summary, there were no known obstructions to connectivity along the reach at the time of biological monitoring.

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 537:

- Below average (<21%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Station 94RD511 (17%)

Late maturing fish species 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 response. 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 MIBI impairment associated with AUID 537. Aquatic macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

The Snake River has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge (MSTRWD, 2011). Groshens (2007) attributed the river's flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. According to the MPCA (2013), 49% of the watercourses in the subwatershed have been physically altered (i.e.,

channelized, ditched, or impounded), including 3% of AUID 537. The MPCA biological monitoring staff did not encounter any flow-related issues at Stations 13RD006, 13RD080, and 94RD511 along AUID 537. The MDNR and MPCA have cooperatively conducted continuous flow monitoring at Site H68006001 (State Highway 1 crossing) since 2004; the location of the site is shown in Figure 18. Table 13 presents the percentile flow values for the site. The highest mean daily peak flow recorded at the site was 2769.6 cfs, while the lowest flow was 0.0 cfs. Approximately 29% of the total mean daily flow values were less than 1.0 cfs. Figure 20 provides the 2013 and 2014 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 10.6 (Q25) to 0.3 (Q75) cfs. Additionally, the estimated median flow (Q50) was 1.5 cfs, while the projected Q5 flow was 197.0 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 36:1, 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. Clark and Vinje (2017) noted "almost lentic" conditions with abundant duckweed and arrowhead within the channel at Station 13RD080 on September 22, 2015 (Figure 19). The MPCA SID staff conducted reconnaissance along the reach on September 21, 2016 and documented flow conditions. No flow-related issues were noted. Additionally, a Google Earth Street View image captured at the CSAH 17 crossing in August 2012 shows a nearly dry stream channel (Figure 19). Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

Table 13. Percentile flow values for Site H68006001 (2004-2015; *n*=3090) along AUID 537.

Date range	*n*	Percentile values – Mean daily discharge (cfs)						
		5th	10th	20th	40th	60th	80th	100th
2004-2015	3090	0.0	0.0	0.1	2.5	10.0	62.0	2769.5

Figure 19. Images of low flow conditions along AUID 537, including the CSAH 17 crossing during August 2012 (left), courtesy of Google Earth; and Station 13RD080 on September 22, 2015 (right).

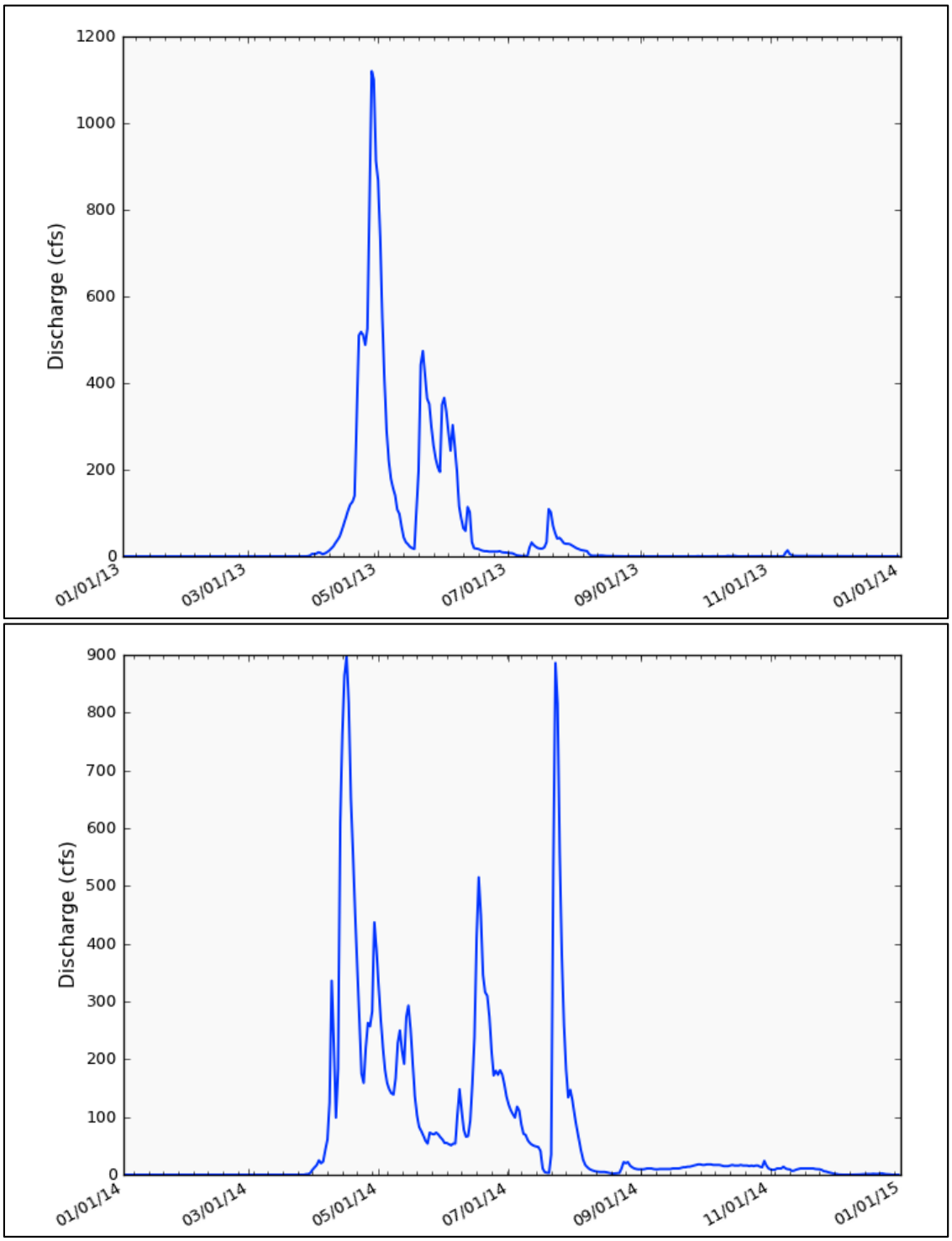


Figure 20. Annual (2013 and 2014) hydrographs for Site H68006001 along AUID 537.

B*iotic response – fish*

The following evidence (Appendix A) *strongly supports* the case for flow regime instability as a stressor to the fish community of AUID 537:

- Above average (>48/49%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 13RD006 (76%), 13RD080 (76%), and 94RD511 (75%)
- Above average (>21/43%) relative abundance of individuals that are generalists (GeneralPct) at Stations 13RD006 (84%) and 94RD511 (75%)

- Above average (>56/63%) relative abundance of individuals with a female mature age equal to or less than two years (MA<2Pct) at Stations 13RD006 (86%) and 94RD511 (67%)
- Below average (<0.76/1.00) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD006 (0.02), 13RD080 (0.05), and 94RD511 (0.05)
- Above average (>6/20%) relative abundance of individuals that are pioneers (PioneerPct) at Stations 13RD006 (63%) and 94RD511 (47%)
- Above average (>15/16%) relative abundance of individuals that are short-lived (SLvdPct) at Stations 13RD006 (63%) and 94RD511 (53%)

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) *strongly supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 537:

- Below average (<37%) relative abundance of Ephemeroptera, Plecoptera, and Trichoptera individuals (EPTPct) at Stations 13RD006 (1%), 13RD080 (2%), and 94RD511 (14%)
- Below average (<8%) relative abundance of long-lived individuals (LongLivedPct) at Stations 13RD006 (0%), 13RD080 (0%), and 94RD511 (0%)
- Below average (<38) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 13RD006 (21), 13RD080 (23), and 94RD511 (37)
- Above average (>81%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Stations 13RD006 (95%) and 13RD080 (83%)
- Below average (<5%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Stations 13RD006 (0%), 13RD080 (1%), and 94RD511 (4%)

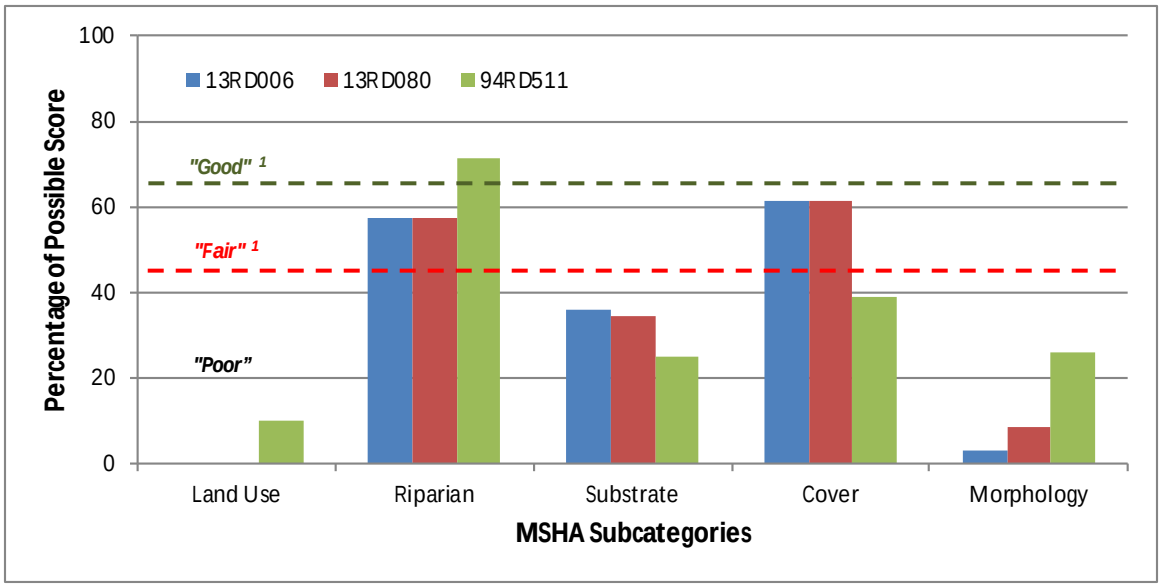
Flow regime instability tends to limit macroinvertebrate diversity, particularly taxa that belong to the orders of Ephemeroptera, Plecoptera, and Trichoptera, and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; USEPA, 2012b). Additionally, the macroinvertebrate assemblage of the stations was dominated by taxa that are adapted to lentic environments (i.e., *Hyalella,* Oligochaeta, and *Physa*).

Insufficient physical habitat

Available data

The physical habitat of AUID 537 was evaluated at Stations 13RD006, 13RD080, and 94RD511 using the MSHA. Each of the stations is located along a natural segment of the reach (MPCA, 2013). Stations 13RD006 (MSHA=30/"poor"), 13RD080 (MSHA=32/"poor"), and 94RD511 (MSHA=33/"poor") scored uniformly low. Figure 21 displays the MSHA subcategory results for the stations. Each of the stations scored poorly in the land use subcategory due to the predominance of agricultural row crops immediately surrounding the stations. The riparian subcategory scores were positively influenced by a "moderate" to "wide" zone width; however, a "moderate" to "heavy" amount of bank erosion was noted at each of the stations. The stations scored uniformly poor in the substrate subcategory due to inherent lack of riffle habitat and coarse substrate (e.g., cobble and gravel). Stations 13RD006 and 13RD080 scored well in the cover subcategory due to the diversity and "moderate" amount of cover present. Conversely, Station 94RD511 scored substantially lower, offering only a "sparse" amount of cover. Common cover types noted along the reach included deep pools, macrophytes (floating leaf and

submergent), rootwads, and woody debris. Lastly, the stations scored very poorly in the morphology subcategory due to "low" to "moderate" channel stability and "poor" channel development.



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

Figure 21. MSHA subcategory results for Stations 13RD006, 13RD080, and 94RD511 along AUID 537.

Clark and Vinje (2017) conducted fluvial geomorphology assessments near Stations 94RD511 and 13RD080 along AUID 537 between 2014 and 2015. The results of these assessments are provided in Appendix C, as well as summarized below:

> *"A Rosgen Level II survey was completed at [Station 94RD511], but it appears that the Pfankuch stability assessment might have been missed. The river through this reach was classified as an E6 stream type (low width-to-depth ratio, clay/silt bed stream). There was some cutting on the banks, especially on outside bends, but overall the reach was well vegetated and appeared stable. Buckthorn was very thick within the riparian zone, but may have reduced plant diversity but Carex sedges were a dominant species near bankfull (Carex has very dense, robust root systems). Based on the survey data, this reach was slightly incised but only slightly entrenched – at 2x the maximum bankfull depth at the riffles, the river had access to a narrow (approx. 150' wide) floodplain. At the time of the survey, there was adequate depth/holding cover in both the pools and the riffles, and riffles were difficult to discern due to the water depth. Woody debris was also fairly common through this reach, although it did not appear to be affecting stability. No pebble counts were completed due to the high percentage of silt/clay particles."*
>
> *"A Pfankuch stability assessment was completed at this [Station 13RD080], but not a Level II survey. With an estimated width-to-depth ratio of approximately 21, the stream type through this reach was a C6 (>12 width-to-depth ratio, silt/clay bed stream). The Pfankuch score for this site was 68, which is good for a C6 stream. Overall, the river here looked to be in very good condition, and it did not look to be either incised or entrenched. The bottom was very soft and mucky throughout, with abundant aquatic vegetation (duckweed and arrowhead were abundant within the channel). The river was almost lentic in nature at the time of the site visit – perhaps leading to temperature and DO issues. There was sufficient water depth, but nearly the entire reach was wadable and lacked deep, lateral scour pools."*

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by bank erosion, a lack of riffle habitat and coarse substrate, and inadequate channel development. Additionally, Clark and Vinje (2017) noted that the lack of lateral scour pools was adversely affecting the habitat of the reach.

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 537:

- Below average (<20/20%) relative abundance of individuals that are benthic insectivores, excluding tolerant species (BenInsect-TolPct) at Stations 13RD006 (2%), 13RD080 (8%), and 94RD511 (4%)
- Below average (<8/14%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Stations 13RD006 (0%), 13RD080 (0%), and 94RD511 (0%)
- Above average (>24/20%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 13RD006 (43%), 13RD080 (33%), and 94RD511 (50%)
- Below average (<34/17%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 13RD006 (0%), 13RD080 (0%), and 94RD511 (14%)
- Below average (<44/40%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Stations 13RD006 (29%), 13RD080 (33%), and 94RD511 (33%)
- Below average (<30%) relative abundance of individuals that predominately utilize riffle habitats (RifflePct) at Stations 13RD006 (8%) and 94RD511 (28%)
- Below average (<25/37%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Stations 13RD006 (8%), 13RD080 (20%), and 94RD511 (33%)

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 537:

- Above average (>9%) relative abundance of burrower individuals (BurrowerPct) at Stations 13RD080 (18%) and 94RD511 (16%)
- Below average (<22%) relative percentage of climber individuals (ClimberPct) at Stations 13RD006 (13%) and 13RD080 (10%)
- Below average (<36%) relative percentage of clinger individuals (ClingerPct) at Stations 13RD006 (1%) and 13RD080 (9%)
- Above average (>42%) relative abundance of legless individuals (LeglessPct) at Station 94RD511 (52%)
- Above average (>19%) relative abundance of sprawler individuals (SprawlerPct) at Stations 13RD006 (79%) and 13RD080 (60%)

Climber and clinger taxa require clean, coarse substrate or other objects to attach themselves to, while burrower, legless, and sprawler macroinvertebrates are tolerant of poor benthic habitat that is dominated by fine sediment.

High suspended sediment

Available data

According to the MSTRWD (2011), the Snake River is prone to high sediment loads. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 13RD080, 13RD006, and 94RD511 along AUID 537 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 24 mg/L. Table 14 summarizes all available discrete TSS data for Site S004-142 (State Highway 1); the location of the site is shown in Figure 18. The site had a high proportion of TSS values that exceeded the 65 mg/L standard (46%). Additionally, the SRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 64 and 78% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

Table 14. Discrete TSS data for Site S004-142 (1998-2014; *n*=78) along AUID 537.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S004-142	1998-2014	78	2	448	89	36

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for high suspended sediment as a stressor to the fish community of AUID 537:

- Above average (>32/18 mg/L) mean TSS TIV at Stations 13RD006 (27 mg/L), 13RD080 (50 mg/L), and 94RD511 (24 mg/L)
- Below average (<9/56%) probability of meeting the TSS standard at Stations 13RD006 (10%), 13RD080 (0%), and 94RD511 (19%)

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 537:

- Below average (<18%) relative abundance of collector-filterer individuals (Collector-FiltererPct) at Stations 13RD006 (0%) and 13RD080 (0%)
- Above average (>44%) relative abundance of high TSS tolerant taxa at Station 94RD511 (49%)
- Below average (<3%) relative abundance of high TSS intolerant taxa at Stations 13RD006 (0%), 13RD080 (0%), and 94RD511 (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 reach has an existing DO impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a combined seven discrete DO measurements at Stations 13RD006, 13RD080, and 94RD511 along AUID 537 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 5.3 to 13.2 mg/L. While none of the values were below the 5.0 mg/L standard, Station 13RD080 had an extremely high DO concentration (13.2 mg/L) and saturation percentage (169%) at the time of the June 25, 2013, fish monitoring visit. Such elevated DO conditions

are commonly caused by excessive aquatic plant (i.e., algae and submergent macrophyte) growth. Figure 22 displays all available discrete DO data for Site S004-142 (1998-2014; *n*=105). Approximately 10% of the DO values for the sites were below the 5.0 mg/L standard; however, only eight of the measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. During this period, stream flow is usually low and water temperature is high. Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

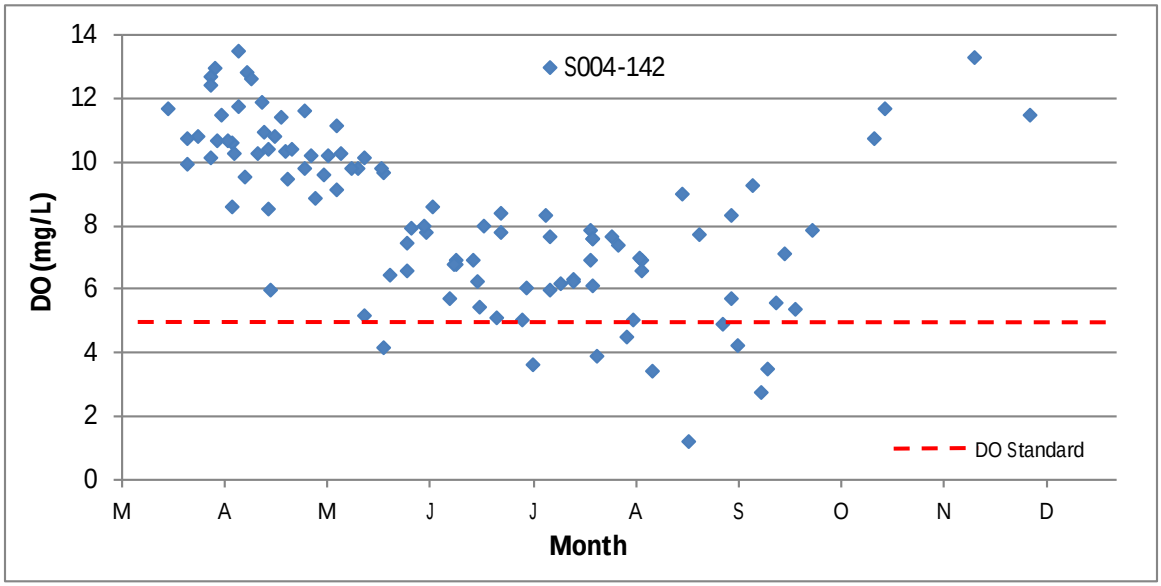


Figure 22. Discrete DO data for Site S004-142 (1998-2014; *n*=105) along AUID 537.

Eutrophication-related data for AUID 537 is limited to the following parameters: TP and Chl-a. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 13RD006, 13RD080, and 94RD511 along AUID 537 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 467 µg/L. Two of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Station 13RD006 had a concentration of 345 µg/L on June 25, 2013, while Station 94RD511 had a concentration of 467 µg/L on the same date. Discrete TP data are available for Site S004-142 (1998-2014; *n*=77). Collectively, the mean TP concentration for the sites was 230 µg/L, while the highest concentration was 1400 µg/L and the lowest concentration was 10 µg/L. Approximately 60% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S004-142 (2009; *n*=8). The mean Chl-a concentration for the site was 23 µg/L, while the highest concentration was 57 µg/L and the lowest concentration was 4 µg/L. There were three exceedances of the 35 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 the September 21, 2016 reconnaissance visit along the reach. While the reach is prone to high TP concentrations, there is insufficient response variable (i.e., Chl-a, 5-day biochemical oxygen demand (BOD_5), and DO flux) 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 537:

- Below average (<7.2 mg/L) mean DO TIV at Stations 13RD006 (6.4 mg/L) and 94RD511 (6.7 mg/L)
- Below average (<56%) probability of meeting the DO standard at Stations 13RD006 (24%) and 94RD511 (36%)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for low DO as a stressor to the macroinvertebrate community of AUID 537:

- Below average (<9) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Stations 13RD006 (1), 13RD080 (4), and 94RD511 (8)
- Below average (<38) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 13RD006 (21), 13RD080 (23), and 94RD511 (37)
- Below average (<6.8 mg/L) mean DO TIV at Stations 13RD006 (5.9 mg/L) and 13RD080 (4.5 mg/L)
- Above average (>16%) relative abundance of low DO tolerant taxa at Stations 13RD006 (89%) and 13RD080 (62%)
- Below average (<9%) relative abundance of low DO intolerant taxa at Stations 13RD006 (0%), 13RD080 (0%), and 94RD511 (5%)

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; USEPA, 2012b).

Summary of stressors

The evidence suggests that the FIBI and MIBI impairments associated with AUID 537 are each attributed to flow regime instability, insufficient physical habitat, high suspended sediment, and low DO. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.4 Snake River (AUID 502)

Physical setting

AUID 502 represents the segment of the Snake River from its confluence with CD 3, to its confluence with the Middle River (Figure 23); a total length of 11 miles. The reach has a subwatershed area of 429 square miles (274,606 acres). The subwatershed contains 237 miles of intermittent stream, 227 miles of intermittent drainage ditch, 88 miles of river (which includes AUID 502), 14 miles of perennial drainage ditch, and two miles of perennial stream (MDNR, 2003). According to the MPCA (2013), 49% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 16% of AUID 502. The NLCD 2011 (USGS, 2011) lists cultivated crops (86%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included developed (4%), wetlands (3%), forest (3%), and hay/pasture (2%).

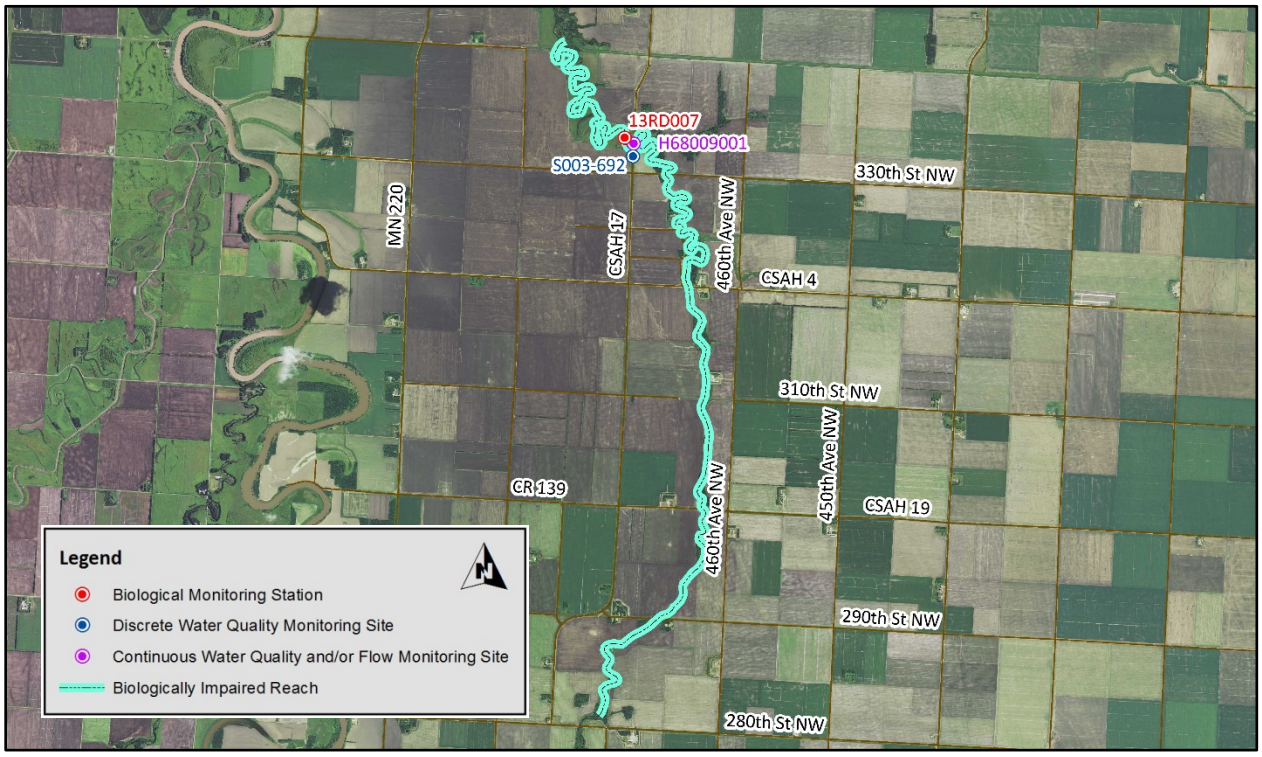


Figure 23. Map of AUID 502 and associated biological monitoring station and water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 502 was monitored at Station 13RD007 (0.2 mile downstream of the CSAH 17 crossing) on July 11, 2013. The location of the station is shown in Figure 23. The station was designated as General Use within the Southern Rivers FIBI Class. The impairment threshold for the station is an FIBI score of 49. Monitoring of the station yielded a FIBI score of 20. Overall, the fish assemblage of the station was dominated by bigmouth buffalo, common carp, and fathead minnow. Several longer-lived, riverine species (e.g., bigmouth buffalo, common carp, and walleye) were sampled at the station, which is likely the result of the close proximity and unimpeded connectivity to the Red River of the North.

Macroinvertebrate (MIBI)

The macroinvertebrate community of AUID 502 was monitored at Station 13RD007 on August 6, 2013. The station was designated as General Use within the Prairie Streams-Glide/Pool Habitats MIBI Class. Accordingly, the impairment threshold for the station is an MIBI score of 41. Monitoring of the station yielded a MIBI score (30) below the impairment threshold. The macroinvertebrate assemblage of the station was dominated by *Hyalella* (amphipods).

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 13RD007 along AUID 502. According to the MDNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. On September 21, 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. A log jam (Figure 24) was documented at the upstream end of the 330th Street NW crossing. Given its size and density, the log jam was likely interfering with connectivity at the time of discovery. However, based upon an examination of a September 1, 2013, aerial photo (courtesy of Google Earth), which was acquired shortly after fish and macroinvertebrate monitoring, the log jam was not present. In addition to the assessment, MPCA SID staff performed a detailed review of an April 29, 2016, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo. In summary, there were no known obstructions to connectivity along the reach at the time of biological monitoring.

Figure 24. Images of a log jam located at the 330th Street NW crossing along AUID 502 on September 21, 2016.

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 502:

- Below average (<41%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Station 13RD007 (23%)
- Below average (<30%) relative abundance of taxa that are migratory (MgrTxPct) at Station 13RD007 (23%)

Late maturing and migratory fish species 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. 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 MIBI impairment associated with AUID 502. Aquatic macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

The Snake River has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge (MSTRWD, 2011). Groshens (2007) attributed the river's flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. According to the MPCA (2013), 49% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 16% of AUID 502. The MPCA biological monitoring staff did not encounter any flow-related issues at Station 13RD007 along AUID 502. 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 14.9 (Q25) to 0.4 (Q75) cfs. Additionally, the estimated median flow (Q50) was 2.1 cfs, while the projected Q5 flow was 262.0 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 36:1, 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 September 21, 2016 and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

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 502:

- Above average (>48%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Station 13RD007 (58%)
- Above average (>21%) relative abundance of individuals that are generalists (GeneralPct) at Station 13RD007 (93%)
- Above average (>56%) relative abundance of individuals with a female mature age equal to or less than two years (MA<2Pct) at Station 13RD007 (64%)
- Below average (<0.76) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD007 (0.06)
- Above average (>6%) relative abundance of individuals that are pioneers (PioneerPct) at Station 13RD007 (34%)
- Above average (>15%) relative abundance of individuals that are short-lived (SLvdPct) at Station 13RD007 (34%)

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) *strongly supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 502:

- Below average (<37%) relative abundance of Ephemeroptera, Plecoptera, and Trichoptera individuals (EPTPct) at Station 13RD007 (25%)
- Below average (<8%) relative abundance of long-lived individuals (LongLivedPct) at Station 13RD007 (1%)
- Below average (<38) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD007 (31)
- Above average (>81%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Station 13RD007 (90%)
- Below average (<5%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Station 13RD007 (2%)

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; USEPA, 2012b). Additionally, the macroinvertebrate assemblage of the station was dominated by taxa that are adapted to lentic environments (i.e., *Hyalella*).

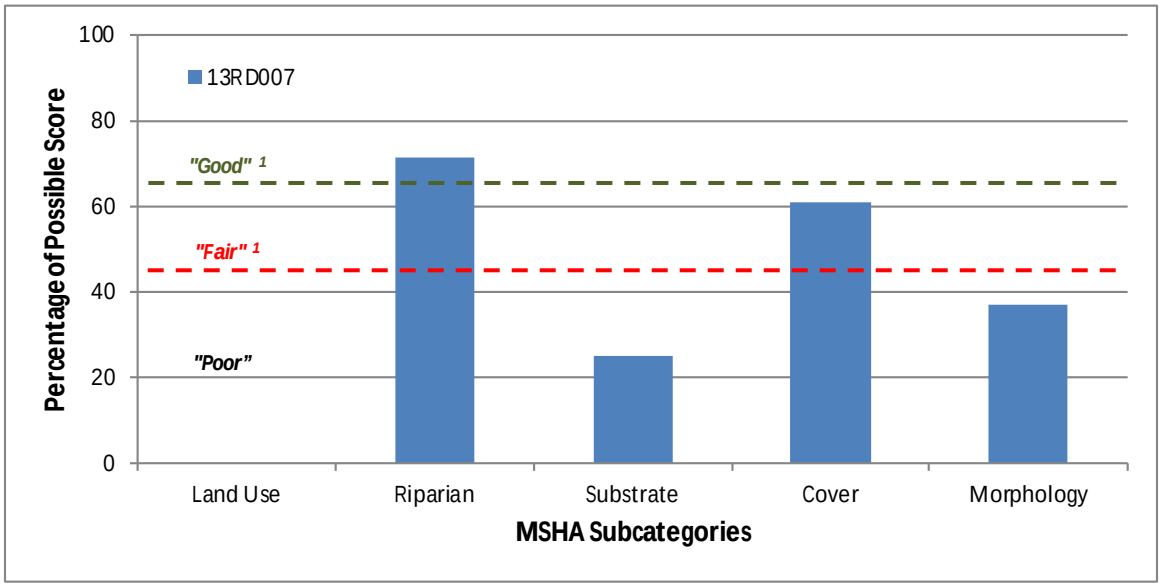
Insufficient physical habitat

Available data

The physical habitat of AUID 502 was evaluated at Station 13RD007 using the MSHA. The station is located along a natural segment of the reach (MPCA, 2013). The station yielded a MSHA score of 41 ("poor"). Figure 25 displays the MSHA subcategory results for the station. The station had a score of zero in the land use subcategory as a result to the predominance of agricultural row crops immediately surrounding the station. The station scored well in the riparian subcategory due to a "moderate" to "extensive" zone width and only a "little" amount of bank erosion. Conversely, the station had an exceptionally poor substrate score. The station inherently lacked riffle habitat and coarse substrate (e.g., cobble and gravel). The station scored well in the cover subcategory due to the diversity and "moderate" amount of cover present. Cover types noted included macrophytes (emergent, floating leaf, and submergent), overhanging vegetation, rootwads, and woody debris. Lastly, the morphology subcategory score was adversely affected by "moderate" channel stability and "poor" channel development.

Clark and Vinje (2017) conducted a fluvial geomorphology assessment near Station 13RD007 along AUID 502 on May 29, 2014 (Appendix C). A summary of the assessment results is provided below:

> *"MDNR Site 9 was 1.4 river miles upstream of [Station 13RD007], but based on aerial imagery, the Pfankuch stability assessment is likely applicable at the [station] as well. A Rosgen Level II survey was not completed at this location. The river was estimated to be a stable C6 stream type (>12 width-to-depth ratio, silt/clay bed stream), with a Pfankuch score of 69. The river did not appear to be either incised or entrenched at this location (it had access to a wide floodplain at bankfull flows and higher), and both the upper and lower banks appeared to be in very good condition (no mass erosion or cutting). Given the large drainage area to this location, the river was surprisingly shallow and lacked pool depth, although there was sufficient depth throughout for holding cover."*



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

Figure 25. MSHA subcategory results for Station 13RD007 along AUID 502.

In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by a lack of riffle habitat and coarse substrate, as well as inadequate channel development. Additionally, Clark and Vinje (2017) noted that the lack of pool depth was adversely affecting the habitat of the reach.

Biotic response – fish

The following evidence (Appendix A) *convincingly supports* the case for insufficient physical habitat as a stressor to the fish community of AUID 502:

- Below average (<25%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Station 13RD007 (0%)
- Below average (<8%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Station 13RD007 (0%)
- Above average (>42%) relative abundance of individuals that are detritivorous (DetNWQPct) at Station 13RD007 (65%)
- Below average (<34%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 13RD007 (3%)
- Below average (<56%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Station 13RD007 (4%)
- Below average (<25%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 13RD007 (7%)

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 502:

- Below average (<22%) relative percentage of climber individuals (ClimberPct) at Station 13RD007 (14%)

- Below average (<36%) relative percentage of clinger individuals (ClingerPct) at Station 13RD007 (24%)
- Above average (>19%) relative abundance of sprawler individuals (SprawlerPct) at Station 13RD007 (50%)

Climber and clinger taxa require clean, coarse substrate or other objects to attach themselves to, while sprawler macroinvertebrates are tolerant of poor benthic habitat that is dominated by fine sediment.

High suspended sediment

Available data

The Snake River is prone to high sediment loads (MSTRWD, 2011). According to D. Omdahl, MSTRWD (personal communication, 2017), a long-term resident along this reach has stated that high sediment loads have reduced the river's channel capacity. The reach has an existing turbidity impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD007 along AUID 502 at the time of the July 11, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 81 mg/L. Table 15 summarizes all available discrete TSS data for Site S003-692 (CSAH 17 crossing); the location of the site is shown in Figure 23. The site had a high proportion of TSS values that exceeded the 65 mg/L standard (24%). Additionally, the SRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 56 and 63% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

Table 15. Discrete TSS data for Site S003-692 (2004-2013; *n*=45) along AUID 502.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S003-692	2004-2013	45	2	206	53	11

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 502:

- Below average (<9%) probability of meeting the TSS standard at Station 13RD007 (3%)

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 502:

- Below average (<18%) relative abundance of collector-filterer individuals (Collector-FiltererPct) at Station 13RD007 (4%)
- Below average (<3%) relative abundance of high TSS intolerant taxa at Station 13RD007 (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

The reach has an existing DO impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD007 along AUID 502 at the time of fish and macroinvertebrate monitoring. One measurement was below the 5.0 mg/L standard; the station had a DO concentration of 4.2 mg/L at the time of the July 11, 2013, fish monitoring visit. Figure 26 displays all available discrete DO data for Site S003-692 (2004-2014; *n*=74). Approximately 22% of the DO values for the site were below the 5.0 mg/L standard; however, only four of the measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of June, July, and August. During this period, stream flow is usually low and water temperature is high. The MPCA conducted continuous DO monitoring at Site H68009001 (CSAH 17 crossing) from August 19, 2016, to September 1, 2016; the location of the site is shown in Figure 23. The monitoring results are provided in Table 16, as well as displayed in Figure 27. None of the DO measurements within the monitoring period were below the standard. Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

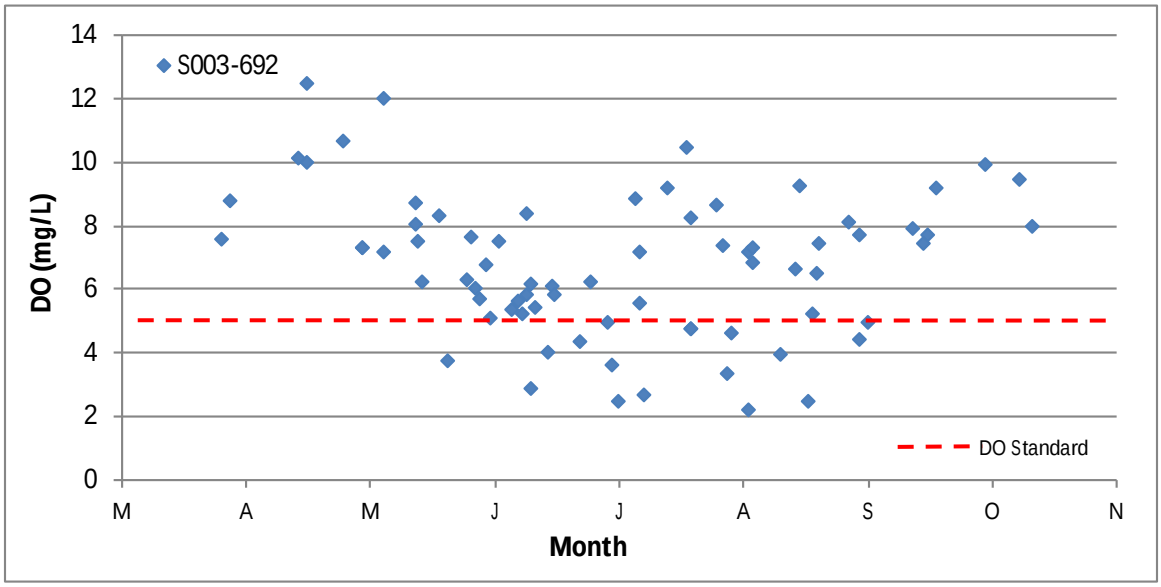


Figure 26. Discrete DO data for Site S003-692 (2004-2014; *n*=74) along AUID 502.

Table 16. Continuous DO data for Site H68009001 (2016; *n*=1255) along AUID 502.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 19, 2016 – September 1, 2016	1255	6.7	14.9	0	0	4.6

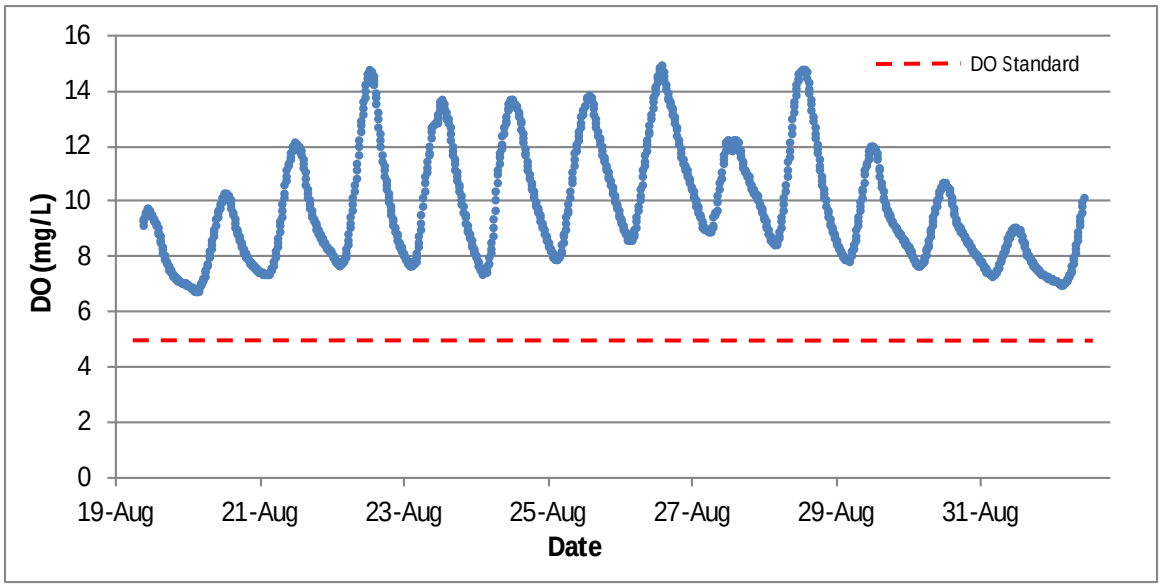


Figure 27. Continuous DO data for Site H68009001 (2016; *n*=1255) along AUID 502.

Eutrophication-related data for AUID 502 includes the following parameters: TP, Chl-a, and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD007 along AUID 502 at the time of the July 11, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TP. The station had a TP concentration of 946 µg/L. Discrete TP data are available for Site S003-692 (2004-2013; *n*=45). The mean TP concentration for the site was 268 µg/L, while the highest concentration was 672 µg/L and the lowest concentration was 77 µg/L. Approximately 84% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S003-692 (2009; *n*=8). The mean Chl-a concentration for the site was 33 µg/L, while the highest concentration was 43 µg/L and the lowest concentration was 16 µg/L. There were four exceedances of the 35 µg/L South River Nutrient Region Chl-a standard. The mean daily DO flux documented during continuous DO monitoring at Site H68009001 (Table 16) was 4.6 mg/L, which is slightly above 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 the September 21, 2016 reconnaissance visit along the reach. While the reach is prone to high TP concentrations, the limited response variable (i.e., Chl-a and DO flux) data and field observations are inconclusive as to 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 502:

- Below average (<7.7 mg/L) mean DO TIV at Station 13RD007 (6.6 mg/L)
- Below average (<73%) probability of meeting the DO standard at Station 13RD007 (31%)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for low DO as a stressor to the macroinvertebrate community of AUID 502:

- Below average (<9) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Station 13RD007 (5)
- Below average (<38) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD007 (31)

- Below average (<6.8 mg/L) mean DO TIV at Station 13RD007 (6.4 mg/L)
- Above average (>16%) relative abundance of low DO tolerant taxa at Station 13RD007 (56%)

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; USEPA, 2012b).

Summary of stressors

The evidence suggests that the FIBI and MIBI impairments associated with AUID 502 are each attributed to flow regime instability, insufficient physical habitat, low DO, and, to a lesser extent, high suspended sediment. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.5 Snake River (AUID 501)

Physical setting

AUID 501 represents the segment of the Snake River from its confluence with the Middle River, to its confluence with the Red River of the North (Figure 28); a total length of 10 miles. The reach has a subwatershed area of 779 square miles (498,543 acres). The subwatershed contains 434 miles of intermittent drainage ditch, 352 miles of intermittent stream, 185 miles of river (which includes AUID 501), 32 miles of perennial drainage ditch, and three miles of perennial stream (MDNR, 2003). According to the MPCA (2013), 52% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded); the entire length of AUID 501 is classified as natural. The NLCD 2011 (USGS, 2011) lists cultivated crops (79%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (7%), forest (6%), developed (5%), and hay/pasture (3%).

Figure 28. Map of AUID 501 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 501 was monitored at Station 13RD009 (0.2 mile upstream of the State Highway 220 crossing) on August 7, 2013. The location of the station is shown in Figure 28. The station was designated as General Use within the Southern Rivers FIBI Class. Accordingly, the impairment threshold for the station is an FIBI score of 49. Monitoring of the station yielded a FIBI score of 44. Overall, the fish assemblage of the station was dominated by fathead minnow and spotfin shiner. However, several longer-lived, riverine species (e.g., goldeye, quillback, sauger, and walleye) were sampled at the station, which is likely the result of the close proximity and unimpeded connectivity to the Red River of the North.

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 13RD009 along AUID 501. According to the MDNR (2014), there are no man-made dams on the reach. On September 21, 2016, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed the lone road crossing on the reach 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 an April 29, 2016, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo. In summary, there were no known obstructions to connectivity along the reach at the time of biological monitoring.

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 501:

- Below average (<41%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Station 13RD009 (32%)

Late maturing fish species 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 response.

Flow regime instability

Available data

The Snake River has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge (MSTRWD, 2011). Groshens (2007) attributed the river's flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. According to the MPCA (2013), 52% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded); the entire length of AUID 501 is classified as natural. The MPCA biological monitoring staff did not encounter any flow-related issues at Station 13RD009 along AUID 501. 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 31.0 (Q25) to 1.0 (Q75) cfs. Additionally, the estimated median flow (Q50) was 4.6 cfs, while the projected Q5 flow was 469.0 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 32:1, 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 September 21, 2016 and documented flow conditions. No flow-related issues were noted. Additionally, a Google Earth Street View image captured at the State Highway 220 crossing in August 2012 shows the river at a very low stage (Figure 29). 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 29. Images of stage variability at the State Highway 220 crossing along AUID 501, including low stage conditions during August 2012 (left), courtesy of Google Earth; and high stage conditions on June 23, 2014 (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 501:

- Above average (>48%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Station 13RD009 (81%)
- Above average (>21%) relative abundance of individuals that are generalists (GeneralPct) at Station 13RD009 (52%)
- Above average (>56%) relative abundance of individuals with a female mature age equal to or less than two years (MA<2Pct) at Station 13RD009 (94%)
- Below average (<0.76) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD009 (0.49)
- Above average (>6%) relative abundance of individuals that are pioneers (PioneerPct) at Station 13RD009 (40%)
- Above average (>15%) relative abundance of individuals that are short-lived (SLvdPct) at Station 13RD009 (41%)

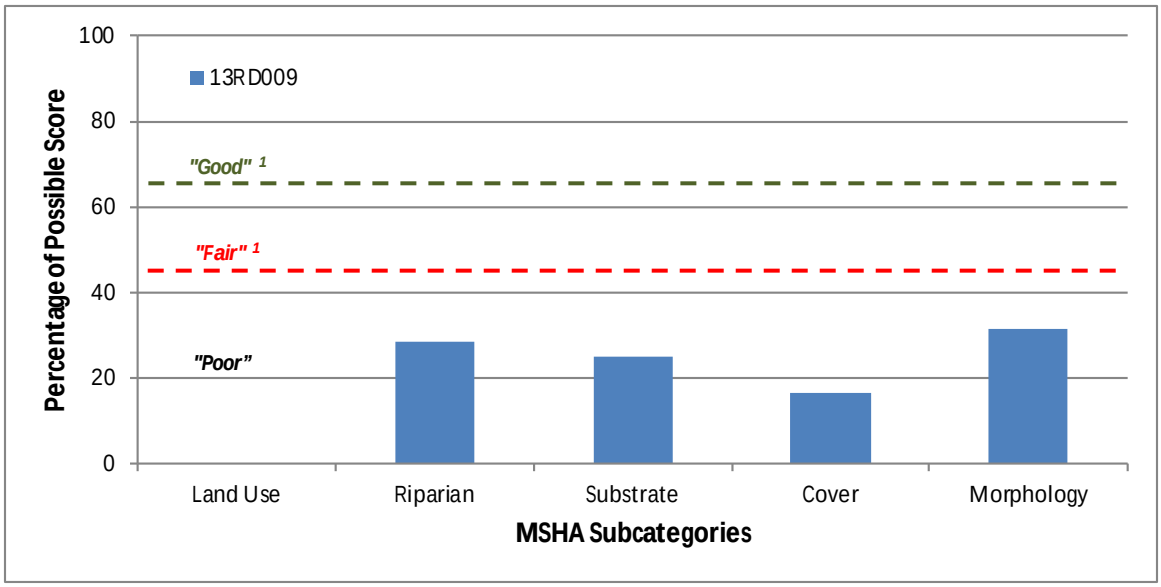
Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 501 was evaluated at Station 13RD009 using the MSHA. The station is located along a natural segment of the reach (MPCA, 2013). The station yielded a MSHA score of 25 ("poor"). Figure 30 displays the MSHA subcategory results for the station. The station yielded a poor score for each of the subcategories. The station had a score of zero for the land use subcategory due to

the predominance of agricultural row crops immediately surrounding the station. The riparian zone width of the station was characterized as "moderate" and a "severe" amount of bank erosion was noted. The station inherently lacked riffle habitat and coarse substrate (e.g., cobble and gravel). The station had a "nearly absent" amount of cover. The only cover types noted were deep pools, submergent macrophytes, and woody debris. Lastly, the station had "low" channel stability and "poor" channel development. In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by bank erosion, a lack of riffle habitat and coarse substrate, sparse cover, cover diversity, and inadequate channel development.



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

Figure 30. MSHA subcategory results for Station 13RD009 along AUID 501.

Biotic response – fish

The following evidence (Appendix A) *convincingly supports* the case for insufficient physical habitat as a stressor to the fish community of AUID 501:

- Below average (<20%) relative abundance of individuals that are benthic insectivores, excluding tolerant species (BenInsect-TolPct) at Station 13RD009 (1%)
- Below average (<5%) relative abundance of individuals that are darters and sculpins (DarterSculpPct) at Station 13RD009 (1%)
- Above average (>42%) relative abundance of individuals that are detritivorous (DetNWQPct) at Station 13RD009 (92%)
- Below average (<56%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Station 13RD009 (46%)
- Below average (<13%) relative abundance of individuals that predominately utilize riffle habitats (RifflePct) at Station 13RD009 (1%)
- Below average (<25%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 13RD009 (4%)

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

According to the MSTRWD (2011), the Snake River is prone to high sediment loads. The reach has an existing turbidity impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD009 along AUID 501 at the time of the August 7, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 33 mg/L. Table 17 summarizes all available discrete TSS data for Site S000-185 (State Highway 220 crossing); the location of the site is shown in Figure 28. The site had a high proportion of TSS values that exceeded the 65 mg/L standard (47%). Additionally, the SRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 42 and 56% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

Table 17. Discrete TSS data for Site S000-185 (1971-2015; *n*=426) along AUID 501.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S000-185	1971-2015	426	1	2640	120	199

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 501:

- Below average (<9%) probability of meeting the TSS standard at Station 13RD009 (3%)

Low dissolved oxygen

Available data

The reach has an existing DO impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD009 along AUID 501 at the time of the August 7, 2013, fish monitoring visit. The station had a DO concentration of 9.8 mg/L. Figure 31 displays all available discrete DO data for Site S000-185 (1971-2015; *n*=448). Approximately 13% of the DO values for the site were below the 5.0 mg/L standard; however, only 69 of the DO measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels occurred during the winter (i.e., December, January, February, and March) and summer (i.e., June, July, and August). Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

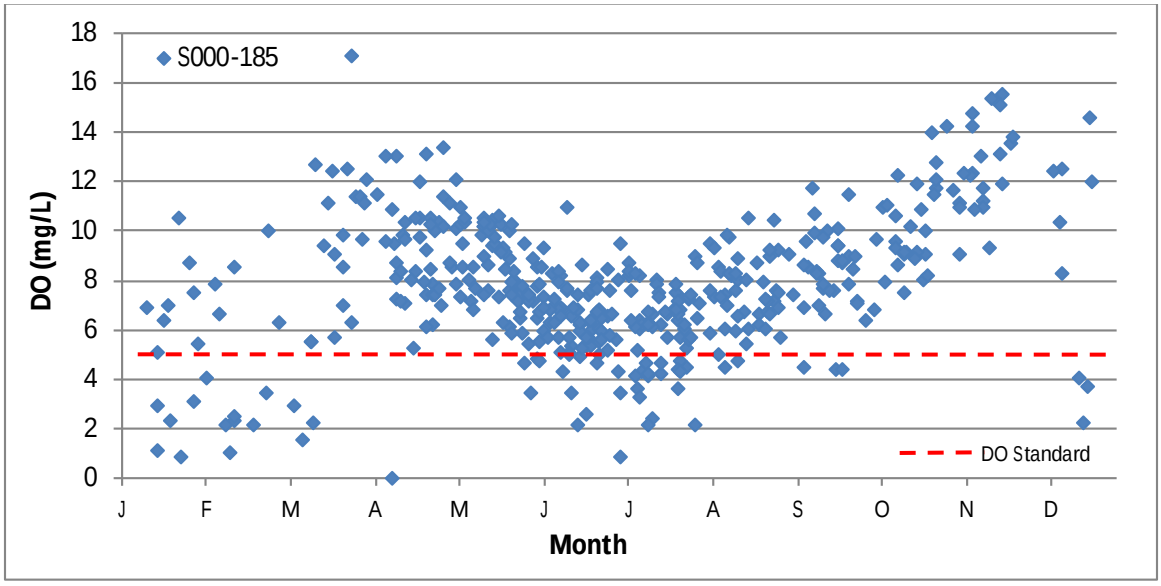


Figure 31. Discrete DO data for Site S000-185 (1971-2015; *n*=448) along AUID 501.

Eutrophication-related data for AUID 501 includes the following parameters: TP, Chl-a, and BOD_5. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD009 along AUID 501 at the time of the August 7, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TP. The station had a TP concentration of 153 µg/L. Discrete TP data are available for Site S000-185 (1971-2015; *n*=419). Collectively, the mean TP concentration for the sites was 300 µg/L, while the highest concentration was 1910 µg/L and the lowest concentration was 10 µg/L. Approximately 81% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are available for Site S000-185 (2000-2014; *n*=39). The mean Chl-a concentration for the site was 15 µg/L, while the highest concentration was 43 µg/L and the lowest concentration was 1 µg/L. There were three exceedances of the 35 µg/L South River Nutrient Region Chl-a standard. Discrete 5-day biochemical oxygen demand (BOD_5) data are available for Site S000-185 (1971-2010; *n*=89); however, most (91%) of the data was collected prior to 2007. The mean BOD_5 concentration for the site was 4.0 mg/L, while the highest concentration was 13.0 mg/L and the lowest concentration was 0.9 mg/L. There were 43 exceedances of the 3.0 mg/L South River Nutrient Region BOD_5 standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during the September 21, 2016 reconnaissance visit along the reach. Overall, the available data suggest that eutrophication may be 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 501:

- Below average (<7.7 mg/L) mean DO TIV at Station 13RD009 (6.8 mg/L)
- Below average (<73%) probability of meeting the DO standard at Station 13RD009 (39%)

Summary of stressors

The evidence suggests that the FIBI impairment associated with AUID 501 is attributed to flow regime instability, insufficient physical habitat, low DO, and, to a lesser extent, high suspended sediment. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.6 South Branch of the Snake River (AUID 546)

Physical setting

AUID 546 represents the modified channel of the South Branch of the Snake River (Figure 32), which extends from its headwaters, to its confluence with the Snake River; a total length of 14 miles. The reach has a subwatershed area of 60 square miles (38,542 acres). The subwatershed contains 36 miles of intermittent drainage ditch (which includes AUID 546), 20 miles of intermittent stream, and one mile of perennial drainage ditch (MDNR, 2003). According to the MPCA (2013), 71% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 84% of AUID 546. The channelized upstream portion of the reach is also known as JD 14, while the channelized downstream segment is considered CD 22. The NLCD 2011 (USGS, 2011) lists cultivated crops (64%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (13%), forest (9%), hay/pasture (8%), and developed (4%).

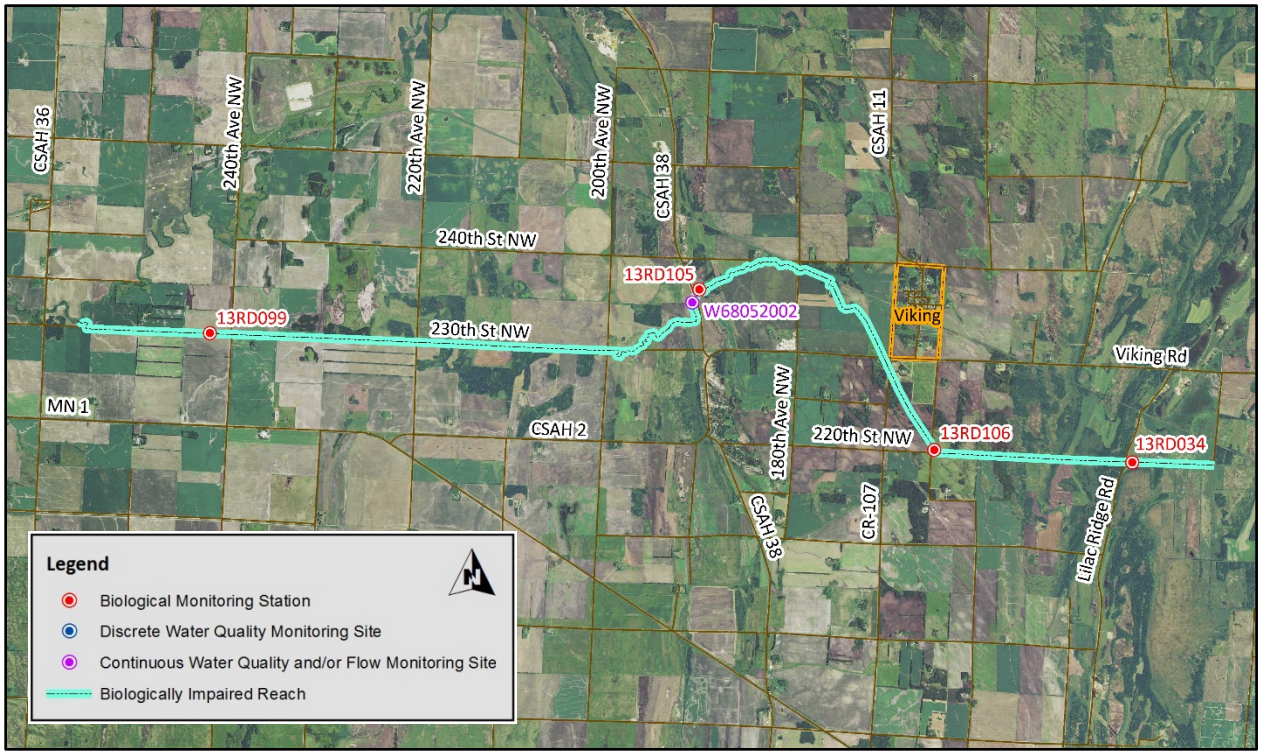


Figure 32. Map of AUID 546 and associated biological monitoring stations and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 546 was monitored at Station 13RD034 (0.1 mile upstream of the Lilac Ridge Road crossing) on July 9, 2013; Station 13RD099 (0.2 mile downstream of the 240th Avenue NW crossing) on June 10, 2013(1) and June 14, 2013(2); Station 13RD105 (0.1 mile upstream of the CSAH 38 crossing) on July 9, 2013; and Station 13RD106 (0.1 mile upstream of the 165th Avenue NW crossing) on June 13, 2013. The location of each station is shown in Figure 32. Station 13RD099 was designated as General Use within the Northern Streams FIBI Class. The impairment threshold for the station is an FIBI score of 47. Stations 13RD034, 13RD105, and 13RD106 were designated as General Use within the Northern Headwaters FIBI Class. Accordingly, the impairment threshold for these stations is an FIBI score of 42. Stations 13RD034 (FIBI=37), 13RD099 (FIBI=32 and 38), and 13RD105 (FIBI=24) each scored below their respective impairment threshold, while Station 13RD106 (FIBI=43) scored above its

threshold. Overall, the fish assemblage of the stations was dominated by tolerant taxa, specifically blacknose dace, creek chub, fathead minnow, and white sucker.

Candidate causes

Loss of longitudinal connectivity

Available data

According to D. Omdahl, MSTRWD (personal communication, 2017), beaver dams are prevalent along this reach. The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 13RD034, 13RD099, 13RD105, and 13RD106 along AUID 546. According to the MDNR (2014), there are no man-made dams on the reach. However, the Warren Diversion Dam is located downstream of the reach along the Snake River (AUID 504). On September 21, 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 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 29, 2016, aerial photo (courtesy of Google Earth) of the reach. Two private road crossings (Figure 33) were identified; one crossing was located near 180th Avenue NW, while the other crossing was situated near County Road (CR) 107. The crossings appeared to have an undersized culvert(s) that is likely altering stream flow and potentially limiting connectivity. In summary, beaver dams, the Warren Storage Dam, and private road crossings are the only known potential obstructions to connectivity that may have been affecting the reach at the time of biological monitoring.

Figure 33. Images of potential connectivity barriers along AUID 546, including a private road crossing near 180th Avenue NW on April 29, 2016 (left), courtesy of Google Earth; and a private road crossing near CR 107 on April 29, 2016 (right), courtesy of Google Earth.

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 546:

- Below average (<24/6%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Stations 13RD034 (0%), 13RD099(1) (0%), 13RD099(2) (0%), 13RD105 (0%), and 13RD106 (0%)
- Below average (<18%) relative abundance of taxa that are migratory (MgrTxPct) at Stations 13RD099(1) (14%) and 13RD099(2) (11%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. However, there is no compelling

evidence that the Warren Storage Dam (refer to Subsection 3.3.2) or the private road crossings are responsible for the abovementioned metric responses. The responses for Stations 13RD034 and 13RD106, which are situated upstream of the crossings, are similar to those of Stations 13RD099 and 12RD105, which are located further downstream. Additionally, there is insufficient information to determine if beaver dams and the culverts associated with road crossings (i.e., creating a velocity barrier during high flow conditions) are impeding fish passage.

Flow regime instability

Available data

The South Branch of the Snake River has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge (MSTRWD, 2011). Local water resource managers indicated that AUID 546 is prone to periods of intermittency (MPCA, 2015). Additionally, the MDNR (2003) has classified the flow regime of AUID 546 as intermittent. Groshens (2007) attributed the river's flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. According to the MPCA (2013), 71% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 84% of AUID 546. The MPCA biological monitoring staff did not encounter any flow-related issues at Stations 13RD034, 13RD099, 13RD105, and 13RD106 along AUID 546. 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 1.3 (Q25) to less than 0.1 (Q75) cfs. Additionally, the estimated median flow (Q50) was 0.2 cfs, while the projected Q5 flow was 34.8 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 41:1, 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 three separate dates (i.e., July 1, 2015, July 15, 2015, and September 21, 2016) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

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 546:

- Above average (>52/58%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 13RD034 (60%), 13RD099(1) (55%), 13RD099(2) (65%), and 13RD105 (92%)
- Above average (>34/44%) relative abundance of individuals that are generalists (GeneralPct) at Stations 13RD034 (86%), 13RD099(1) (76%), 13RD099(2) (89%), 13RD105 (92%), and 13RD106 (74%)
- Above average (>63/84%) relative abundance of individuals with a female mature age equal to or less than two years (MA<2Pct) at Stations 13RD034 (91%), 13RD099(1) (79%), 13RD099(2) (93%), and 13RD106 (93%)
- Below average (<0.96/0.95) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD034 (0.05), 13RD099(1) (0.03), 13RD099(2) (0.04), 13RD105 (0.01), and 13RD106 (0.12)
- Above average (>15/23%) relative abundance of individuals that are pioneers (PioneerPct) at Stations 13RD034 (36%), 13RD099(1) (55%), 13RD099(2) (43%), 13RD105 (57%), and 13RD106 (41%)

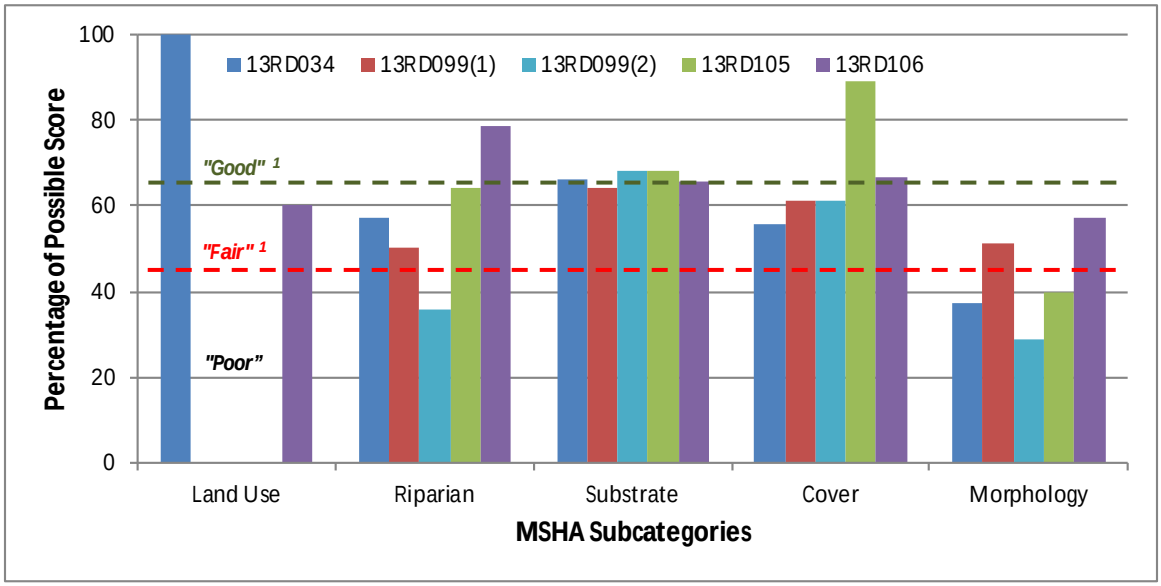
- Above average (>10/29%) relative abundance of individuals that are short-lived (SLvdPct) at Stations 13RD034 (67%), 13RD099(1) (36%), 13RD099(2) (61%), and 13RD106 (49%)

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 546 was evaluated at Stations 13RD034, 13RD099, 13RD105, and 13RD106 using the MSHA. Station 13RD105 is located along a natural segment of the reach, while Stations 13RD034, 13RD099, and 13RD106 are found along channelized portions of the reach (MPCA, 2013). Stations 13RD034 (MSHA=55/"fair"), 13RD099 (MSHA=54/"fair" and 45/"fair"), 13RD105 (MSHA=58/"fair"), and 13RD106 (MSHA=64/"fair") yielded largely uniform scores. Figure 34 displays the MSHA subcategory results for the stations. Stations 13RD099, 13RD105, and 13RD106 had a score of zero in the land use subcategory due to the predominance of agricultural row crops immediately surrounding the stations. Stations 13RD105 and 13RD106 yielded higher scores in the riparian subcategory than the other stations due to an "extensive" riparian width. A minimal amount of bank erosion was noted at Stations 13RD034, 13RD099, and 13RD105. The stations scored universally well in the substrate subcategory, offering coarse substrate (e.g., cobble and gravel) with only "light" embeddedness. Riffle habitat was only noted at Stations 13RD034 and 13RD106. The stations also scored well in the cover subcategory, primarily due to the diversity and "moderate" to "extensive" amount of cover present. Common cover types noted included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, undercut banks, and woody debris. Lastly, the morphology subcategory scores for the stations were adversely affected by "moderate" channel stability and "poor" channel development. Lastly, the morphology subcategory scores were adversely affected by "fair" to "poor" channel development. In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by a lack of riffle habitat and inadequate channel development.



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

Figure 34. MSHA subcategory results for Stations 13RD034, 13RD099, 13RD105, and 13RD106 along AUID 546.

Clark and Vinje (2017) conducted fluvial geomorphology assessments near Stations 13RD099 and 13RD105 along AUID 546 on July 14, 2015. The results of these assessments are provided in Appendix C, as well as summarized below:

> *"A Pfankuch stability assessment was completed 1.5 miles upstream of [Station 13RD099]. Though not directly at the [station], the ditch at the Pfankuch assessment site was in similar condition to the ditch near the [station] (as determined by reconnaissance observations and photos). With an estimated width-to-depth ratio of 6, this stream appeared to be an E4 stream type (low width-to-depth ratio, gravel bed stream). However, being a confined ditch, the flood-prone width was only 60 feet, so it was slightly entrenched (entrenchment ratio = 2.86). Overall, though, it appeared to be a stable ditch at this location. The main issues through this reach appeared to be remnants of beaver dams that were causing some erosion/cutting issues in some areas. The stream had a predominantly firm gravel bottom, with some areas of finer sediment deposits. Even though it had good substrate, being a ditch, it was lacking in the typical riffle-pool sequence of a meandering stream, so habitat was likely lacking throughout the reach."*

> *"A Pfankuch stability assessment was completed at [Station 13RD105], but not a Level II survey. With an estimated width-to-depth ratio of approximately 7, the stream type through this reach was an E4 (low width-to-depth ratio, gravel bed stream). The Pfankuch score for this site was 59, which is good for an E4 stream. Overall, the stream appeared to be in very good condition and was not incised or entrenched, although the floodplain narrows as it approaches the road crossing. The channel bottom was moderately packed and the substrate appeared to be primarily small gravel with some sand and cobble. The main issue here appeared to be beaver related – there was one blown out dam and one active dam being overtopped by high flows during the time of the site visit. The crossing downstream was a 13' wide x 8' high concrete arch culvert, with no sediment in the bottom. It didn't appear that the culvert was a barrier to fish passage, but some roughness in the culvert to aid fish passage could be beneficial. Besides the beaver dams, other potential stressors for this site could be the degraded condition of the stream approximately one mile downstream, as well as the ditching that has occurred downstream of the next road crossing."*

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 546:

- Below average (<27/18%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Stations 13RD034 (0%), 13RD099(1) (0%), 13RD099(2) (11%), 13RD105 (0%), and 13RD106 (0%)
- Below average (<14/13%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Stations 13RD034 (0%), 13RD099(1) (0%), 13RD099(2) (11%), 13RD105 (0%), and 13RD106 (0%)
- Above average (>11/15%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 13RD034 (25%), 13RD099(1) (29%), 13RD099(2) (33%), 13RD105 (20%), and 13RD106 (29%)
- Below average (<15/14%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 13RD034 (8%), 13RD099(1) (5%), 13RD099(2) (0%), and 13RD105 (2%)
- Below average (<44/27%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 13RD034 (8%), 13RD099(1) (5%), 13RD099(2) (1%), 13RD105 (2%), and 13RD106 (23%)

- Below average (<24/16%) relative abundance of individuals that predominately utilize riffle habitats (RifflePct) at Stations 13RD034 (11%), 13RD099(1) (21%), 13RD099(2) (7%), and 13RD106 (7%)
- Below average (<35/27%) relative abundance of taxa that are simple lithophilic spawning species (SLithopTxPct) at Stations 13RD099(1) (14%), 13RD099(2) (33%), and 13RD105 (20%)

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 South Branch of the Snake River is prone to high sediment loads (MSTRWD, 2011). According to D. Omdahl, MSTRWD (personal communication, 2017), the downstream segment of the reach (i.e., CD 22) is particularly prone erosion due to a high gradient and the presence of coarse textured soils. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 13RD034, 13RD099, 13RD105, and 13RD106 along AUID 546 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 6 mg/L. Additionally, the SRW HSPF model estimates that the reach had a TSS concentration in excess of the 30 mg/L standard between 97 and 99% of the time during the period of 1996 to 2009. 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 546:

- Above average (>13 mg/L) mean TSS TIV at Stations 13RD034 (15 mg/L), 13RD099(1) (17 mg/L), 13RD099(2) (15 mg/L), 13RD105 (16 mg/L), and 13RD106 (15 mg/L)
- Below average (<83/81%) probability of meeting the TSS standard at Stations 13RD034 (72%), 13RD099(1) (59%), 13RD099(2) (72%), 13RD105 (69%), and 13RD106 (72%)

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a combined 10 discrete DO measurements at Stations 13RD034, 13RD099, 13RD105, and 13RD106 along AUID 546 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 5.7 to 10.2 mg/L. The MPCA conducted continuous DO monitoring at Site W68052002 (CSAH 38 crossing) from July 1, 2015, to July 15, 2015; the location of the site is shown in Figure 32. The monitoring results are provided in Table 18, as well as displayed in Figure 35. While 17% of the total values were below the 5.0 mg/L standard, 69% of the daily minimum values were below the standard. A large rain event (≈2-3") interrupted the diurnal pattern on and after July 5, 2015. Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard approximately 32% 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 18. Continuous DO data for Site W68052002 (2015; *n*=1347) along AUID 546.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 1, 2015 - July 15, 2015	1347	2.1	9.8	17	69	3.8

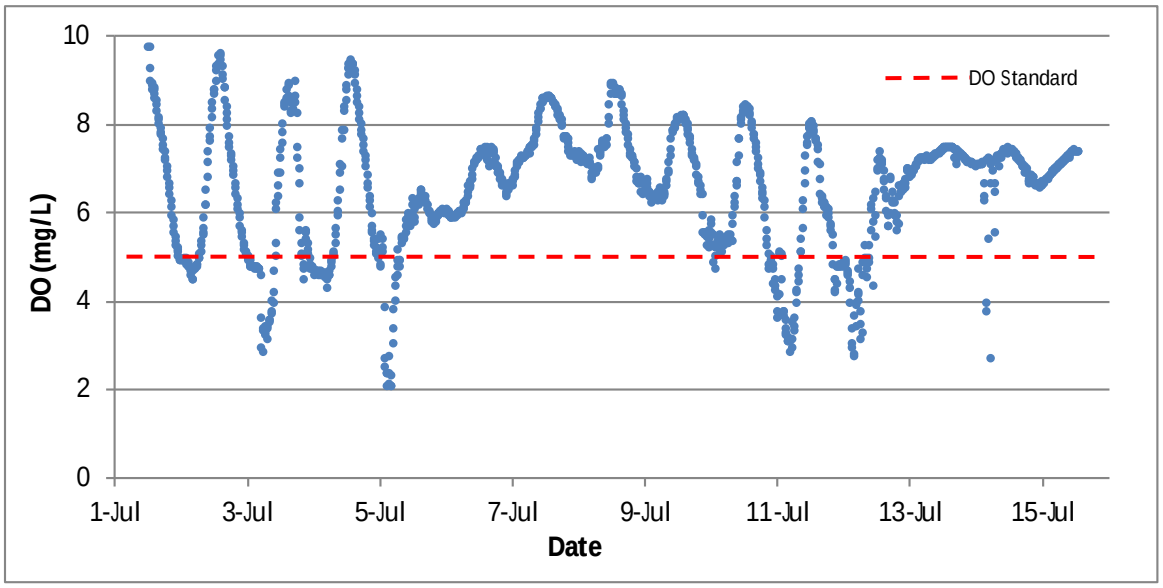


Figure 35. Continuous DO data for Site W68052002 (2015; *n*=1347) along AUID 546.

Eutrophication-related data for AUID 546 is limited to the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 13RD034, 13RD099, 13RD105, and 13RD106 along AUID 546 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 57 µg/L; the South River Nutrient Region TP standard is 150 µg/L. The mean daily DO flux documented during continuous DO monitoring at Site W68052002 (Table 18) was 3.8 mg/L, which is 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., abundant algae) during three separate reconnaissance visits along the reach (i.e., July 1, 2015, July 15, 2015, and September 21, 2016). Overall, the limited 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) *strongly supports* the case for low DO as a stressor to the fish community of AUID 546:

- Below average (<7.1 mg/L) mean DO TIV at Station 13RD099(1) (6.6 mg/L)
- Below average (<53%) probability of meeting the DO standard at Station 13RD099(1) (29%)

Summary of stressors

The evidence suggests that the FIBI impairment associated with AUID 546 is attributed to flow regime instability, insufficient physical habitat, low DO, and, to a lesser extent, high suspended sediment. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.7 South Branch of the Snake River (AUID 544)

Physical setting

AUID 544 represents the segment of the original channel of the South Branch of the Snake River (Figure 36) from its confluence with JD 25-1, to its confluence with the Snake River; a total length of three miles. The reach has a subwatershed area of 42 square miles (26,690 acres). The subwatershed contains 27 miles of intermittent stream (which includes AUID 544) and 13 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 34% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded); the entire length of AUID 544 is classified as natural. The NLCD 2011 (USGS, 2011) lists cultivated crops (93%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included developed (3%), forest (2%), hay/pasture (1%), and wetlands (1%).

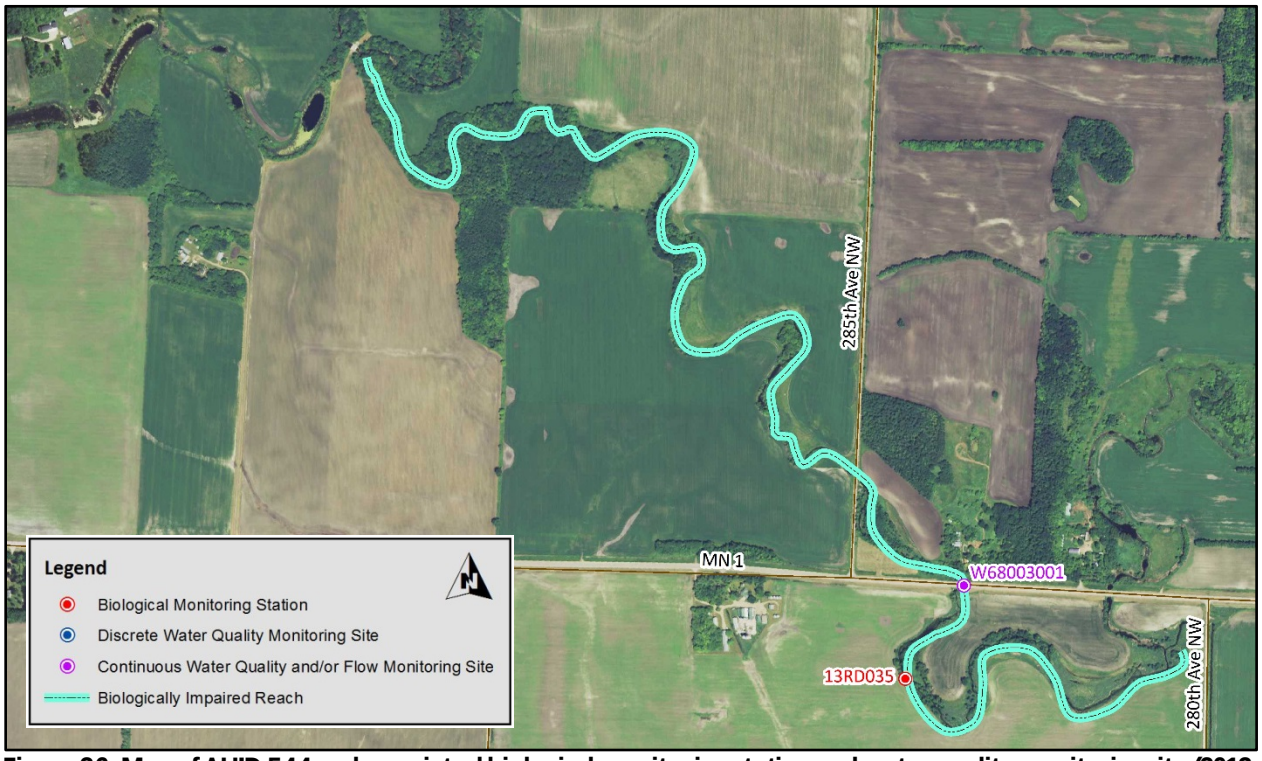


Figure 36. Map of AUID 544 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 544 was monitored at Station 13RD035 (0.2 mile upstream of the State Highway 1 crossing) on August 5, 2013. The location of the station is shown in Figure 36. The station was designated as General Use within the Low Gradient Streams FIBI Class. Accordingly, the impairment threshold for the station is an FIBI score of 42. Monitoring of the station yielded a FIBI score of 31. Overall, the fish assemblage of the station was dominated by tolerant taxa, specifically brook stickleback and fathead minnow.

Macroinvertebrate (MIBI)

The macroinvertebrate community of AUID 544 was monitored at Station 13RD035 on August 1, 2013. The station was designated as General Use within the Southern Streams-Riffle/Run Habitats MIBI Class. Accordingly, the impairment threshold for the station is an MIBI score of 37. Monitoring of the station

yielded a MIBI score (15) below the impairment threshold. The macroinvertebrate assemblage of the station was dominated by *Paratanytarsus* (midges).

Candidate causes

Loss of longitudinal connectivity

Available data

According to local water resource managers, beaver dams are common along AUID 544 (MPCA, 2015). The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD035 along AUID 544. According to the MDNR (2014), there are no man-made dams on the reach. However, the Warren Diversion Dam is located downstream of the reach along the Snake River (AUID 504). On July 1, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed the two road crossings on the reach as part of the assessment. A rock check dam (Figure 37) was noted immediately upstream of the State Highway 1 crossing. According to D. Omdahl, MSTRWD (personal communication, 2017), the check dam was temporarily placed in the channel as part of a sediment removal project and was later removed on September 1, 2015. In addition to the assessment, MPCA SID staff performed a detailed review of an April 29, 2016, aerial photo (courtesy of Google Earth) of the reach. A private road crossing (Figure 37) was identified immediately upstream of the confluence with the Snake River. According to D. Omdahl, MSTRWD (personal communication, 2017), the crossing has three large culverts and was permitted and installed as part of the Agassiz Valley Water Resource Management Impoundment project. Based upon the aerial photo, the crossing do not appear to be limiting connectivity. In summary, beaver dams, the Warren Storage Dam, and rock check dam are the only known potential obstructions to connectivity that may have been affecting the reach at the time of biological monitoring.

Figure 37. Images of connectivity barriers along AUID 544, including rock check dam upstream of the State Highway 1 crossing on July 1, 2015 (left); and a private road crossing near the confluence with the Snake River on April 29, 2016 (right), courtesy of Google Earth.

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 544:

- Below average (<10%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Station 13RD035 (0%)
- Below average (<13%) relative abundance of taxa that are migratory (MgrTxPct) at Station 13RD035 (10%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. However, there is no compelling evidence that the Warren Storage Dam (refer to Subsection 3.3.2) or rock check dam are responsible for the abovementioned metric responses. The flow condition at the time of fish monitoring at Station 13RD035 was described as "moderate", which likely would have enabled passage along the entire reach; during low flow periods, the rock check dam impedes connectivity. Additionally, there is insufficient information to determine if beaver dams and the culverts associated with road crossings (i.e., creating a velocity barrier during high flow conditions) are impeding fish passage. Therefore, the available data are inconclusive and *neither supports nor weakens* the case for loss of longitudinal connectivity as a stressor to the fish community of AUID 544.

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the MIBI impairment associated with AUID 544. Aquatic 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 MDNR (2003), AUID 544 has an intermittent flow regime. According to the MPCA (2013), 34% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded); the entire length of AUID 544 is classified as natural. The MPCA biological monitoring staff did not encounter any flow-related issues at Station 13RD035 along AUID 544. 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 0.8 (Q25) to less than 0.1 (Q75) cfs. Additionally, the estimated median flow (Q50) was 0.1 cfs, while the projected Q5 flow was 24.3 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 42:1, 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 three separate dates (i.e., July 1, 2015, July 15, 2015, and September 21, 2016) and documented flow conditions. Stagnant conditions were noted at the State Highway 1 crossing on July 1, 2015 (Figure 38). Additionally, while flow was noted along the reach on July 15, 2015 and September 21, 2016, all of the flow appeared to be derived from the Agassiz Valley Water Resource Management Impoundment (Figure 38), which is located approximately one-mile south of the reach. The impoundment has a gated storage capacity of 6,840 acre feet and discharges to an unnamed ditch that outlets to the upstream end of the reach. According to D. Omdahl, MSTRWD (personal communication, 2017), the elevation of the impoundment's gate is adjusted "according to flow events or downstream maintenance needs". Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Figure 38. Images of flow regime-related issues related to AUID 544, including stagnant conditions at the State Highway 1 crossing on July 1, 2015 (left); and the Agassiz Valley Water Resource Management Impoundment on September 21, 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 544:

- Above average (>62%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Station 13RD035 (90%)
- Above average (>35%) relative abundance of individuals that are generalists (GeneralPct) at Station 13RD035 (82%)
- Above average (>80%) relative abundance of individuals with a female mature age equal to or less than two years (MA<2Pct) at Station 13RD035 (96%)
- Below average (<0.95) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD035 (0.07)
- Above average (>14%) relative abundance of individuals that are pioneers (PioneerPct) at Station 13RD035 (75%)
- Above average (>23%) relative abundance of individuals that are short-lived (SLvdPct) at Station 13RD035 (91%)

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) *strongly supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 544:

- Below average (<43%) relative abundance of Ephemeroptera, Plecoptera, and Trichoptera individuals (EPTPct) at Station 13RD035 (0%)
- Below average (<9%) relative abundance of long-lived individuals (LongLivedPct) at Station 13RD035 (0%)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD035 (31)
- Above average (>72%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Station 13RD035 (94%)

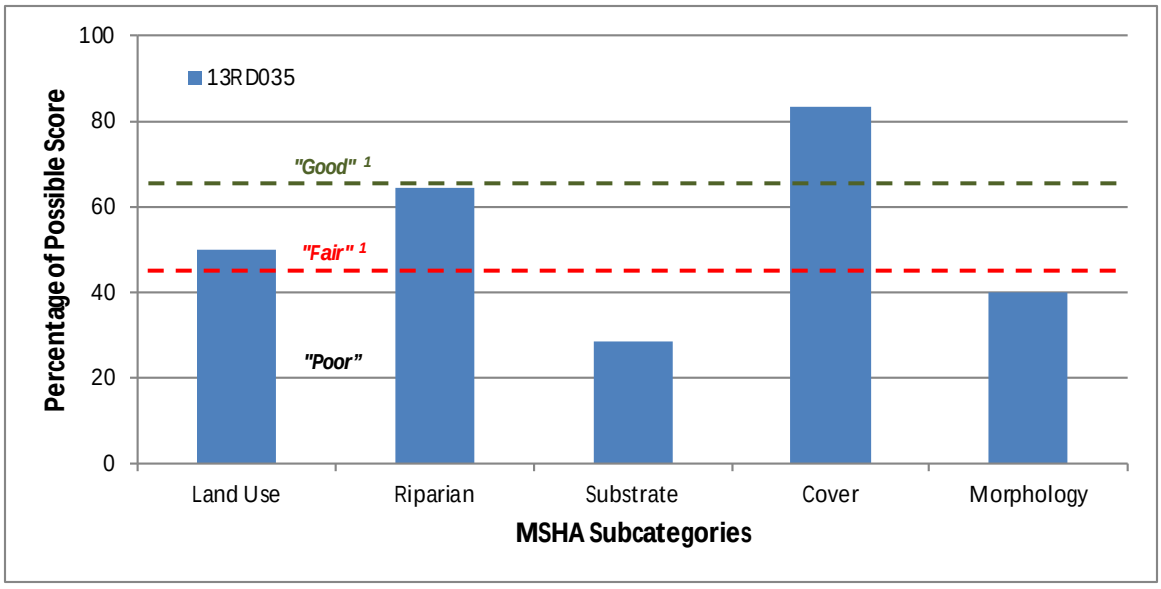
- Below average (<6%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Station 13RD035 (0%)

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; USEPA, 2012b). Additionally, the macroinvertebrate assemblage of the station was dominated by taxa that are adapted to lentic environments (i.e., *Paratanytarsus*).

Insufficient physical habitat

Available data

The physical habitat of AUID 544 was evaluated at Station 13RD035 using the MSHA. The station is located along a natural segment of the reach (MPCA, 2013). The station yielded a MSHA score of 48 ("fair"). Figure 39 displays the MSHA subcategory results for the station. The land use subcategory score for the station was limited by the predominance of agricultural row crops immediately surrounding the station. The station scored well in the riparian subcategory due to a "moderate" zone width and only a "little" amount of bank erosion. Conversely, the station had an exceptionally poor substrate score. The station lacked riffle habitat and had only limited coarse substrate (e.g., cobble and gravel). Additionally, the coarse substrate had a "severe" level of embeddedness. The station scored very well in the cover subcategory due to the diversity and "extensive" amount of cover present. Cover types noted included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, and woody debris. Lastly, the morphology subcategory score was adversely affected by "moderate" channel stability and "fair" channel development. In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by a lack of riffle habitat, limited coarse substrate, embeddedness, and inadequate 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 Station 13RD035 along AUID 544.

Clark and Vinje (2017) conducted a fluvial geomorphology assessment at Station 13RD035 along AUID 544 on July 14, 2015 (Appendix C). A summary of the assessment results is provided below:

> *"A Pfankuch stability assessment was completed at [Station 13RD035], but not a Level II survey. The stream was estimated to be an E6 stream type (low width-to-depth ratio, silt/clay bed stream), with*

a moderately unstable Pfankuch score of 75. The stream was not incised or entrenched through this reach, but the reach had been cleaned out in 2014. The scores for the channel bottom are likely what pushed the score into the moderately unstable category, as the bottom was fairly uniform and there were no discernable facets (which would be expected as a result of the clean out). The bottom was also very mucky, with abundant aquatic vegetation and slimy algae in water. There was good riparian vegetation establishing post-cleanout, but very poor buffer widths in most areas. There were 2 10' high x 10' wide concrete box culverts at the downstream of the site, and they did not appear to be barriers to fish passage. This is a highly altered system at this location, with the South Branch (upstream of this location) being ditched straight west to the Snake River mainstem. That ditch begins near 230th St NW and 200th Ave NW. During the reconnaissance visit (July 14, 2015) the natural channel did not appear to have any flow crossing [State Highway] 1 (north to south) but did have flow crossing back across CR 1 (south to north). Nearly all the flow appeared to be coming from a ditch on the east side of 280th Ave NW. There was an impoundment about one mile south."

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 544:

- Below average (<13%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Station 13RD035 (0%)
- Below average (<9%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Station 13RD035 (0%)
- Above average (>15%) relative abundance of individuals that are detritivorous (DetNWQPct) at Station 13RD035 (80%)
- Below average (<10%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 13RD035 (0%)
- Below average (<26%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Station 13RD035 (0%)
- Below average (<11%) relative abundance of individual that predominately utilize riffle habitats (RifflePct) at Station 13RD035 (3%)
- Below average (<24%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 13RD035 (3%)

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 544:

- Above average (>8%) relative abundance of burrower individuals (BurrowerPct) at Station 13RD035 (9%)
- Above average (>38%) relative abundance of legless individuals (LeglessPct) at Station 13RD035 (92%)

Burrower and legless macroinvertebrates are tolerant of degraded benthic habitat (i.e., excess fine sediment).

High suspended sediment

Available data

According to the MSTRWD (2011), the South Branch of the Snake River is prone to high sediment loads. Local water resource managers indicated that three separate sediment cleanouts have occurred along AUID 544 since 2009 (MPCA, 2016). The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD035 along AUID 544 at the time of the August 5, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 6 mg/L. The SRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L standard 53% 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 "severe" level of embeddedness of coarse substrate documented at Station 13RD035. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for high suspended sediment as a stressor to the fish community of AUID 544:

- Above average (>13 mg/L) mean TSS TIV at Station 13RD035 (24 mg/L)
- Below average (<80%) probability of meeting the TSS standard at Station 13RD035 (22%)

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 544:

- Below average (<26%) relative abundance of collector-filterer individuals (Collector-FiltererPct) at Station 13RD035 (5%)
- Below average (<5%) relative abundance of high TSS intolerant taxa at Station 13RD035 (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 13RD035 along AUID 544 at the time of fish and macroinvertebrate monitoring. Both measurement values (5.7 and 6.5 mg/L) were above the 5.0 mg/L standard. The MPCA conducted continuous DO monitoring at Site W68003001 (State Highway 1 crossing) from July 2, 2015, to July 15, 2015; the location of the site is shown in Figure 36. The monitoring results are provided in Table 19, as well as displayed in Figure 40. Approximately 14% of the total values and 17% of the daily minimum values were below the 5.0 mg/L standard. Additionally, the SRW HSPF model estimates that the reach did not have a DO concentration below the standard during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences occasional periods of low DO.

Table 19. Continuous DO data for Site W68003001 (2015; *n*=1246) along AUID 544.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 2, 2015 - July 15, 2015	1246	3.2	13.6	14	17	5.7

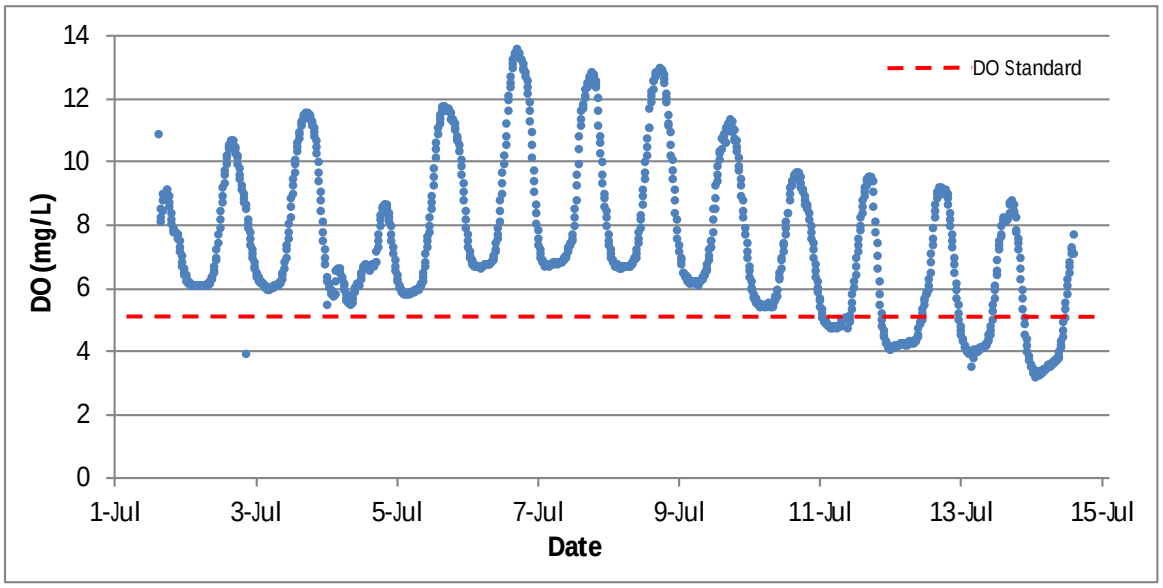


Figure 40. Continuous DO data for Site W68003001 (2015; *n*=1246) along AUID 544.

Eutrophication-related data for AUID 544 is limited to the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD035 along AUID 544 at the time of the August 5, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TP. The station had a TP concentration of 89 µg/L; the South River Nutrient Region TP standard is 150 µg/L. The mean daily DO flux documented during continuous DO monitoring at Site W68003001 (Table 19) was 5.7 mg/L, which is above the 4.5 mg/L South River Nutrient Region DO flux standard. Also, the MPCA biological monitoring staff noted that all of the instream habitats sampled during the August 1, 2013, macroinvertebrate monitoring visit at Station 13RD035 were "covered with long strands of algae". In addition, MPCA SID staff observed signs of eutrophication (i.e., excessive duckweed) at the State Highway 1 crossing on July 1, 2015 (Figure 38). Overall, the limited data and field observations suggest that eutrophication may be 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 544:

- Below average (<6.4 mg/L) mean DO TIV at Station 13RD035 (6.1 mg/L)
- Below average (<26%) probability of meeting the DO standard at Station 13RD035 (14%)

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for low DO as a stressor to the macroinvertebrate community of AUID 544:

- Above average (>7) Hilsenhoff's Biotic Index value (HBI_MN) at Station 13RD035 (9)

- Below average (<11) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Station 13RD035 (1)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD035 (31)
- Below average (<7.1 mg/L) mean DO TIV at Station 13RD035 (6.0 mg/L)
- Above average (>9%) relative abundance of low DO tolerant taxa at Station 13RD035 (68%)
- Below average (<24%) relative abundance of low DO intolerant taxa at Station 13RD035 (0%)

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; USEPA, 2012b).

Summary of stressors

The evidence suggests that the FIBI impairment associated with AUID 544 is attributed to flow regime instability, insufficient physical habitat, high suspended sediment, and, to a lesser extent, low DO. Additionally, the evidence indicates that the MIBI impairment is likely the result of flow regime instability, low DO, and, to a lesser extent, insufficient physical habitat and high suspended sediment. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.8 Middle River (AUID 538)

Physical setting

AUID 538 represents the segment of the Middle River from its headwaters, to the upstream end of AUID 539 (Figure 41); a total length of seven miles. The reach has a subwatershed area of 39 square miles (25,014 acres). The subwatershed contains 30 miles of intermittent drainage ditch, seven miles of intermittent stream (i.e., AUID 538), and one mile of river (MDNR, 2003). According to the MPCA (2013), 91% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 73% of AUID 538. The NLCD 2011 (USGS, 2011) lists cultivated crops (47%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (22%), forest (19%), hay/pasture (6%), and developed (4%).

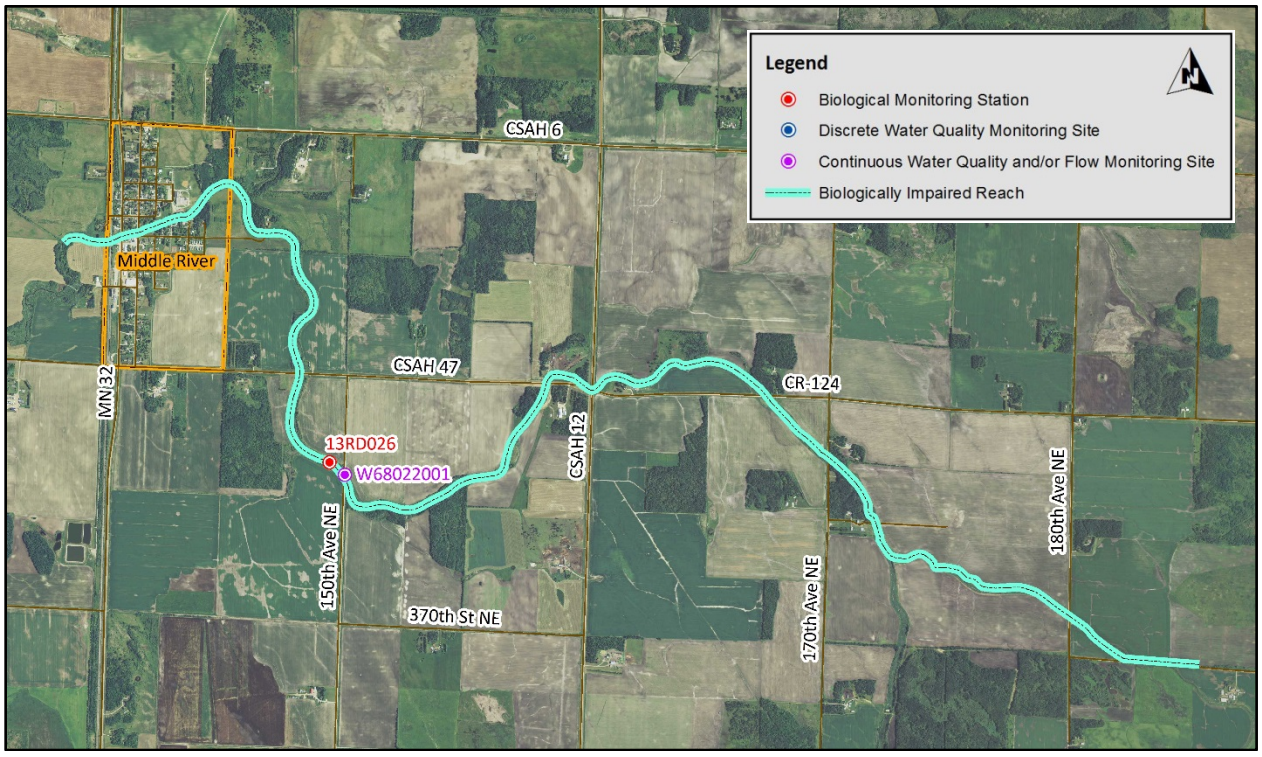


Figure 41. Map of AUID 538 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 538 was monitored at Station 13RD026 (0.1 mile downstream of the 150th Avenue NE crossing) on June 12, 2013. The location of the station is shown in Figure 41. The station was designated as Modified Use within the Low Gradient Streams FIBI Class. Accordingly, the impairment threshold for the station is an FIBI score of 15. Monitoring of the station yielded a FIBI score of 39. Overall, the station had a very limited sample population (<25 individuals) that was comprised of seven species (i.e., brassy minnow, central mudminnow, fathead minnow, finescale dace, northern redbelly dace, pearl dace, and white sucker).

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 13RD026 along AUID 538. According to the MDNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. On September 23, 2015, 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 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 29, 2016, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo. In summary, there were no known obstructions to connectivity along the reach at the time of biological monitoring.

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 538:

- Below average (<10%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Station 13RD026 (0%)

Late maturing fish species 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 response. 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

The Middle River has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge (MSTRWD, 2011). Additionally, the MDNR (2003) has classified the flow regime of AUID 538 as intermittent. Groshens (2007) attributed the river's flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. According to the MPCA (2013), 91% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 73% of AUID 538. The MPCA biological monitoring staff was unable to sample Station 13RD026 for macroinvertebrates on August 6, 2013 due to the absence of flow (Figure 42). 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 1.1 (Q25) to less than 0.1 (Q75) cfs. Additionally, the estimated median flow (Q50) was 0.2 cfs, while the projected Q5 flow was 27.6 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 41:1, 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., July 1, 2015, July 15, 2015, September 23, 2016, and October 10, 2016) and documented flow conditions. Lentic conditions were noted along the reach on July 1, 2015, September 23, 2015 (Figure 42), and October 10, 2016. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

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 538:

- Above average (>80%) relative abundance of individuals with a female mature age equal to or less than two years (MA<2Pct) at Station 13RD026 (89%)
- Below average (<0.95) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD026 (0.04)
- Above average (>23%) relative abundance of individuals that are short-lived (SLvdPct) at Station 13RD026 (37%)

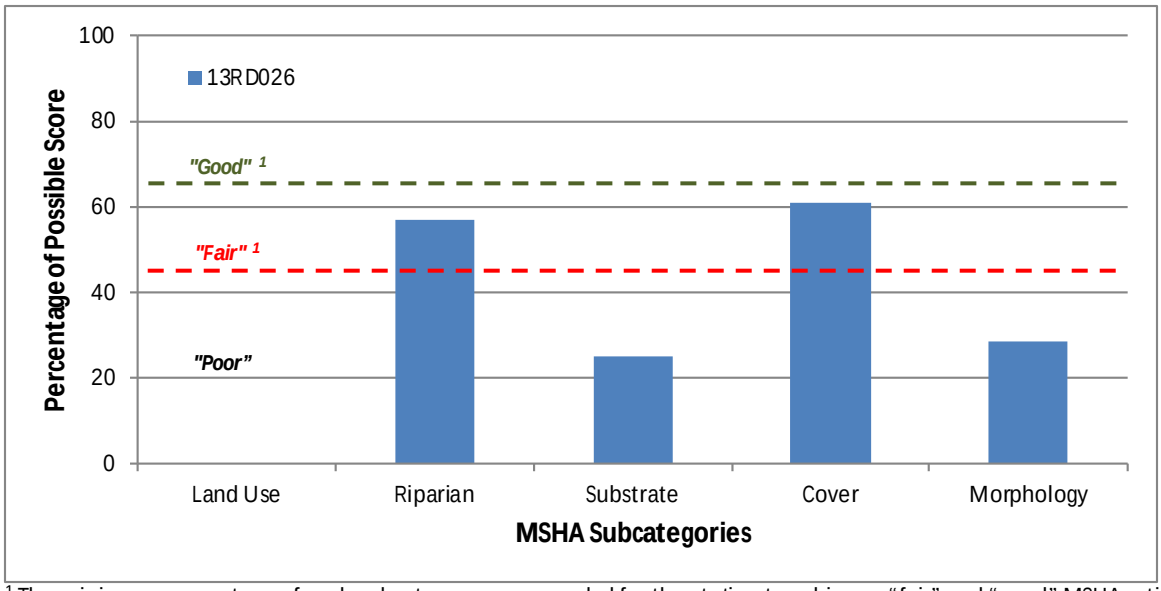
Flow regime instability tends to limit species diversity and favor taxa that are early maturing, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Figure 42. Images of flow intermittency at the 150th Avenue NE crossing along AUID 538, including a dry channel on August 6, 2013 (left); and lentic conditions on September 23, 2015 (right).

Insufficient physical habitat

Available data

The physical habitat of AUID 538 was evaluated at Station 13RD026 using the MSHA. The station is located along a channelized segment of the reach (MPCA, 2013). The station yielded a MSHA score of 36 ("poor"). Figure 43 displays the MSHA subcategory results for the station. The station had a score of zero in the land use subcategory due to the predominance of agricultural row crops immediately surrounding the station. The station scored well in the riparian subcategory due to a "moderate" zone width and no bank erosion. Conversely, the station had an exceptionally poor substrate score. The station lacked riffle habitat and coarse substrate (e.g., cobble and gravel). The station scored well in the cover subcategory due to the "extensive" amount of cover present. However, the only cover type noted was macrophytes (emergent, floating leaf, and submergent). Lastly, the morphology subcategory score was adversely affected by "poor" channel development. In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by a lack of riffle habitat and coarse substrate, cover diversity, and inadequate channel development.



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

Figure 43. MSHA subcategory results for Station 13RD026 along AUID 538.

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 538:

- Below average (<13%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Station 13RD026 (0%)
- Below average (<9%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Station 13RD026 (0%)
- Above average (>15%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Station 13RD026 (43%)
- Below average (<32%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Station 13RD026 (29%)
- Below average (<24%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 13RD026 (11%)

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

According to the MSTRWD (2011), the Middle River is prone to high sediment loads. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD026 along AUID 538 at the time of the June 12, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 4 mg/L. Additionally, the SRW HSPF model estimates that the reach had a TSS concentration in excess of the 30 mg/L standard between 32 and 35% of the time during the period of 1996 to 2009. 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 538:

- Above average (>13 mg/L) mean TSS TIV at Station 13RD026 (14 mg/L)
- Below average (<80%) probability of meeting the TSS standard at Station 13RD026 (77%)

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD026 along AUID 538 at the time of the June 12, 2013, fish monitoring visit. The station had a DO concentration of 10.8 mg/L. The MPCA conducted continuous DO monitoring at Site W68022001 (150th Avenue NE crossing) from July 1, 2015, to July 14, 2015; the location of the site is shown in Figure 41. The monitoring results are provided in Table 20, as well as displayed in Figure 44. Approximately 99% of the total values were below the standard, including all of the daily minimum values. A large rain event (≈2-3") interrupted the diurnal pattern on and after July 5, 2015. Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard approximately 2% 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.

Table 20. Continuous DO data for Site W68022001 (2015; *n*=1210) along AUID 538.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 1, 2015 - July 14, 2015	1210	0.0	5.1	99	100	2.2

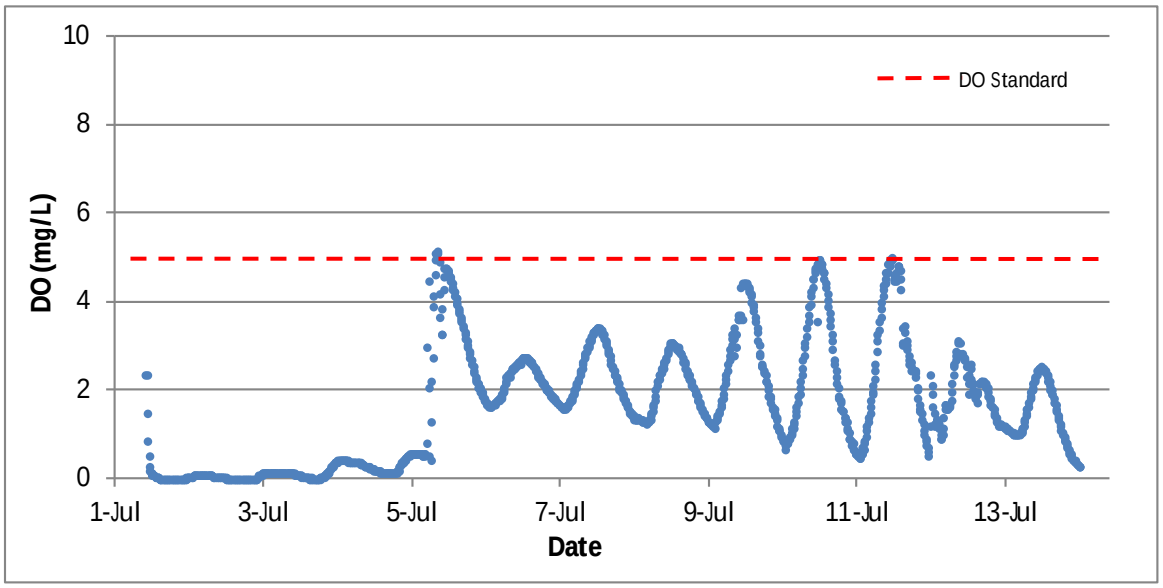


Figure 44. Continuous DO data for Site W68022001 (2015; *n*=1210) along AUID 538.

Eutrophication-related data for AUID 538 is limited to the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD026 along AUID 538 at the time of the June 12, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TP. The station had a TP concentration of 71 µg/L; the South River Nutrient Region TP standard is 150 µg/L. The mean daily DO flux documented during continuous DO monitoring at Site W68022001 (Table 20) was 2.2 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff observed signs of eutrophication (i.e., excessive algal and duckweed growth) along the downstream extent of the reach (starting at the 150th Avenue NE crossing) on July 1, 2015, September 23, 2015 (Figure 42), and October 10, 2016. Overall, the limited data do not suggest or deny that 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 538:

- Below average (<6.4 mg/L) mean DO TIV at Station 13RD026 (6.0 mg/L)
- Below average (<26%) probability of meeting the DO standard at Station 13RD026 (13%)

Summary of stressors

The evidence suggests that the FIBI impairment associated with AUID 538 is attributed to insufficient physical habitat, low DO, and, to a lesser extent, flow regime instability and high suspended sediment. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.9 Middle River (AUID 540)

Physical setting

AUID 540 represents the segment of the Middle River from the CR 114 crossing, to the upstream end of AUID 541 (Figure 45); a total length of 46 miles. The reach has a subwatershed area of 285 square miles (182,423 acres). The subwatershed contains 162 miles of intermittent drainage ditch, 106 miles of intermittent stream, 85 miles of river (which includes AUID 540), and 14 miles of perennial drainage ditch (MDNR, 2003). According to the MPCA (2013), 54% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded); the entire length of AUID 540 is classified as natural. The NLCD 2011 (USGS, 2011) lists cultivated crops (64%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (15%), forest (10%), hay/pasture (5%), and developed (5%).

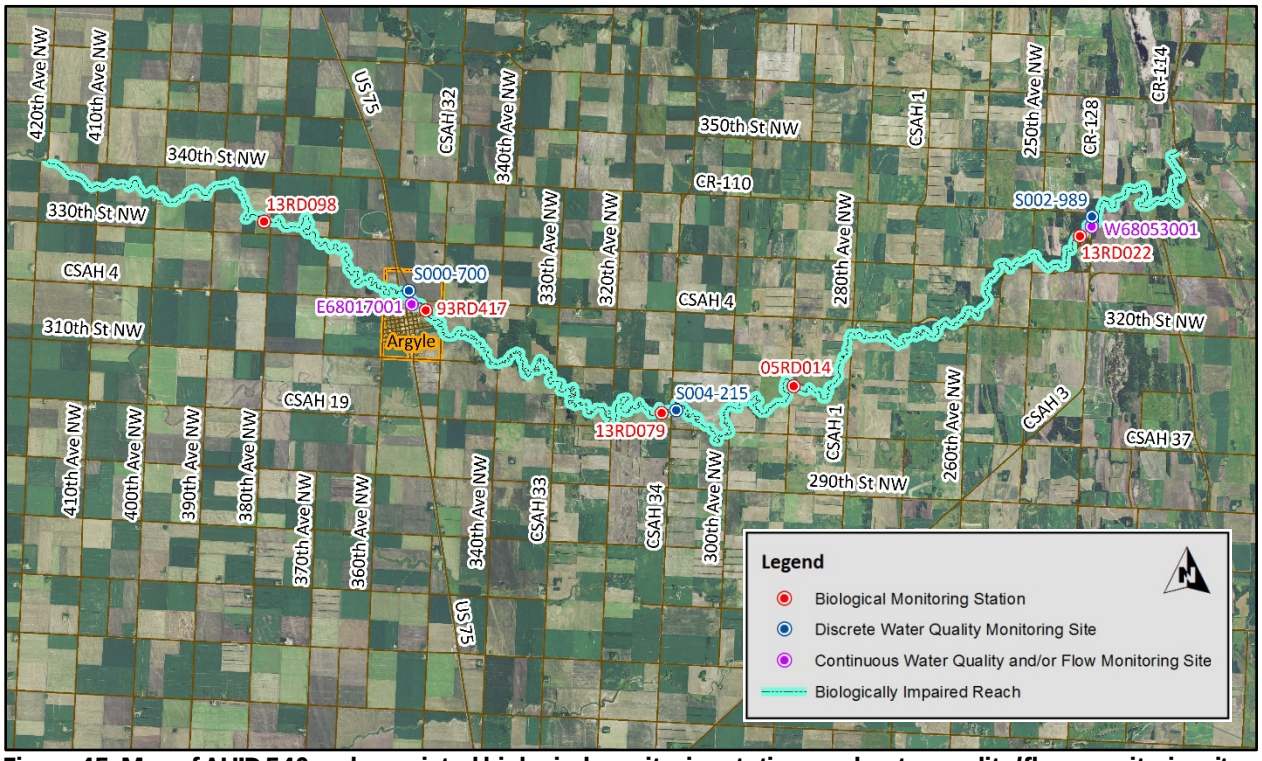


Figure 45. Map of AUID 540 and associated biological monitoring stations and water quality/flow monitoring sites (2013 NAIP aerial image).

Biological impairments

Macroinvertebrate (MIBI)

The macroinvertebrate community of AUID 540 was monitored at Station 05RD014 (0.1 mile upstream of the 290th Avenue NW crossing) on September 27, 2005; Station 13RD022 (0.4 mile downstream of the CR 128 crossing) on July 29, 2013(1) and August 6, 2013(2); Station 13RD079 (0.2 mile downstream of the CSAH 34 crossing) on August 7, 2013; Station 13RD098 (0.1 mile downstream of the 380th Avenue NW crossing) on August 6, 2013; and Station 93RD417 (0.7 mile upstream of the CSAH 4 crossing) on August 6, 2013. The location of each station is shown in Figure 45. Stations 13RD022, 13RD079, and 13RD098 were designated as General Use within the Southern Streams-Riffle/Run Habitats MIBI Class. The impairment threshold for these stations is an MIBI score of 37. Stations 13RD022(1) (MIBI=23), 13RD022(2) (MIBI=31), 13RD079 (MIBI=27), and 13RD098 (MIBI=36) each scored below the impairment threshold. Stations 05RD014 and 93RD417 were designated as General Use within the Prairie Streams-Glide/Pool Habitats MIBI Class. Accordingly, the impairment threshold for this station is an MIBI score of

41. Stations 05RD014 (MIBI=60), 93RD417(1) (MIBI=57), and 93RD417(2) (MIBI=54) each scored substantially above the impairment threshold. The macroinvertebrate assemblage of the stations was dominated by tolerant taxa, specifically, *Caenis* (mayflies), *Hydroptila* (caddisflies), Oligochaeta (worms), *Physa* (snails), and *Polypedilum* (midges).

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 05RD014, 13RD022, 13RD079, 13RD098, and 93RD417 along AUID 540. According to the MDNR (2014), there are no existing man-made dams on the reach or between the reach and the Red River of the North. According to Aadland (2010), two dams (i.e., Argyle Dam and Old Mill Dam) have been removed along the reach since 2001. On October 10, 2016, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed the lone road crossing on the reach 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 an April 29, 2016, aerial photo (courtesy of Google Earth) of the reach. A private road crossing was identified near 390th Avenue NW. The crossing appeared to have an undersized culvert that was likely altering stream flow and potentially limiting connectivity. According to D. Omdahl, MSTRWD (personal communication, 2017), a reconstruction of the crossing was permitted and completed near the end of 2016. The crossing now has two large concrete box culverts. In summary, the private road crossing was the only known potential obstruction to connectivity that may have been affecting the reach at the time of biological monitoring.

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the MIBI impairment associated with AUID 540. Aquatic macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

The Middle River has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge (MSTRWD, 2011). Groshens (2007) attributed the river's flow regime instability to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. According to the MPCA (2013), 54% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded); the entire length of AUID 540 is classified as natural. The MPCA biological monitoring staff did not encounter any flow-related issues at Stations 05RD014, 13RD022, 13RD079, 13RD098, and 93RD417 along AUID 540. The USGS has conducted continuous flow monitoring at Site E68017001 (CSAH 4 crossing) since 1945; the location of the site is shown in Figure 45. Table 21 presents the percentile flow values for the site. The highest mean daily peak flow recorded at the site was 4800.0 cfs, while the lowest flow was 0.0 cfs. Approximately 30% of the total mean daily flow values were less than 1.0 cfs. Figure 46 provides the 2013 and 2014 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 9.1 (Q25) to 0.3 (Q75) cfs. Additionally, the estimated median flow (Q50) was 1.4 cfs, while the projected Q5 flow was 169.0 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 34:1, 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 three separate dates (i.e., July 1, 2015, July 15, 2015, and October 10, 2016) and documented flow conditions. Bankfull conditions were noted at the CR 128 crossing on July 15, 2015 (Figure 47). The area received approximately five inches of rainfall during the 10 days prior to the visit. Additionally, a Google Earth Street View image captured at the CSAH 4 crossing in August 2012 shows a nearly dry stream channel (Figure 47). Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

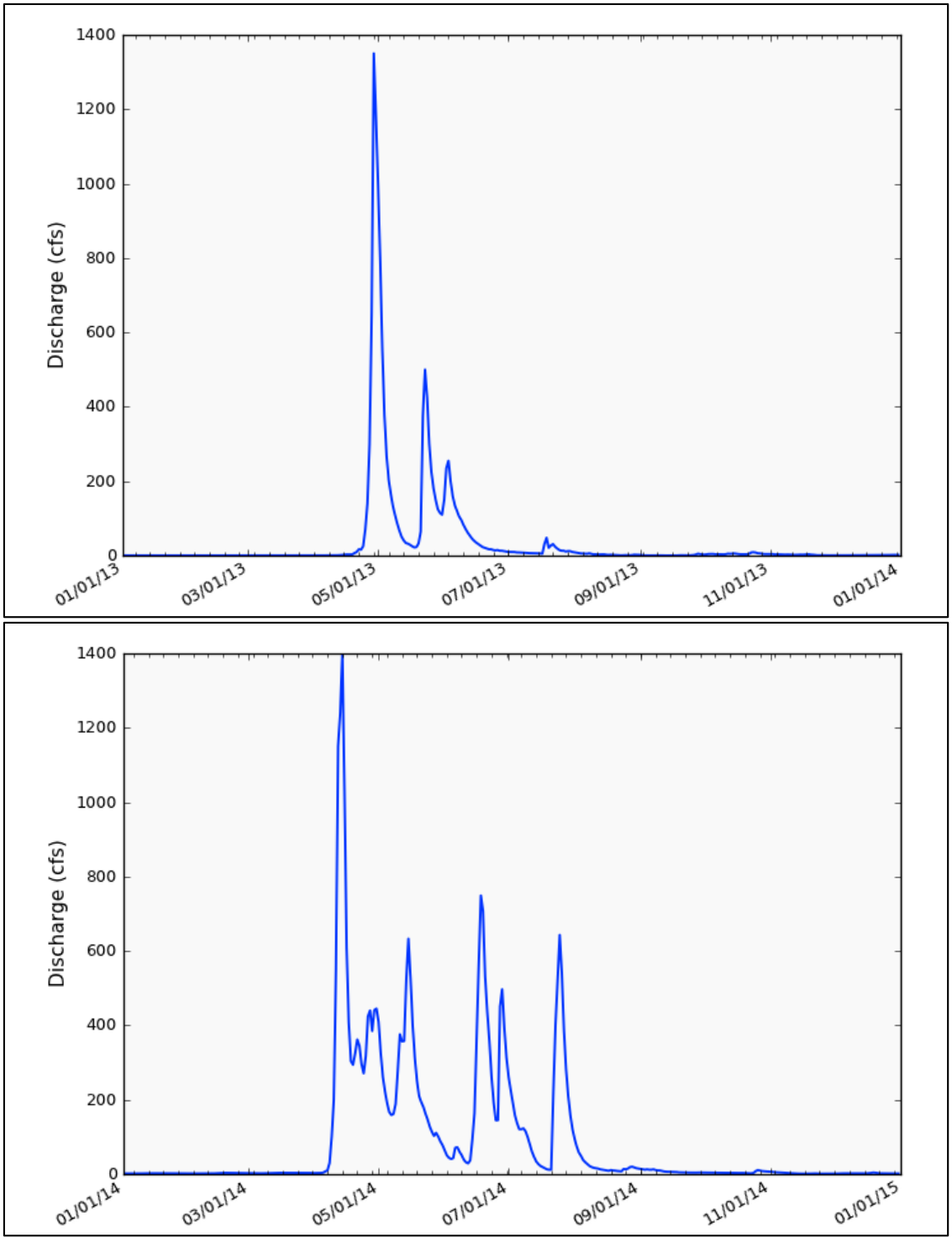


Figure 46. Annual (2013 and 2014) hydrographs for Site E68017001 along AUID 540.

Table 21. Percentile flow values for Site E68017001 (1945-2016; *n*=23950) along AUID 540.

Date range	*n*	Percentile values – Mean daily discharge (cfs)						
		5th	10th	20th	40th	60th	80th	100th
1945-2016	23950	0.0	0.0	0.3	2.0	7.0	40.0	4800.0

Figure 47. Images of stage variability along AUID 540, including a nearly dry channel at the CSAH 4 crossing during August 2012 (left), courtesy of Google Earth; and bankfull conditions at the CR 128 crossing on July 15, 2016 (right).

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 540:

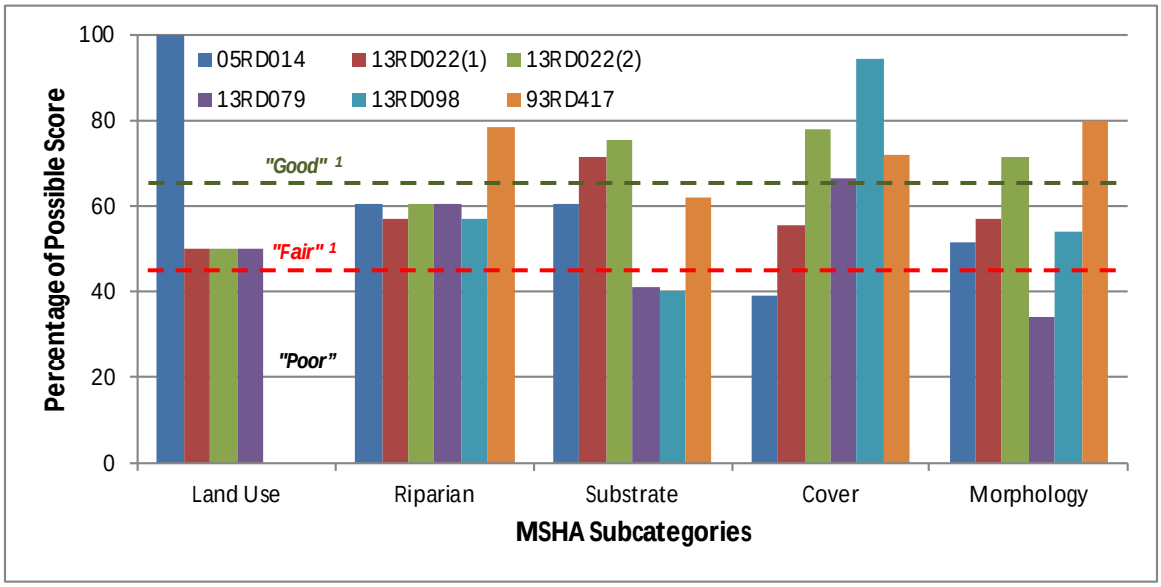
- Below average (<43/37%) relative abundance of Ephemeroptera, Plecoptera, and Trichoptera individuals (EPTPct) at Stations 13RD022(1) (27%), 13RD022(2) (31%), 13RD079 (6%), 13RD098 (30%), and 93RD417(1) (32%)
- Below average (<9/8%) relative abundance of long-lived individuals (LongLivedPct) at Stations 05RD014 (2%), 13RD022(1) (1%), 13RD022(2) (2%), 13RD079 (1%), 13RD098 (7%), 93RD417(1) (6%), and 93RD417(2) (3%)
- Below average (<43/38) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 13RD022(1) (30), 13RD022(2) (40), and 13RD079 (34)
- Above average (>72/81%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Stations 13RD022(1) (77%), 13RD022(2) (85%), 13RD079 (82%), and 13RD098 (85%)
- Below average (<6/5%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Stations 05RD014 (3%), 13RD022(1) (2%), 13RD079 (2%), and 13RD098 (5%)

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; USEPA, 2012b). Additionally, the macroinvertebrate assemblage of the stations had a large composition of taxa that are adapted to lentic environments (e.g., *Caenis* and *Physa*).

Insufficient physical habitat

Available data

The physical habitat of AUID 540 was evaluated at Stations 05RD014, 13RD022, 13RD079, 13RD098, and 93RD417 using the MSHA. The entire length of the reach is considered natural (MPCA, 2013). The MSHA scores for Stations 05RD014 (55/"fair"), 13RD022 (61/"fair" and 71/"good"), 13RD079 (46/"fair"), 13RD098 (55/"fair"), and 93RD417 (69/"fair") exhibited no spatial trend. Figure 48 displays the MSHA subcategory results for the stations. The land use subcategory score for Stations 13RD022, 13RD079, 13RD098, and 93RD417 was limited by the predominance of agricultural row crops in the immediate vicinity of the stations. All stations scored well in the riparian subcategory due to a "moderate" to "extensive" zone width. However, a substantial amount of bank erosion was noted at Stations 13RD022, 13RD079, 13RD098, and 93RD417. Stations 05RD014, 13RD022, and 93RD417 scored well in the substrate subcategory, offering riffle habitat and coarse substrate (e.g., cobble and gravel) with only a "light" amount of embeddedness. Conversely, Stations 13RD079 and 13RD098 had poor scores for this subcategory due to a lack of riffle habitat and a "moderate" to "severe" level of embeddedness. With the exception of Station 05RD014, each of the stations scored well in the cover subcategory due to the diversity and "moderate" to "extensive" amount of cover present. Common cover types noted along the reach included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, rootwads, undercut banks, and woody debris. Lastly, the morphology subcategory score for the Station 13RD079 was adversely affected by "low" channel stability and "poor" channel development. In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by bank erosion, embeddedness, and inadequate channel development.



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

Figure 48. MSHA subcategory results for Stations 05RD014, 13RD022, 13RD079, 13RD098, and 93RD417 along AUID 540.

Clark and Vinje (2017) conducted fluvial geomorphology assessments at Stations 93RD417 and 13RD079 along AUID 540 in 2014. The results of these assessments are provided in Appendix C, as well as summarized below:

> *"A Rosgen Level II survey and a Pfankuch stability assessment were conducted at [Station 93RD417]. The river at this location was classified as an F5 stream type (high width-to-depth ratio, entrenched, sand bed stream). A dam on the Middle River was removed and replaced with grade control*

structures in 2007. The Pfankuch rating for this site was 103, which is good for an F5 stream type. However, F stream types located in this valley type are considered unstable. The stable channel type in this location would likely be a C or E. A C5 stream type with a Pfankuch score of 103 would be moderately unstable, and an E5 would be unstable. Most Pfankuch categories rated as fair, reflecting the relatively unstable nature of this reach. There were some bankfull benches present, but for the most part this reach was both incised and entrenched. Excess stress on the banks due to the incision and entrenchment were leading to some mass erosion issues on the upper banks, as well as cutting on the lower banks. In the stream bed, excessive, loose sand deposition was evident. Despite the sand deposition, the pools were scouring out and had sufficient depth/holding cover at the time of the survey. Investigation of some of the road crossings downstream indicated potential crossing issues at 380th Ave NW, 390th Ave NW, and a private crossing downstream of 390th Ave NW."

"A Pfankuch stability assessment was completed at [Station 13RD079], but not a Level II survey. With an estimated width-to-depth ratio of approximately 12, this reach had the potential to be a C or E stream type, but was likely an F5 stream type (high width-to-depth ratio, entrenched, sand bed stream) at the time of the site visit. The Pfankuch score was 117, which is poor for C5 and E5 channels and fair for F5 channels; however, F5 channels in this valley type are considered unstable. Excess stress on the banks due to incision and entrenchment were leading to some mass erosion issues on the upper banks, as well as cutting on the lower banks. In the stream bed, excessive, loose sand deposition was evident. Even though this reach had a well vegetated riparian corridor lined with large, deep rooted trees, the banks were still eroding. There was also a lot of large woody debris in the channel."

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 540:

- Above average (>8/9%) relative abundance of burrower individuals (BurrowerPct) at Stations 13RD022(1) (37%), 13RD098 (30%), 93RD417(1) (14%), and 93RD417(2) (11%)
- Below average (<22%) relative percentage of climber individuals (ClimberPct) at Stations 05RD014 (15%) and 93RD417(2) (21%)
- Below average (<48%) relative percentage of clinger individuals (ClingerPct) at Stations 13RD022(1) (32%), 13RD079 (13%), and 13RD098 (15%)
- Above average (>38/42%) relative abundance of legless individuals (LeglessPct) at Stations 13RD022(1) (72%), 13RD022(2) (65%), 13RD079 (90%), 13RD098 (60%), 93RD417(1) (59%), and 93RD417(2) (46%)

Climber and clinger taxa require clean, coarse substrate or other objects to attach themselves to, while burrower and legless macroinvertebrates are tolerant of degraded benthic habitat (i.e., excess fine sediment).

High suspended sediment

Available data

According to the MSTRWD (2011), the Middle River is prone to high sediment loads. The reach has an existing turbidity impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD014, 13RD022, 13RD079, 13RD098, and 93RD417 along AUID 540 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 22 mg/L. Table 22 summarizes all available discrete TSS data for Sites S000-700 (CSAH 4 crossing), S002-989 (CSAH 39 crossing), and S004-215 (CSAH 34 crossing); the location of each site is shown in Figure 45.

Each of the sites had multiple TSS values that exceeded the 65 mg/L standard, as well as a high maximum value (≥102 mg/L). Site S000-700 had the highest proportion of values that exceeded the standard (28%). The SRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 2 and 26% 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 13RD079 and 13RD098. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment. According to Clark and Vinje (2017), mass erosion caused by incision and entrenchment is a contributing source of excess sediment to the reach. Figure 49 shows images of sediment-related issues associated with the reach, including streambank instability and the confluence of the Middle River (light brown colored due to high TSS) and the Snake River (dark colored due to relatively low TSS).

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 540:

- Below average (<26/18%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Stations 05RD014 (11%), 13RD022(1) (23%), 13RD022(2) (21%), 13RD079 (4%), 13RD098 (15%), and 93RD417(2) (16%)
- Above average (16 mg/L) mean TSS TIV at Stations 13RD079 (18 mg/L) and 13RD098 (19 mg/L)
- Above average (>35%) relative abundance of high TSS tolerant taxa at Stations 13RD079 (73%) and 13RD098 (52%)
- Below average (<5/3%) relative abundance of high TSS intolerant taxa at Stations 05RD014 (2%), 13RD022(1) (1%), 13RD022(2) (2%), 13RD079 (0%), 13RD098 (0%), 93RD417(1) (2%), and 93RD417(2) (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).

Table 22. Discrete TSS data for Sites S000-700 (1980-2015; *n*=99), S002-989 (1998-2006; *n*=42), and S004-215 (1998-2000; *n*=18) along AUID 540.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S000-700	1980-2015	99	2	308	45	28
S002-989	1998-2006	42	1	184	17	3
S004-215	1998-2000	18	2	102	30	3

Figure 49. Images of sediment-related issues associated with AUID 540, including bank erosion at Station 93RD417 on October 20, 2014 (upper left), courtesy of Clark and Vinje (2017); bank erosion along an unnamed ditch tributary at the 330th Street NW and 370th Avenue NW crossing (upper right), courtesy of Clark and Vinje (2017); bank erosion near 310th Street NW (lower left), courtesy of Google Earth; and the confluence of the Middle River (light brown colored due to high TSS) and the Snake River (dark colored due to relatively low TSS) (lower right), courtesy of Google Earth.

Low dissolved oxygen

Available data

The reach has an existing DO impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a combined 12 discrete DO measurements at Stations 05RD014, 13RD022, 13RD079, 13RD098, and 93RD417 along AUID 540 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 6.4 to 12.5 mg/L. While none of the values were below the 5.0 mg/L standard, Station 13RD022 had an extremely high DO concentration (12.5 mg/L) and saturation percentage (153%) at the time of the July 29, 2013, fish and macroinvertebrate monitoring visit. Such elevated DO conditions are commonly caused by excessive aquatic plant (i.e., algae and submergent macrophyte) growth. Figure 50 displays all available discrete DO data for Sites S000-700 (1980-2015; *n*=175), S002-989 (1998-2015; *n*=103), and S004-215 (1998-2012; *n*=47). Collectively, 5% of the DO values for the sites were below the 5.0 mg/L standard; however, only 22 of the measurements was collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. During this period, stream flow is usually low and water temperature is high. The MPCA conducted continuous DO monitoring at Site W68053001 (CR 128 crossing) from July 1, 2015, to July 5, 2015; the location of the site is shown in Figure 45. The monitoring results are provided in Table 23, as well as displayed in Figure 51. None of the DO measurements within the monitoring period were below the standard. Additionally, the SRW HSPF model estimates that the

reach had a DO concentration below the standard less than 1% 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.

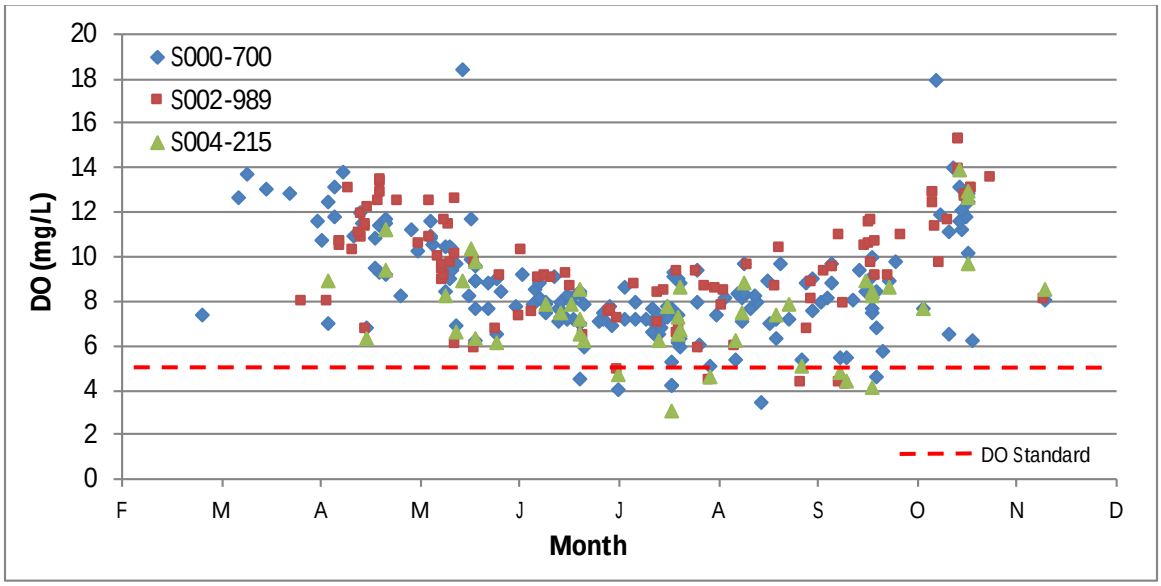


Figure 50. Discrete DO data for Sites S000-700 (1980-2015; *n*=175), S002-989 (1998-2015; *n*=103), and S004-215 (1998-2012; *n*=47) along AUID 540.

Table 23. Continuous DO data for Site W68053001 (2015; *n*=363) along AUID 540.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 1, 2015 - July 5, 2015	363	5.5	11.9	0	0	5.9

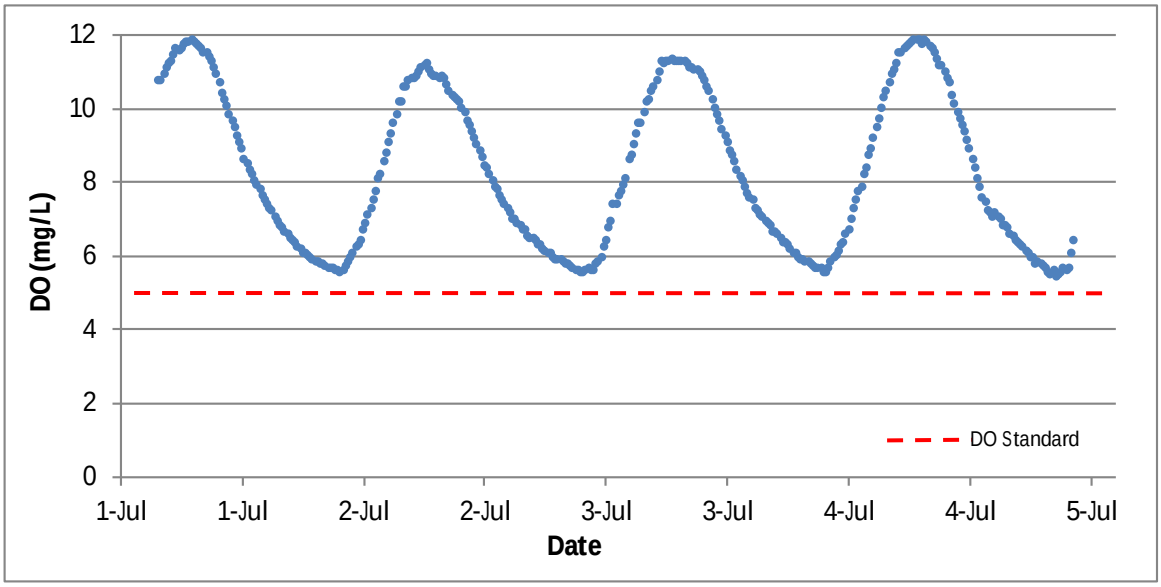


Figure 51. Continuous DO data for Site W68053001 (2015; *n*=363) along AUID 540.

Eutrophication-related data for AUID 540 is limited to the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD014, 13RD022, 13RD079, 13RD098, and 93RD417 along AUID 540 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 265 µg/L. Only one of the values exceeded the 150 µg/L South River Nutrient Region TP standard; Station 13RD098 had a concentration of 265 µg/L on June 25, 2013. Discrete TP data are available for Sites S000-700 (1980-2015; *n*=92), S002-989 (1998-2009; *n*=52), and S004-215 (1998-2000; *n*=18). Collectively, the mean TP concentration for the sites was 132 µg/L, while the highest concentration was 504 µg/L and the lowest concentration was 10 µg/L. Approximately 36% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. The mean daily DO flux documented during continuous DO monitoring at Site W68053001 (Table 23) was 5.9 mg/L, which is above 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 three separate reconnaissance visits along the reach (i.e., July 1, 2015, July 15, 2015, and October 10, 2016). Overall, the available data suggest that eutrophication may be 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 540:

- Above average (>7) Hilsenhoff's Biotic Index value (HBI_MN) at Stations 13RD022(2) (8), 13RD079 (9), and 13RD098 (8)
- Below average (<11/9) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Stations 13RD022(1) (7), 13RD022(2) (9), 13RD079 (5), 93RD417(1) (7), and 93RD417(2) (8)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Stations 13RD022(1) (30), 13RD022(2) (40), and 13RD079 (34)
- Below average (<7.1 mg/L) mean DO TIV at Stations 13RD022(1) (4.8 mg/L), 13RD022(2) (6.9 mg/L), 13RD079 (6.7 mg/L), and 13RD098 (6.9 mg/L)
- Above average (>9%) relative abundance of low DO tolerant taxa at Stations 13RD022(2) (17%), 13RD079 (12%), and 13RD098 (11%)
- Below average (<24/9%) relative abundance of low DO intolerant taxa at Stations 13RD022(1) (13%), 13RD022(2) (9%), 13RD079 (1%), 13RD098 (7%), and 93RD417(1) (5%)

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; USEPA, 2012b).

Summary of stressors

The evidence suggests that the MIBI impairment associated with AUID 540 is attributed to flow regime instability, insufficient physical habitat, high suspended sediment, and, to a lesser extent, low DO. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.10 Judicial Ditch 28 (AUID 529)

Physical setting

AUID 529 represents the segment of Judicial Ditch 28 from its confluence with an unnamed ditch, to its confluence with the Middle River (Figure 52); a total length of eight miles. The reach has a subwatershed area of 14 square miles (9,010 acres). The subwatershed contains 16 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 98% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 529. The NLCD 2011 (USGS, 2011) lists forest (42%) and wetlands (32%) as the predominant land cover groups in the subwatershed. Other notable land cover groups in the subwatershed included cultivated crops (14%), hay/pasture (8%), and developed (3%).

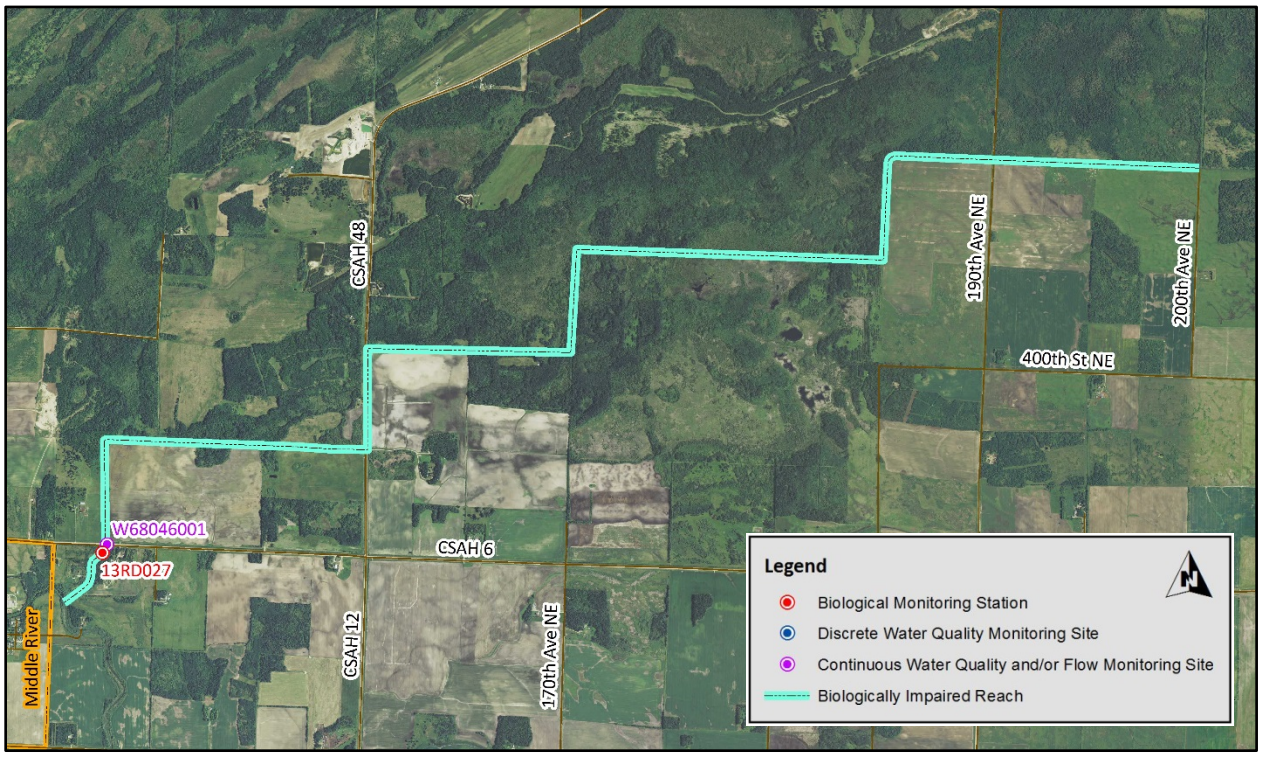


Figure 52. Map of AUID 529 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Macroinvertebrate (MIBI)

The macroinvertebrate community of AUID 529 was monitored at Station 13RD027 (0.1 mile downstream of the CSAH 6 crossing) on August 6, 2013. The location of the station is shown in Figure 52. The station was designated as Modified Use within the Southern Streams-Riffle/Run Habitats MIBI Class. Accordingly, the impairment threshold for the station is an MIBI score of 24. Monitoring of the station yielded a MIBI score (13) below the impairment threshold. The macroinvertebrate assemblage of the station was dominated by Oligochaeta (worms).

Candidate causes

Loss of longitudinal connectivity

Available data

According to local water resource managers, beaver dams are common along AUID 529 (MPCA, 2015). The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD027 along AUID 529. According to the MDNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. On September 23, 2015, 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. A beaver dam was identified downstream of the 190th Avenue NE crossing. The dam had an associated pool and appeared to be a complete barrier to connectivity at the time of discovery. The same beaver dam was present in a May 8, 2013, aerial photo (courtesy of Google Earth), which was acquired just a few months prior to macroinvertebrate monitoring. In addition to the assessment, MPCA SID staff performed a detailed review of an April 29, 2016, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo. In summary, the beaver dam was the only known potential obstruction to connectivity that may have been affecting the reach at the time of biological monitoring.

Biotic response – macroinvertebrate

There is *no evidence* of a causal relationship between a loss of longitudinal connectivity and the MIBI impairment associated with AUID 529. Aquatic 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 MDNR (2003), AUID 529 has an intermittent flow regime. According to the MPCA (2013), 98% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 529. The MPCA biological monitoring staff did not encounter any flow-related issues at Station 13RD027 along AUID 529. 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 0.5 (Q25) to less than 0.1 (Q75) cfs. Additionally, the estimated median flow (Q50) was 0.1 cfs, while the projected Q5 flow was 12.1 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 31:1, 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., July 1, 2015, July 15, 2015, September 23, 2015, August 19, 2016, September 1, 2016, and October 10, 2016) and documented flow conditions. Minimal flow (<≈0.5 cfs) was noted at the CSAH 6 crossing on September 23, 2015 and September 1, 2016. Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Biotic response – macroinvertebrate

The following evidence (Appendix B) *strongly supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 529:

- Below average (<43%) relative abundance of Ephemeroptera, Plecoptera, and Trichoptera individuals (EPTPct) at Station 13RD027 (0%)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD027 (27)

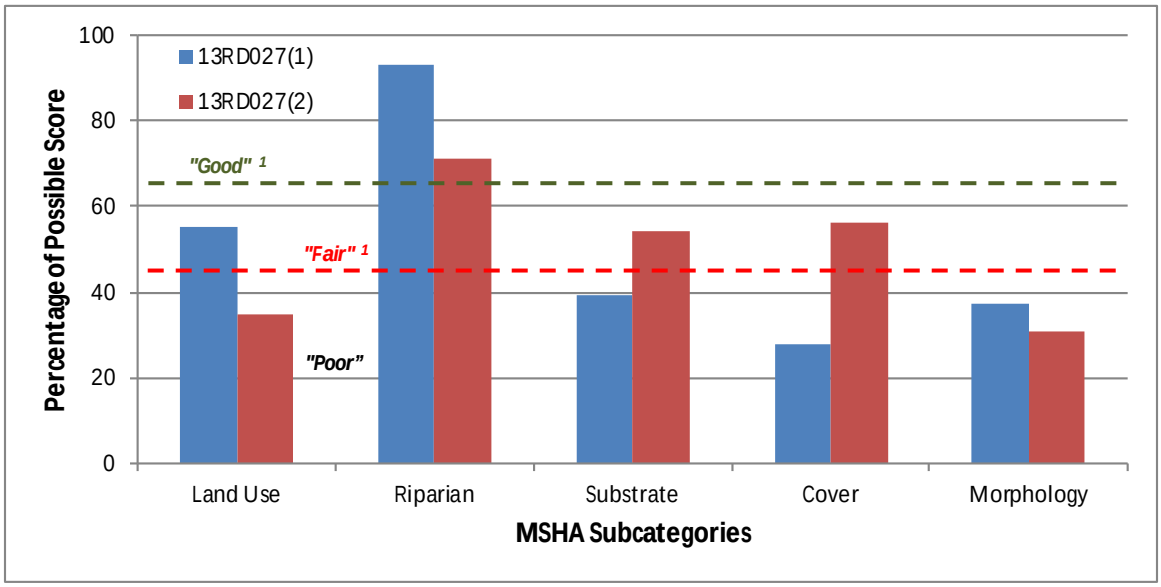
- Above average (>72%) relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct) at Station 13RD027 (93%)
- Below average (<6%) relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) at Station 13RD027 (0%)

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 tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; USEPA, 2012b). Additionally, the macroinvertebrate assemblage of the station was dominated by taxa that are adapted to lentic environments (i.e., Oligochaeta and *Physa*). The available data *strongly supports* the case for flow regime instability as a stressor to the macroinvertebrate community of AUID 529.

Insufficient physical habitat

Available data

The physical habitat of AUID 529 was evaluated at Station 13RD027 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded MSHA scores of 45 ("fair") and 48 ("fair"). Figure 53 displays the MSHA subcategory results for the station. The land use subcategory scores for station were limited by the predominance of agricultural row crops in the immediate vicinity of the station. The station scored well in the riparian subcategory due to a "moderate" to "extensive" zone width and "little" to no bank erosion. The substrate subcategory scores for the station were adversely affected by a lack of riffle habitat and coarse substrate (e.g., cobble and gravel). While the station offered a "moderate" amount of cover, the only cover types noted were submergent macrophytes, undercut banks, and woody debris. Lastly, the morphology subcategory scores were limited by "fair" to "poor" channel development. In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by a lack of riffle habitat and coarse substrate, cover diversity, and inadequate channel development.



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

Figure 53. MSHA subcategory results for Station 13RD027 along AUID 529.

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 529:

- Above average (>8%) relative abundance of burrower individuals (BurrowerPct) at Station 13RD027 (41%)
- Below average (<48%) relative percentage of clinger individuals (ClingerPct) at Station 13RD027 (22%)
- Above average (>38%) relative abundance of legless individuals (LeglessPct) at Station 13RD027 (70%)

Clinger taxa require clean, coarse substrate or other objects to attach themselves to, while burrower and legless macroinvertebrates are tolerant of poor benthic habitat that is dominated by fine sediment.

High suspended sediment

Available data

According to local water resource managers, a sediment cleanout was performed in 2015 on an approximately two mile segment of AUID 529, starting roughly one-half mile upstream of Station 13RD027 (MPCA, 2015). The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD027 along AUID 529 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The station had TSS concentrations of 5 and 8 mg/L. Additionally, the SRW HSPF model estimates that the reach had a TSS concentration in excess of the 30 mg/L standard 32% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

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 529:

- Below average (<26%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Station 13RD027 (10%)
- Below average (<5%) relative abundance of high TSS intolerant taxa at Station 13RD027 (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 three discrete DO measurements at Station 13RD027 along AUID 529 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 5.4 to 8.5 mg/L. The MPCA conducted continuous DO monitoring at Site W68046001 (CSAH 6 crossing) from August 19, 2016, to September 1, 2016; the location of the site is shown in Figure 52. The monitoring results are provided in Table 24, as well as displayed in Figure 54. None of the DO measurements within the monitoring period were below the standard. Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences very infrequent periods of low DO.

Table 24. Continuous DO data for Site W68046001 (2016; *n*=1245) along AUID 529.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 19, 2016 – September 1, 2016	1245	5.1	13.4	0	0	5.8

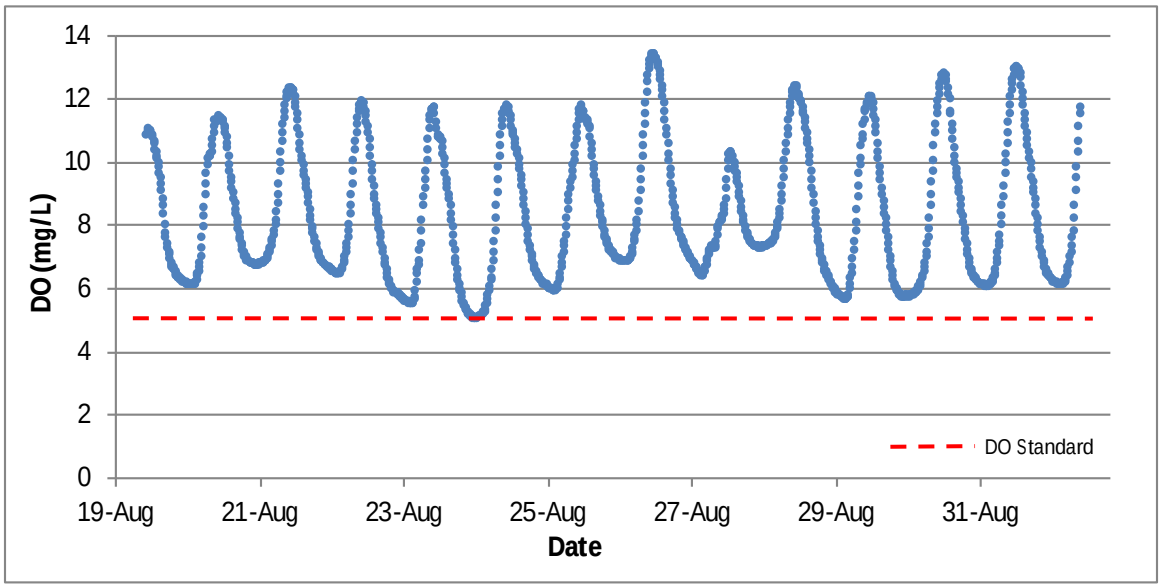


Figure 54. Continuous DO data for Site W68046001 (2016; *n*=1245) along AUID 529.

Eutrophication-related data for AUID 529 is limited to the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD027 along AUID 529 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TP. Both samples had a TP concentration of 25 µg/L; the South River Nutrient Region TP standard is 150 µg/L. The mean daily DO flux documented during continuous DO monitoring at Site W70030003 (Table 24) was 5.8 mg/L, which is well above the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff observed signs of eutrophication (i.e., excessive algal growth) at the 400th Street NE crossing on September 23, 2015. Overall, the limited response variable data and field observations suggest that eutrophication may be 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 529:

- Above average (>7) Hilsenhoff's Biotic Index value (HBI_MN) at Station 13RD027 (8)
- Below average (<11) taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at Station 13RD027 (1)
- Below average (<43) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD027 (27)
- Below average (<7.1 mg/L) mean DO TIV at Station 13RD027 (4.0 mg/L)
- Above average (>9%) relative abundance of low DO tolerant taxa at Station 13RD027 (14%)
- Below average (<24%) relative abundance of low DO intolerant taxa at Station 13RD027 (0%)

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; USEPA, 2012b).

Summary of stressors

The evidence suggests that the MIBI impairment associated with AUID 529 is attributed to flow regime instability, insufficient physical habitat, and, to a lesser extent, high suspended sediment and low DO. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

3.3.11 Judicial Ditch 29 (AUID 519)

Physical setting

AUID 519 represents Judicial Ditch 29 (Figure 55), which extends from its headwaters, to its confluence with the Snake River; a total length of 11 miles. The reach has a subwatershed area of 16 square miles (10,387 acres). The subwatershed contains 16 miles of intermittent drainage ditch (which includes AUID 519) and two miles of intermittent stream (MDNR, 2003). According to the MPCA (2013), 82% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 98% of AUID 519. The NLCD 2011 (USGS, 2011) lists cultivated crops (95%) as the predominant land cover in the subwatershed. The only other notable land cover group in the subwatershed was developed (4%).

Figure 55. Map of AUID 519 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (FIBI)

The fish community of AUID 519 was monitored at Station 13RD010 (0.1 mile downstream of the 480th Avenue NW crossing) on June 12, 2013. The location of the station is shown in Figure 55. The station

was designated as General Use within the Southern Headwaters FIBI Class. Accordingly, the impairment threshold for the station is an FIBI score of 55. Monitoring of the station yielded a FIBI score of 0. Overall, the fish assemblage of the station was nearly entirely comprised of fathead minnow; one northern pike was also sampled.

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 13RD010 along AUID 519. According to the MDNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. On September 21, 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. A rock check dam (Figure 56) was noted immediately downstream of the 480th Avenue NW crossing. The check dam is approximately two feet high and is a barrier to connectivity during low flow conditions. In addition to the assessment, MPCA SID staff performed a detailed review of an April 29, 2016, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo. In summary, the rock check dam was the only known potential obstruction to connectivity that may have been affecting the reach at the time of biological monitoring.

Figure 56. Images of a rock check dam at the 480th Avenue NW crossing along AUID 519 on July 1, 2015 (left) and September 21, 2016 (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 519:

- Below average (<5%) relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolTxPct) at Station 13RD010 (0%)
- Below average (<20%) relative abundance of taxa that are migratory (MgrTxPct) at Station 13RD010 (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. However, there is no compelling evidence that the rock check dam was responsible for the abovementioned metric responses. The dam is situated upstream of Station 13RD010 and there are no known obstructions to connectivity between the station and the Snake River; the confluence is located approximately one mile downstream.

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 local water resource managers, AUID 519 is prone to periods of intermittency (MPCA, 2015). Additionally, the MDNR (2003) has classified the flow regime of the reach as intermittent. According to the MPCA (2013), 82% of the watercourses in the subwatershed have been physically altered (i.e., channelized, ditched, or impounded), including 98% of AUID 519. The MPCA biological monitoring staff was unable to sample Station 13RD010 for macroinvertebrates on August 6, 2013 due to the absence of flow. (Figure 57). 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 0.4 (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 12.7 cfs and the Q95 flow was less than 0.1 cfs. The Q25 to Q75 flow values ratio was 60:1, 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 three separate dates (i.e., July 1, 2015, July 15, 2015, and September 21, 2016) and documented flow conditions. Minimal flow (<≈0.5 cfs) to no flow was noted along the entire reach on September 21, 2016 (Figure 57). Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Figure 57. Images of flow intermittency along AUID 519, including Station 13RD010 on August 6, 2013 (left); and the 390th Avenue NW crossing on September 21, 2016 (right).

Biotic response – fish

The following evidence (Appendix A) *convincingly supports* the case for flow regime instability as a stressor to the fish community of AUID 519:

- Above average (>72%) combined relative abundance of the three most abundant taxa (DomThreePct) at Station 13RD010 (100%)
- Above average (>58%) relative abundance of individuals that are generalists (GeneralPct) at Station 13RD010 (97%)
- Above average (>74%) relative abundance of individuals with a female mature age equal to or less than two years (MA<2Pct) at Station 13RD010 (100%)
- Below average (<0.65) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD010 (0.01)

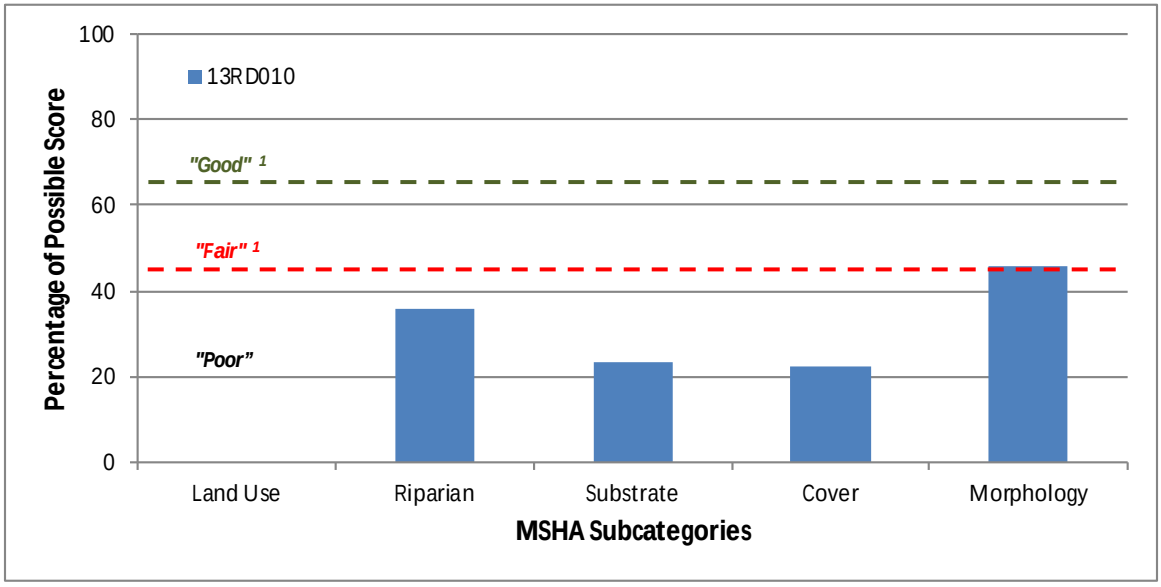
- Above average (>36%) relative abundance of individuals that are pioneers (PioneerPct) at Station 13RD010 (97%)
- Above average (>26%) relative abundance of individuals that are short-lived (SLvdPct) at Station 13RD010 (97%)

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 519 was evaluated at Station 13RD010 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded a MSHA score of 32 ("poor"). Figure 58 displays the MSHA subcategory results for the station. With the exception of the morphology subcategory, the station yielded a poor score for each of the subcategories. The station had a score of zero for the land use subcategory due to the predominance of agricultural row crops immediately surrounding the station. The riparian zone width of the station was characterized as "moderate" to "extensive", but a "severe" amount of bank erosion was noted. The station offered riffle habitat and a minimal amount of coarse substrate (i.e., gravel). However, the coarse substrate had a "severe" level of embeddedness. The station had a "sparse" amount of cover. The only cover type noted was deep pools. Lastly, the station had "moderate" channel stability and "good" channel development. In summary, the MSHA data suggest that the physical habitat of the reach is primarily limited by bank erosion, embeddedness, sparse cover, and cover diversity.



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

Figure 58. MSHA subcategory results for Station 13RD010 along AUID 519.

Biotic response – fish

The following evidence (Appendix A) *convincingly supports* the case for insufficient physical habitat as a stressor to the fish community of AUID 519:

- Below average (<19%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Station 13RD010 (0%)

- Below average (<15%) relative abundance of taxa that are darters and sculpins (DarterSculpTxPct) at Station 13RD010 (0%)
- Above average (>18%) relative abundance of individuals that are detritivorous (DetNWQPct) at Station 13RD010 (97%)
- Below average (<11%) relative abundance of taxa that are insectivorous Cyprinids (InsectCypTxPct) at Station 13RD010 (0%)
- Below average (<25%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Station 13RD010 (0%)
- Below average (<26%) relative abundance of individual that predominately utilize riffle habitats (RifflePct) at Station 13RD010 (0%)
- Below average (<32%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 13RD010 (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

According to local water resource managers, a sediment cleanout is performed on AUID 519 approximately every eight to ten years (MPCA, 2015). Additionally, D. Omdahl, MSTRWD (personal communication, 2017), noted that the ditch channel has degraded approximately four feet downstream of the 480th Avenue NW crossing, which has resulted in severe instability (Figure 56). The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD010 along AUID 519 at the time of the June 12, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 25 mg/L. The SRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L standard 45% 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 "severe" level of embeddedness of coarse substrate documented at Station 13RD010. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

Biotic response – fish

The following evidence (Appendix A) *strongly supports* the case for high suspended sediment as a stressor to the fish community of AUID 519:

- Above average (>15 mg/L) mean TSS TIV at Station 13RD010 (25 mg/L)
- Below average (<70%) probability of meeting the TSS standard at Station 13RD010 (15%)

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD010 along AUID 519 at the time of the June 12, 2013, fish monitoring visit. The station had a DO concentration of 6.2 mg/L. The MPCA conducted continuous DO monitoring at Site W68013001 (480th Avenue NW crossing) from July 1, 2015, to July 5, 2015; the location of the site is shown in Figure 55. The monitoring results are provided in Table 25, as well as displayed in Figure 59. None of the DO measurements within the monitoring period were below the standard. Additionally, the SRW HSPF model estimates that the reach had a DO concentration below the standard approximately 1% of the time during the period of

1996 to 2009. Overall, the available data suggest that the reach experiences very infrequent periods of low DO.

Table 25. Continuous DO data for Site W68013001 (2015; *n*=347) along AUID 519.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 1, 2015 - July 5, 2015	347	6.6	17.8	0	0	8.9

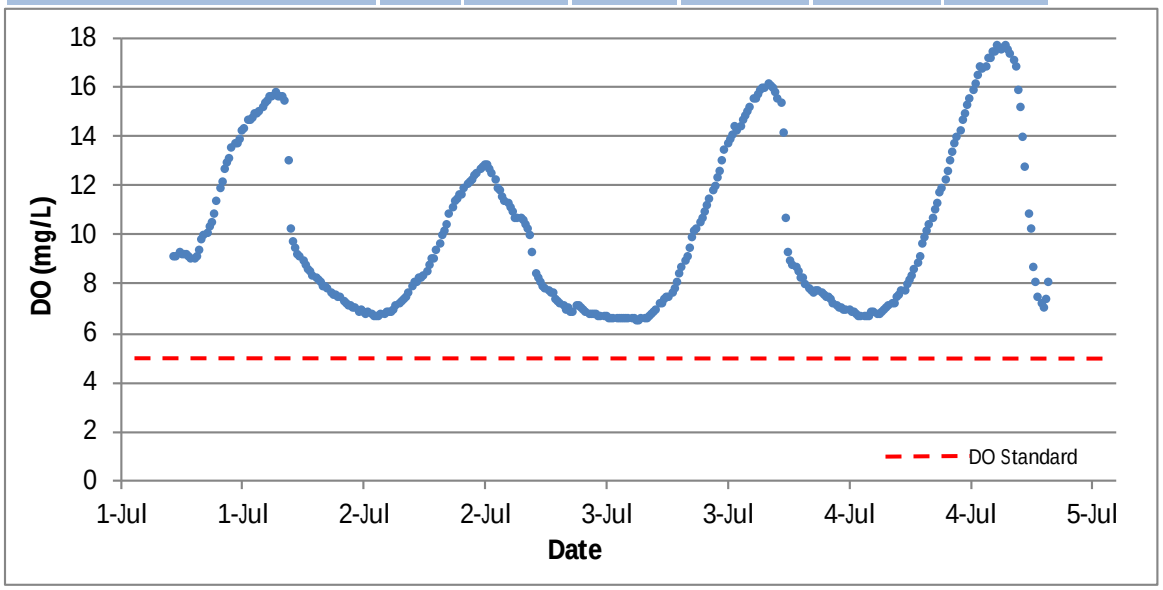


Figure 59. Continuous DO data for Site W68013001 (2015; *n*=347) along AUID 519.

Eutrophication-related data for AUID 519 is limited to the following parameters: TP and DO flux. The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD010 along AUID 519 at the time of the June 12, 2013, fish monitoring visit. The sample was analyzed for several parameters, including TP. The station had a TP concentration of 485 µg/L; the South River Nutrient Region TP standard is 150 µg/L. The mean daily DO flux documented during continuous DO monitoring at Site W68013001 (Table 25) was 8.9 mg/L, which is well above the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff observed signs of eutrophication (i.e., excessive algal growth) at the 430th Avenue NW crossing on September 21, 2016. Overall, the limited data and field observations suggest that eutrophication may be 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 519:

- Below average (<7.1 mg/L) mean DO TIV at Stations 13RD010 (6.1 mg/L)
- Below average (<53%) probability of meeting the DO standard at Station 13RD010 (15%)

Summary of stressors

The evidence suggests that the FIBI impairment associated with AUID 519 is attributed to flow regime instability, insufficient physical habitat, high suspended sediment, and, to a lesser extent, low DO. A summary of recommended actions to alleviate the influence of these stressors in provided in Section 4.2.

Section 4: Conclusions and recommendations

4.1 Conclusions

Table 26 presents a summary of the stressors associated with the biologically impaired reaches in the SRW. Several potential connectivity barriers (e.g., dams and private road crossings) were identified along the reaches. However, there is no conclusive evidence that these barriers are limiting the associated biotic communities. All 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., ditching and channelization) are the primary anthropogenic factors contributing to this flow regime instability. The central and eastern portions of the watershed generally offer the most diverse instream habitat, including coarse substrate and riffles. However, the effects of altered hydrology have degraded the habitat of several reaches in these areas. The habitat of the western portion of the watershed is inherently limited by the predominance of fine lacustrine sediment. Excess suspended sediment appears to be having a substantial effect on the biological communities of several impaired reaches. Soil and instream erosion are the primary sources of this sediment. Lastly, low DO is a stressor for each of the impaired reaches. While the severity of low DO conditions varies amongst the reaches, the lowest concentrations generally coincide with low flow and stagnant conditions that occur during the late summer (i.e., July, August, and September).

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.

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 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.

Other recommendations

- Further evaluate and remove/modify barriers (e.g., private road crossings) that are impeding connectivity.
- Collect additional eutrophication-related data for each of the reaches to better understand the relationship, if any, to low DO.

Table 26. Summary of the stressors associated with the biologically impaired reaches in the SRW.

AUID suffix	Reach name	Biological impairment(s)	Candidate causes[1]				
			Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
543	Snake River	FIBI	0	++	++	++	+++
		MIBI	NE	++	++	+	+++
504	Snake River	FIBI	0	++	++	++	+
		MIBI	NE	++	++	+	+
537	Snake River	FIBI	0	++	++	++	++
		MIBI	NE	++	++	++	++
502	Snake River	FIBI	0	++	+++	+	++
		MIBI	NE	++	++	+	++
501	Snake River	FIBI	0	++	+++	+	++
546	South Branch of the Snake River	FIBI	0	++	++	+	++
544	South Branch of the Snake River	FIBI	0	++	++	++	+
		MIBI	NE	++	+	+	++
538	Middle River	FIBI	0	+	++	+	++
540	Middle River	MIBI	NE	++	++	++	+
529	Judicial Ditch 28	MIBI	NE	++	++	+	+
519	Judicial Ditch 29	FIBI	0	+++	+++	++	+

[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, and **NE** *no evidence* is available

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Appendix A: Individual FIBI Metric and Related Data

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

AUID Suffix	Station	Visit Date	Class	Metrics												
				BenInsect-TolPct	DarterPct	DarterSculpPct	DetNWQPct	DomThreePct	DomTwoPct	GeneralPct	Hdw-TolPct	InsectCypPct	Insect-TolPct	LLvdPct	MA<1Pct	MA<2Pct
501	13RD009	07-Aug-13	1	1	1	1	92	90	81	52	0	42	46	15	41	94
502	13RD007	11-Jul-13	1	0	0	0	65	82	58	93	0	3	4	52	35	64
504	05RD175	24-Jul-06	2	13	9	9	54	71	56	84	0	4	16	3	43	83
	13RD004	25-Jun-13	2	0	0	0	58	99	90	100	0	0	0	0	49	91
	13RD108	24-Jun-13	2	1	1	1	90	98	90	91	0	0	1	0	65	66
	93RD416	27-Jun-13	2	0	0	0	96	98	96	97	0	0	0	1	64	66
519	13RD010	12-Jun-13	3	0	0	0	97	100	10	97	0	0	0	3	97	100
537	13RD006	25-Jun-13	2	2	0	0	82	86	76	84	0	0	6	31	63	86
	13RD080	25-Jun-13	1	8	0	0	16	84	76	16	0	0	76	92	0	8
	94RD511	02-Sep-14	2	4	0	0	89	89	75	75	0	14	18	6	53	67
538	13RD026	12-Jun-13	7	0	0	0	32	63	47	21	42	26	26	0	47	89
543	13RD036(1)	05-Aug-13	5	3	3	3	59	93	85	62	0	0	4	1	46	49
	13RD036(2)	09-Jun-14	5	0	0	0	62	84	75	59	4	2	2	1	82	90
	13RD104(1)	11-Jun-13	5	0	0	0	65	78	65	69	6	0	0	0	73	84
	13RD104(2)	10-Jun-14	5	0	0	0	54	87	74	69	5	3	3	1	74	94
544	13RD035	05-Aug-13	7	0	0	0	80	93	90	82	1	0	0	3	90	96
546	13RD034	09-Jul-13	6	0	0	0	29	76	60	86	6	8	8	0	27	91
	13RD099(1)	10-Jun-13	5	0	0	0	48	76	55	76	12	5	5	0	38	79
	13RD099(2)	10-Jun-14	5	1	1	1	23	79	65	89	2	0	1	0	23	93
	13RD105	09-Jul-13	6	0	0	0	35	96	92	92	2	2	2	0	6	65
	13RD106	13-Jun-13	6	0	0	0	29	71	49	74	25	23	23	0	23	93
Class 1 State MTS Average				20	5	5	42	58	48	21	0	34	56	43	13	56
Class 2 State MTS Average				20	12	12	29	61	49	43	3	17	35	14	21	63
Class 3 State MTS Average				13	12	12	18	72	60	58	6	5	17	4	28	74
Class 5 State MTS Average				28	16	18	11	65	52	34	3	15	44	18	20	63
Class 6 State MTS Average				15	9	11	13	71	58	44	16	14	27	4	32	84
Class 7 State MTS Average				8	7	7	15	74	62	35	12	10	26	11	43	80

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

AUID Suffix	Station	Visit Date	Class	Metrics												
				MA>3-TolPct	MgrPct	MinnowPct	Minnows-TolPct	OmnivorePct	PioneerPct	RifflePct	SLithopPct	SLvdPct	SSpnPct	WetlandPct		
501	13RD009	07-Aug-13	1	5	4	92	42	52	40	1	4	41	81	40		
502	13RD007	11-Jul-13	1	3	6	62	5	92	34	4	7	34	37	41		
504	05RD175	24-Jul-06	2	3	20	73	14	50	63	17	33	39	40	36		
	13RD004	25-Jun-13	2	0	9	90	1	58	90	9	10	49	49	49		
	13RD108	24-Jun-13	2	0	34	57	0	90	57	34	34	65	56	65		
	93RD416	27-Jun-13	2	0	34	63	0	96	63	34	34	64	62	64		
519	13RD010	12-Jun-13	3	0	0	97	0	97	97	0	0	97	97	100		
537	13RD006	25-Jun-13	2	6	8	76	0	84	63	8	8	63	63	73		
	13RD080	25-Jun-13	1	84	20	8	0	16	0	16	20	0	0	0		
	94RD511	02-Sep-14	2	6	33	61	14	75	47	28	33	53	61	49		
538	13RD026	12-Jun-13	7	0	11	63	42	21	11	11	11	37	32	79		
543	13RD036(1)	05-Aug-13	5	0	51	12	1	59	14	51	51	42	8	43		
	13RD036(2)	09-Jun-14	5	1	9	61	4	55	50	9	9	84	48	79		
	13RD104(1)	11-Jun-13	5	0	16	59	6	65	53	16	16	67	55	80		
	13RD104(2)	10-Jun-14	5	0	6	67	6	54	62	6	7	75	50	79		
544	13RD035	05-Aug-13	7	0	3	79	1	81	75	3	3	91	74	92		
546	13RD034	09-Jul-13	6	0	9	84	9	29	36	11	50	67	22	32		
	13RD099(1)	10-Jun-13	5	0	21	67	12	48	55	21	21	36	33	50		
	13RD099(2)	10-Jun-14	5	0	7	85	5	21	43	7	47	61	16	22		
	13RD105	09-Jul-13	6	0	35	59	2	35	57	35	35	4	0	8		
	13RD106	13-Jun-13	6	0	7	92	25	29	41	7	33	49	23	48		
			Class 1 State MTS Average	37	23	47	30	16	6	13	25	15	36	3		
			Class 2 State MTS Average	13	27	50	24	19	20	30	37	16	28	12		
			Class 3 State MTS Average	2	23	60	12	16	36	26	32	26	15	16		
			Class 5 State MTS Average	17	17	41	30	10	15	24	45	10	13	18		
			Class 6 State MTS Average	3	10	57	31	12	23	16	33	29	15	39		
			Class 7 State MTS Average	7	12	41	28	14	14	11	24	23	21	53		

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

AUID Suffix	Station	Visit Date	Class	Metrics												
				BenInsect-TolTxPct	DarterSculpTxPct	DarterTxPct	DetNWQTxPct	GeneralTxPct	Hdw-TolTxPct	HerbvTxPct	InsectCypTxPct	Insect-TolTxPct	LLvdTxPct	MA<1TxPct	MA<2TxPct	MA>3-TolTxPct
501	13RD009	07-Aug-13	1	18	9	9	32	32	0	5	18	41	41	18	59	32
502	13RD007	11-Jul-13	1	0	0	0	38	62	0	0	8	15	54	15	54	23
504	05RD175	24-Jul-06	2	40	20	20	30	50	0	0	10	50	10	20	80	10
	13RD004	25-Jun-13	2	0	0	0	40	80	0	0	0	0	0	40	80	0
	13RD108	24-Jun-13	2	17	17	17	33	50	17	0	17	33	0	50	83	0
	93RD416	27-Jun-13	2	0	0	0	33	56	0	0	0	0	22	33	78	11
519	13RD010	12-Jun-13	3	0	0	0	50	50	0	0	0	0	50	50	10	0
537	13RD006	25-Jun-13	2	14	0	0	43	57	0	0	0	29	71	14	43	29
	13RD080	25-Jun-13	1	17	0	0	33	33	0	0	0	33	83	0	17	67
	94RD511	02-Sep-14	2	17	0	0	50	33	0	0	17	33	17	50	67	17
538	13RD026	12-Jun-13	7	0	0	0	43	29	43	29	29	29	0	43	86	0
543	13RD036(1)	05-Aug-13	5	10	10	10	30	50	20	10	10	20	10	40	90	0
	13RD036(2)	09-Jun-14	5	0	0	0	38	38	25	25	13	13	13	38	75	13
	13RD104(1)	11-Jun-13	5	0	0	0	33	50	17	17	0	0	0	50	83	0
	13RD104(2)	10-Jun-14	5	0	0	0	25	50	25	13	13	13	13	25	88	0
544	13RD035	05-Aug-13	7	0	0	0	30	50	20	10	10	10	20	30	80	0
546	13RD034	09-Jul-13	6	0	0	0	25	63	13	0	25	25	0	25	88	0
	13RD099(1)	10-Jun-13	5	0	0	0	29	43	29	14	14	14	0	43	86	0
	13RD099(2)	10-Jun-14	5	11	11	11	33	56	11	22	0	11	0	44	89	0
	13RD105	09-Jul-13	6	0	0	0	20	40	20	0	20	20	0	40	80	0
	13RD106	13-Jun-13	6	0	0	0	29	57	29	14	14	14	0	29	86	0
Class 1 State MTS Average				25	8	8	24	25	0	2	16	44	47	16	48	41
Class 2 State MTS Average				27	14	14	20	33	4	5	15	40	21	23	62	21
Class 3 State MTS Average				19	15	15	18	42	8	11	11	25	8	36	75	5
Class 5 State MTS Average				27	14	12	11	24	4	2	13	43	26	21	58	24
Class 6 State MTS Average				18	13	11	15	35	16	9	15	32	9	34	80	6
Class 7 State MTS Average				13	9	9	15	32	13	8	13	32	16	36	75	10

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

AUID Suffix	Station	Visit Date	Class	Metrics												
				MgrTxPct	Minnows-TolTxPct	MinnowTxPct	OmnivoreTxPct	PioneerTxPct	RiffleTxPct	SLithopTxPct	SLvdTxPct	SSpnTxPct	WetlandTxPct			
501	13RD009	07-Aug-13	1	32	18	36	27	9	5	32	18	14	18			
502	13RD007	11-Jul-13	1	23	15	31	54	8	8	23	8	15	31			
504	05RD175	24-Jul-06	2	30	20	50	20	30	20	50	20	30	20			
	13RD004	25-Jun-13	2	20	20	60	40	40	20	40	20	20	40			
	13RD108	24-Jun-13	2	17	17	50	33	33	17	33	50	17	50			
	93RD416	27-Jun-13	2	11	11	44	33	22	11	22	22	11	44			
519	13RD010	12-Jun-13	3	0	0	50	50	50	0	0	50	50	10			
537	13RD006	25-Jun-13	2	29	0	29	57	14	29	29	14	14	29			
	13RD080	25-Jun-13	1	50	0	17	33	0	33	50	0	0	0			
	94RD511	02-Sep-14	2	33	17	33	33	17	17	33	50	33	33			
538	13RD026	12-Jun-13	7	14	43	71	29	14	14	14	43	43	71			
543	13RD036(1)	05-Aug-13	5	10	30	60	30	30	10	20	30	20	50			
	13RD036(2)	09-Jun-14	5	13	25	63	25	25	13	13	50	25	50			
	13RD104(1)	11-Jun-13	5	17	17	50	33	33	17	17	50	33	67			
	13RD104(2)	10-Jun-14	5	13	38	63	25	25	13	25	38	25	63			
544	13RD035	05-Aug-13	7	10	20	50	40	20	10	10	30	20	70			
546	13RD034	09-Jul-13	6	13	38	75	25	25	25	38	38	25	38			
	13RD099(1)	10-Jun-13	5	14	29	57	29	29	14	14	43	29	71			
	13RD099(2)	10-Jun-14	5	11	22	67	22	33	11	33	56	22	33			
	13RD105	09-Jul-13	6	20	20	40	20	20	20	20	20	0	60			
	13RD106	13-Jun-13	6	14	29	71	29	29	14	29	43	29	57			
Class 1 State MTS Average				**30**	**15**	**29**	**17**	**8**	**14**	**33**	**15**	**21**	**6**			
Class 2 State MTS Average				**24**	**16**	**39**	**15**	**18**	**25**	**32**	**19**	**28**	**18**			
Class 3 State MTS Average				**20**	**15**	**51**	**15**	**28**	**22**	**29**	**34**	**25**	**24**			
Class 5 State MTS Average				**18**	**19**	**31**	**10**	**12**	**20**	**35**	**13**	**17**	**25**			
Class 6 State MTS Average				**13**	**27**	**49**	**13**	**19**	**15**	**27**	**30**	**20**	**42**			
Class 7 State MTS Average				**13**	**25**	**41**	**15**	**14**	**10**	**20**	**26**	**25**	**51**			

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

AUID Suffix	Station	Visit Date	Class	Metrics													
				NumPerMeter-Tolerant													
501	13RD009	07-Aug-13	1	0.49													
502	13RD007	11-Jul-13	1	0.06													
504	05RD175	24-Jul-06	2	0.33													
	13RD004	25-Jun-13	2	0.01													
	13RD108	24-Jun-13	2	0.01													
	93RD416	27-Jun-13	2	0.01													
519	13RD010	12-Jun-13	3	0.01													
537	13RD006	25-Jun-13	2	0.02													
	13RD080	25-Jun-13	1	0.05													
	94RD511	02-Sep-14	2	0.05													
538	13RD026	12-Jun-13	7	0.04													
543	13RD036(1)	05-Aug-13	5	0.20													
	13RD036(2)	09-Jun-14	5	0.03													
	13RD104(1)	11-Jun-13	5	0.01													
	13RD104(2)	10-Jun-14	5	0.04													
544	13RD035	05-Aug-13	7	0.07													
546	13RD034	09-Jul-13	6	0.05													
	13RD099(1)	10-Jun-13	5	0.03													
	13RD099(2)	10-Jun-14	5	0.04													
	13RD105	09-Jul-13	6	0.01													
	13RD106	13-Jun-13	6	0.12													
Class 1 State MTS Average				0.76													
Class 2 State MTS Average				1.00													
Class 3 State MTS Average				0.65													
Class 5 State MTS Average				0.96													
Class 6 State MTS Average				0.95													
Class 7 State MTS Average				0.95													

Fish TIVs and standard probability data

AUID Suffix	Station	Visit Date	Class	Metrics													
				Mean TSS TIV (mg/L)	Probability of Meeting TSS Standard (%)	Mean DO TIV (mg/L)	Probability of Meeting DO Standard (%)										
501	13RD009	07-Aug-13	1	32	3	6.8	39										
502	13RD007	11-Jul-13	1	32	3	6.6	31										
504	05RD175	24-Jul-06	2	20	45	6.9	41										
	13RD004	25-Jun-13	2	21	36	6.7	34										
	13RD108	24-Jun-13	2	21	36	6.5	26										
	93RD416	27-Jun-13	2	22	31	6.5	27										
519	13RD010	12-Jun-13	3	25	15	6.1	15										
537	13RD006	25-Jun-13	2	27	10	6.4	24										
	13RD080	25-Jun-13	1	50	0	8.5	93										
	94RD511	02-Sep-14	2	24	19	6.7	36										
538	13RD026	12-Jun-13	7	14	77	6.0	13										
543	13RD036(1)	05-Aug-13	5	16	69	6.6	30										
	13RD036(2)	09-Jun-14	5	21	38	6.1	16										
	13RD104(1)	11-Jun-13	5	20	45	6.2	16										
	13RD104(2)	10-Jun-14	5	20	42	6.2	18										
544	13RD035	05-Aug-13	7	24	22	6.1	14										
546	13RD034	09-Jul-13	6	15	72	7.1	54										
	13RD099(1)	10-Jun-13	5	17	59	6.6	29										
	13RD099(2)	10-Jun-14	5	15	72	7.2	56										
	13RD105	09-Jul-13	6	16	69	7.1	53										
	13RD106	13-Jun-13	6	15	72	6.9	44										
Class 1 State MTS Average				32	9	7.7	73										
Class 2 State MTS Average				18	56	7.2	56										
Class 3 State MTS Average				15	70	7.1	53										
Class 5 State MTS Average				13	83	7.1	53										
Class 6 State MTS Average				13	81	6.7	38										
Class 7 State MTS Average				13	80	6.4	26										

Appendix B: Individual MIBI Metric and Related Data

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

AUID Suffix	Station	Visit Date	Class	Metrics												
				BurrowerPct	ClimberPct	ClingerPct	Collector-filtererPct	CrustMollPct	EPTPct	HBI_MN	LeglessPct	LongLivedPct	ScraperPct	SprawlerPct	SwimmerPct	TrichwoHydroPct
502	13RD007	06-Aug-13	7	2	14	24	4	49	25	7	15	1	3	50	10	2
504	04RD002	12-Sep-04	7	25	21	26	10	22	15	8	68	1	21	15	11	0
	05RD175	15-Aug-06	7	12	16	9	3	14	61	9	33	3	12	61	2	0
	13RD004	07-Aug-13	7	3	25	56	40	4	25	7	30	0	2	7	6	11
	13RD108	07-Aug-13	5	5	19	70	64	5	5	7	34	0	6	2	2	1
	93RD416	06-Aug-13	7	23	50	10	6	6	4	8	91	0	6	8	1	2
529	13RD027	06-Aug-13	5	41	32	22	10	25	0	8	70	11	23	3	1	0
537	13RD006	06-Aug-13	7	2	13	1	0	80	1	8	10	0	2	79	5	0
	13RD080	06-Aug-13	7	18	10	9	0	62	2	7	32	0	8	60	2	1
	94RD511	06-Aug-13	7	16	32	37	30	24	14	8	52	0	21	4	10	4
540	05RD014	27-Sep-05	7	8	15	36	11	1	51	7	42	2	10	18	21	3
	13RD022(1)	29-Jul-13	5	37	20	32	23	1	27	7	72	1	2	5	5	2
	13RD022(2)	06-Aug-13	5	8	22	51	21	11	31	8	65	2	15	12	3	10
	13RD079	07-Aug-13	5	8	74	13	4	59	6	9	90	1	58	3	2	2
	13RD098	06-Aug-13	5	30	30	15	15	24	30	8	60	7	12	16	7	5
	93RD417(1)	06-Aug-13	7	14	26	50	18	6	32	8	59	6	9	6	4	21
	93RD417(2)	06-Aug-13	7	11	21	55	16	5	45	7	46	3	7	7	3	21
543	13RD036	01-Aug-13	5	13	22	38	25	17	9	8	65	2	14	21	3	1
	13RD104	06-Aug-13	5	28	54	5	1	46	1	9	92	0	48	6	5	0
544	13RD035	01-Aug-13	5	9	29	58	5	24	0	9	92	0	25	2	2	0
Class 5 State MTS Average				**8**	**15**	**48**	**26**	**9**	**43**	**7**	**38**	**9**	**15**	**16**	**11**	**6**
Class 7 State MTS Average				**9**	**22**	**36**	**18**	**13**	**37**	**8**	**42**	**8**	**16**	**19**	**11**	**5**

Taxa richness (#) per selected M-IBI metric

AUID Suffix	Station	Visit Date	Class	Metrics												
				EPT	LongLived	ScraperCh	TaxaCountAllChir									
502	13RD007	06-Aug-13	7	5	2	2	31									
504	04RD002	12-Sep-04	7	7	1	5	42									
	05RD175	15-Aug-06	7	3	2	3	34									
	13RD004	07-Aug-13	7	7	1	2	34									
	13RD108	07-Aug-13	5	5	0	3	33									
	93RD416	06-Aug-13	7	7	0	4	31									
529	13RD027	06-Aug-13	5	1	1	4	27									
537	13RD006	06-Aug-13	7	1	1	4	21									
	13RD080	06-Aug-13	7	4	0	3	23									
	94RD511	06-Aug-13	7	8	1	5	37									
540	05RD014	27-Sep-05	7	14	6	5	54									
	13RD022(1)	29-Jul-13	5	7	4	4	30									
	13RD022(2)	06-Aug-13	5	9	2	5	40									
	13RD079	07-Aug-13	5	5	2	3	34									
	13RD098	06-Aug-13	5	11	4	6	47									
	93RD417(1)	06-Aug-13	7	7	6	4	46									
	93RD417(2)	06-Aug-13	7	8	5	5	41									
543	13RD036	01-Aug-13	5	6	6	7	55									
	13RD104	06-Aug-13	5	2	1	7	29									
544	13RD035	01-Aug-13	5	1	1	5	31									
Class 5 State MTS Average				11	6	6	43									
Class 7 State MTS Average				9	4	5	38									

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

AUID Suffix	Station	Visit Date	Class	Metrics												
				ClingerChTxPct	Tolerant2ChTxPct	TrichopteraChTxPct										
502	13RD007	06-Aug-13	7	26	90	6										
504	04RD002	12-Sep-04	7	19	93	5										
	05RD175	15-Aug-06	7	21	94	0										
	13RD004	07-Aug-13	7	35	79	9										
	13RD108	07-Aug-13	5	36	88	6										
	93RD416	06-Aug-13	7	35	90	10										
529	13RD027	06-Aug-13	5	22	93	0										
537	13RD006	06-Aug-13	7	10	95	0										
	13RD080	06-Aug-13	7	13	83	9										
	94RD511	06-Aug-13	7	35	81	11										
540	05RD014	27-Sep-05	7	26	70	6										
	13RD022(1)	29-Jul-13	5	40	77	10										
	13RD022(2)	06-Aug-13	5	38	85	13										
	13RD079	07-Aug-13	5	32	82	9										
	13RD098	06-Aug-13	5	23	85	4										
	93RD417(1)	06-Aug-13	7	33	76	4										
	93RD417(2)	06-Aug-13	7	39	71	7										
543	13RD036	01-Aug-13	5	22	87	4										
	13RD104	06-Aug-13	5	17	90	3										
544	13RD035	01-Aug-13	5	26	94	0										
Class 5 State MTS Average				38	72	13										
Class 7 State MTS Average				33	81	11										

Macroinvertebrate TIVs and tolerance-related data

AUID Suffix	Station	Visit Date	Class	Metrics											
				TSS TIV_Index_Score	TSS % Tolerant Taxa	TSS % Very Tolerant Taxa	TSS % Intolerant Taxa	TSS % Very Intolerant Taxa	DO TIV_Index_Score	DO % Tolerant Taxa	DO % Very Tolerant Taxa	DO % Intolerant Taxa	DO % Very Intolerant Taxa			
502	13RD007	06-Aug-13	7	16	26	3	1	0	6.37	56	7	12	12			
504	04RD002	12-Sep-04	7	14	34	2	1	0	5.84	10	2	4	2			
	05RD175	15-Aug-06	7	17	26	6	0	0	6.18	67	3	0	0			
	13RD004	07-Aug-13	7	15	30	1	2	0	7.26	9	3	3	2			
	13RD108	07-Aug-13	5	15	21	1	0	0	7.42	4	0	3	2			
	93RD416	06-Aug-13	7	19	65	12	0	0	6.44	23	0	1	0			
529	13RD027	06-Aug-13	5	10	26	1	0	0	4.00	14	10	0	0			
537	13RD006	06-Aug-13	7	16	18	5	0	0	5.91	89	8	0	0			
	13RD080	06-Aug-13	7	11	9	2	0	0	4.47	62	5	0	0			
	94RD511	06-Aug-13	7	17	49	9	0	0	7.01	9	3	5	5			
540	05RD014	27-Sep-05	7	16	31	12	2	0	7.01	16	1	12	9			
	13RD022(1)	29-Jul-13	5	11	32	1	1	0	4.77	3	0	13	12			
	13RD022(2)	06-Aug-13	5	16	31	2	2	1	6.90	17	4	9	7			
	13RD079	07-Aug-13	5	18	73	1	0	0	6.73	12	3	1	1			
	13RD098	06-Aug-13	5	19	52	20	0	0	6.88	11	1	7	1			
	93RD417(1)	06-Aug-13	7	16	37	7	2	0	7.00	10	1	5	5			
	93RD417(2)	06-Aug-13	7	16	33	5	1	0	6.98	9	1	18	16			
543	13RD036	01-Aug-13	5	15	26	8	0	0	6.42	26	6	1	1			
	13RD104	06-Aug-13	5	19	52	19	0	0	6.29	44	17	0	0			
544	13RD035	01-Aug-13	5	16	18	9	0	0	6.05	68	21	0	0			
Class 5 State MTS Average				16	35	12	5	1	7.1	9	2	24	17			
Class 7 State MTS Average				17	44	16	3	0	6.8	16	3	9	6			

Appendix C: Snake River Watershed Geomorphic Assessment