Water quality

January 2018

Marsh River Stressor Identification Report

A study of local stressors limiting the biotic communities in the Marsh River Watershed.

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Key terms & abbreviations

AUID	Assessment Unit Identification
CADDIS	Causal Analysis/Diagnosis Decision Information System
Chl-*a*	Chlorophyll-*a*
CSAH	County State Aid Highway
DO	Dissolved Oxygen
DNR	Minnesota Department of Natural Resources
EPA	U.S. Environmental Protection Agency
HSPF	Hydrological Simulation Program – FORTRAN
IBI	Index of Biological Integrity
IWM	Intensive Watershed Monitoring
MPCA	Minnesota Pollution Control Agency
MSHA	MPCA Stream Habitat Assessment
SID	Stressor Identification
SOE	Strength of Evidence
TMDL	Total Maximum Daily Load
USGS	U.S. Geological Survey
WRAPS	Watershed Restoration and Protection Strategy
WRWD	Wild Rice Watershed District

Executive summary

Over the past few years, the Minnesota Pollution Control Agency (MPCA) has substantially increased the use of biological monitoring and assessment as a means to determine and report the condition of the state's rivers and streams. This basic approach is to examine fish and aquatic macroinvertebrate communities and related habitat conditions at multiple sites throughout a major watershed. From these data, an Index of Biological Integrity (IBI) score can be developed, which provides a measure of overall community health. If biological impairments are found, stressors to the aquatic community must be identified.

Stressor identification (SID) is a formal and rigorous process that identifies stressors causing biological impairments of aquatic ecosystems and provides a structure for organizing the scientific evidence supporting the conclusions (Cormier et al., 2000). In simpler terms, it is the process of identifying the major factors causing harm to aquatic life. Stressor identification is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act.

This stressor identification report incorporates the Marsh River Watershed biological impairments and the associated stressors. The Marsh River Watershed covers a 362 square mile drainage area that lies within the Lake Agassiz Plain ecoregion in the northwest portion of Minnesota, including Norman and Clay Counties. The Marsh River Watershed has 570 miles of stream length, 67% of which are altered watercourses and 33% of which are natural stream channels (MPCA, 2013). The hydrology includes 51 miles of the Marsh River (a tributary of the Red River of the North [Red River]) in addition to multiple streams and small tributaries flowing into the Marsh River with no notable lakes. Soils formed in the western portion of the watershed include glacial lake deposits featuring fine textures with poor internal drainage. Moving east in the watershed, the beach ridge (a remnant of the now-absent glacial Lake Agassiz) is made up of moderately coarse and medium textured soil mostly comprised of clay with sand and gravel from the lakeshore deposits. The lake plain soil type offers rich soils ideal for agricultural activity, which makes up 88% of the land use in the watershed. Other notable land use types are urban development (5%), wetlands (4%), forest (2%), and open water (1%) (USGS, 2011).

In 2014, the MPCA began intensive watershed monitoring (IWM) on the freshwater ecosystems within the Marsh River Watershed. The biological data collected during biological monitoring identified two stream reaches that were non-supporting for aquatic life based on IBI scores that were below the state's standard for macroinvertebrate and/or fish. The Marsh River was found to be impaired for both fish and macroinvertebrates, while County Ditch 11 was impaired only for fish. Details on the intensive monitoring results can be found in the Marsh River Watershed Monitoring and Assessment Report.

This report summarizes stressor identification work in the Marsh River Watershed and analyzes the causes of the biological impairments in the two reaches. The following five candidate causes were selected for analysis that uses scientific evidence to support conclusions: Loss of connectivity, altered hydrology, insufficient physical habitat, high suspended solids, and low dissolved oxygen. The analysis uses the co-occurrence of the candidate causes along with the biological degradation to support conclusions (EPA, 2000).

Assessment Unit Identification (AUID) 503 (the Marsh River) and AUID 517 (County Ditch 11) were the two impairments in the Marsh River Watershed. Both reaches experience stressors driven by flow regime instability. Typically, the two reaches experience periods of high flows in spring and early summer followed by prolonged low flow conditions in late summer. During high precipitation events, it is likely that water will have an accelerated pathway off the landscape into the water column through drainage systems. Overall, this process causes high-suspended sediment that limits the biological community. In contrast to these high flow time periods, during late summer drought, the Marsh River and County Ditch 11 experience stagnant conditions and in extreme cases, a dried up stream with no potential for supporting aquatic biology. Stagnant conditions allows the potential for low dissolved oxygen when eutrophication allows algal biomass to exploit the stream channel. Lastly, connectivity related issues inhibit the potential for freshwater species to access upper portions of the watershed.

1. Introduction

1.1. Monitoring and assessment

Water quality sampling and biological monitoring in the Marsh River Watershed occurred from 2007-2015. As part of the MPCA's IWM approach, monitoring activities increased in rigor and intensity during the summer of 2014, and focused more on biological monitoring (fish and macroinvertebrates) as a means of assessing stream health. The data collected during this period, as well as historic data obtained prior to 2015 were used to identify stream reaches that were not supporting healthy fish and macroinvertebrate assemblages (Figure 1.1).

Once a biological impairment is discovered, the next step is to identify the source(s) of stress on the biological community. A stressor identification (SID) analysis is a step-by-step approach for identifying probable causes of impairment in a particular system. Completion of the SID process does not result in a finished Total Maximum Daily Load (TMDL) study. The product of the SID process is the identification of the stressor(s) for which the TMDL may be developed. In other words, the SID process may help investigators identify excess fine sediment, for example, as the cause of biological impairment, but a separate effort is required to calculate the TMDL and implementation goals needed to restore the impaired condition.

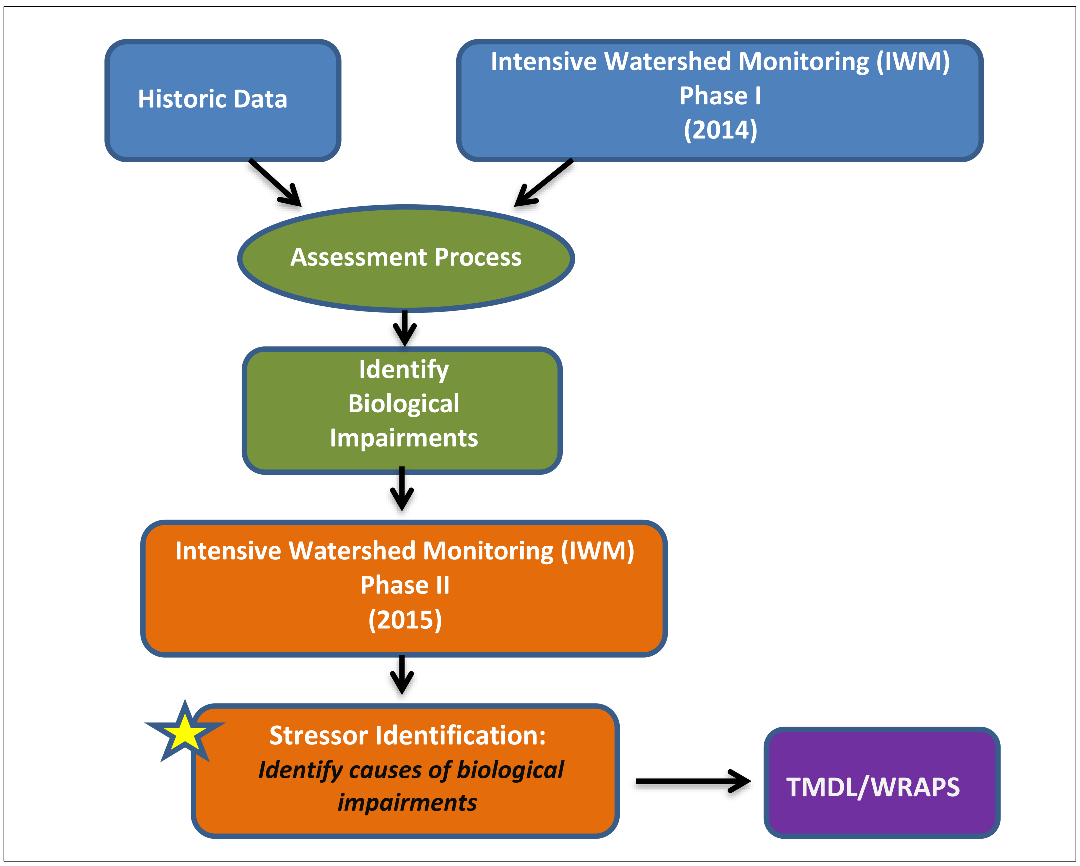


Figure 1.1. Process map of Intensive Watershed Monitoring, Assessment, Stressor Identification and TMDL processes.

1.2. Stressor Identification Process

The MPCA follows the EPA's process of identifying stressors that cause biological impairment, which has been used to develop the MPCA's guidance to stressor identification (Cormier et al., 2000; MPCA, 2008). The EPA has also developed an updated, interactive web-based tool, the Causal Analysis/Diagnosis Decision Information System (CADDIS; EPA, 2010). This system provides an enormous amount of information designed to guide and assist investigators through the process of stressor identification. Additional information on the stressor identification process using CADDIS can be found here: http://www.epa.gov/caddis/

Stressor identification is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act. SID draws upon a broad variety of disciplines and applications, such as aquatic ecology, geology, geomorphology, chemistry, land-use analysis, and toxicology. A conceptual model showing the steps in the SID process is shown in Figure 1.2. Through a review of available data, stressor scenarios are developed that aim to characterize the biological impairment, the cause, and the sources/pathways of the various stressors.

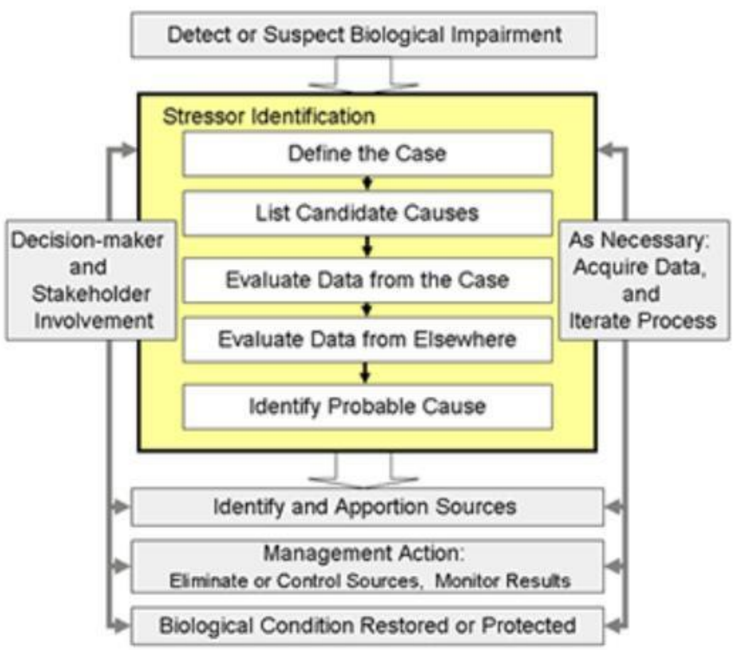


Figure 1.2. Conceptual model of Stressor Identification Process (Cormier et al., 2000).

Strength of evidence (SOE) analysis is used to evaluate the data for candidate causes of stress to biological communities. The relationship between stressor and biological response are evaluated by considering the degree to which the available evidence supports or weakens the case for a candidate cause. Typically, much of the information used in the SOE analysis is from the study watershed (i.e., data from the case). However, evidence from other case studies and the scientific literature is also used in the SID process (i.e., data from elsewhere).

Developed by the EPA, a standard scoring system is used to tabulate the results of the SOE analysis for the available evidence (Table A1). A narrative description of how the scores were obtained from the evidence should be discussed as well. The SOE table allows for organization of all of the evidence, provides a checklist to ensure each type has been carefully evaluated and offers transparency to the determination process.

The existence of multiple lines of evidence that support or weaken the case for a candidate cause generally increases confidence in the decision for a candidate cause. The scoring scale for evaluating each type of evidence in support of or against a stressor is shown in Table A2. Additionally, confidence in the results depends on the quantity and quality of data available to the SID process. In some cases, additional data collection may be necessary to accurately identify the stressor(s) causing impairment. Additional detail on the various types of evidence and interpretation of findings can be found here: https://www.epa.gov/caddis-vol1/caddis-volume-1-stressor-identification-summary-tables-types-evidence .

1.3. Common stream stressors

The five major elements of a healthy stream system are stream connections, hydrology, stream channel assessment, water chemistry, and stream biology. If one or more of the components are unbalanced, the stream ecosystem may fail to function properly and be listed as an impaired water body. Table 1.1 lists the common stream stressors to biology relative to each of the major stream health categories.

Table 1.1. Common streams stressors to biology (i.e., fish and macroinvertebrates).

Stream health	Stressor(s)	Link to biology
Stream connections	**Loss of connectivity** • Dams and culverts • Lack of Wooded riparian cover • Lack of naturally connected habitats/ causing fragmented habitats	Fish and macroinvertebrates cannot freely move throughout system. Stream temperatures also become elevated due to lack of shade.
Hydrology	**Altered hydrology** **Loss of habitat due to channelization** **Elevated levels of total suspended solids (TSS)** • Channelization • Peak discharge (flashy) • Transport of chemicals	Unstable flow regime within the stream can cause a lack of habitat, unstable stream banks, filling of pools and riffle habitat, and affect the fate and transport of chemicals.
Stream channel assessment	**Loss of habitat due to excess sediment** **Elevated levels of TSS** • Loss of dimension/pattern/profile • Bank erosion from instability • Loss of riffles due to accumulation of fine sediment • Increased turbidity and or TSS	Habitat is degraded due to excess sediment moving through system. There is a loss of clean rock substrate from embeddedness of fine material and a loss of intolerant species.
Water chemistry	**Low dissolved oxygen concentrations** **Elevated levels of nutrients** • Increased nutrients from human influence • Widely variable DO levels during the daily cycle • Increased algal and or periphyton growth in stream • Increased nonpoint pollution from urban and agricultural practices • Increased point source pollution from urban treatment facilities	There is a loss of intolerant species and a loss of diversity of species, which tends to favor species that can breathe air or survive under low DO conditions. Biology tends to be dominated by a few tolerant species.
Stream biology	Fish and macroinvertebrate communities are affected by all of the above listed stressors	If one or more of the above stressors are affecting the fish and macroinvertebrate community, the IBI scores will not meet expectations and the stream will be listed as impaired.

2. Overview of Marsh River Watershed

2.1. Background

2.1.1 Physical setting

The Marsh River Watershed, (hydrologic unit code [HUC] 09020107), consists of 362 square miles and is located within the Red River Basin in northwest Minnesota. This watershed includes Norman County (91%), Clay County (8%), and Polk County (1%). Cities located in this watershed include Ada, Shelly, and Halsted. This watershed has a total population of 3,735 people with 10.32 people per square mile (U.S. Department of Commerce, 2010).

2.1.2 Geology and soils

The Marsh River Watershed lies within the glacial Lake Agassiz Plain ecoregion in northwest Minnesota. Soils formed in the western part of the watershed include glacial lake deposits featuring fine textures with poor internal drainage. Moving east in the watershed, the beach ridge (a remnant of the now-absent glacial Lake Agassiz) is made up of moderately coarse and medium textured soil mostly comprised of clay with sand and gravel from the lakeshore deposits. The soils in the watershed have low infiltration rates, thus making them susceptible to runoff with overland flow. The watershed has relatively low relief in the western lake plain with increasing slope moving east into the beach ridge.

2.1.3 Hydrology

Watershed hydrology includes 51 miles of the Marsh River (a tributary of the Red River of the North) in addition to multiple streams and small tributaries flowing into the Marsh River. The main tributary with the largest contributions to Marsh River is County Ditch 11. Over half of the watercourses in the watershed have been hydrologically altered (67%), while only 33% remain natural. All major tributaries within the watershed have been channelized, with the exception of Spring Creek. The watershed experiences an undulating hydrograph with frequent periods of high flows and an overall decline of baseflow; flood management remains an issue during high flows. No notable lakes occur within the watershed.

2.1.4 Land use

The National Land Cover Database (NLCD) 2011 (USGS, 2011) lists the Marsh River Watershed as dominated by agriculture with 88% of the total land use consisting of cultivated row crops, pasture, and hay. The remainder of the watershed land use is comprised of developed (5%), some wetlands in the far eastern portion of the watershed (4%), forested land (2%), and open water (1%).

2.1.5 Ecological health

The Minnesota Department of Natural Resources (DNR) developed a Watershed Health Assessment Framework for the Marsh River Watershed that assessed different attributes that contribute to the quality of a freshwater ecosystem. This assessment provides a holistic overview of the watershed using a combination of hydrology, geomorphology, biology, connectivity, and water quality. Each category has a score that is derived from specific watershed characteristics and the average of all categories is the overall watershed health score. Scores are ranked on a scale from zero (low) to 100 (high). Notable, the Marsh River Watershed has the state's lowest overall health score (40) while the highest score is 84 (Rapid River Watershed located in the Rainy River Basin). Compared to the 16 other major watersheds within the Red River Basin, the Marsh River Watershed has the lowest score in all categories except geomorphology (Marsh: 48; Basin minimum: 47) and water quality (Marsh: 55; Basin minimum: 46). The extremely low overall health scores (i.e., 40) for the Marsh River Watershed can generally be attributed to all categories, with particularly low scores for the biology (31) and connectivity (11) category. The parameters mostly responsible for the low biological health score are terrestrial habitat quality (2) and at-risk species richness (24). The reduced score for the connectivity category score is mostly influenced by terrestrial habitat connectivity (3) and riparian connectivity (11).

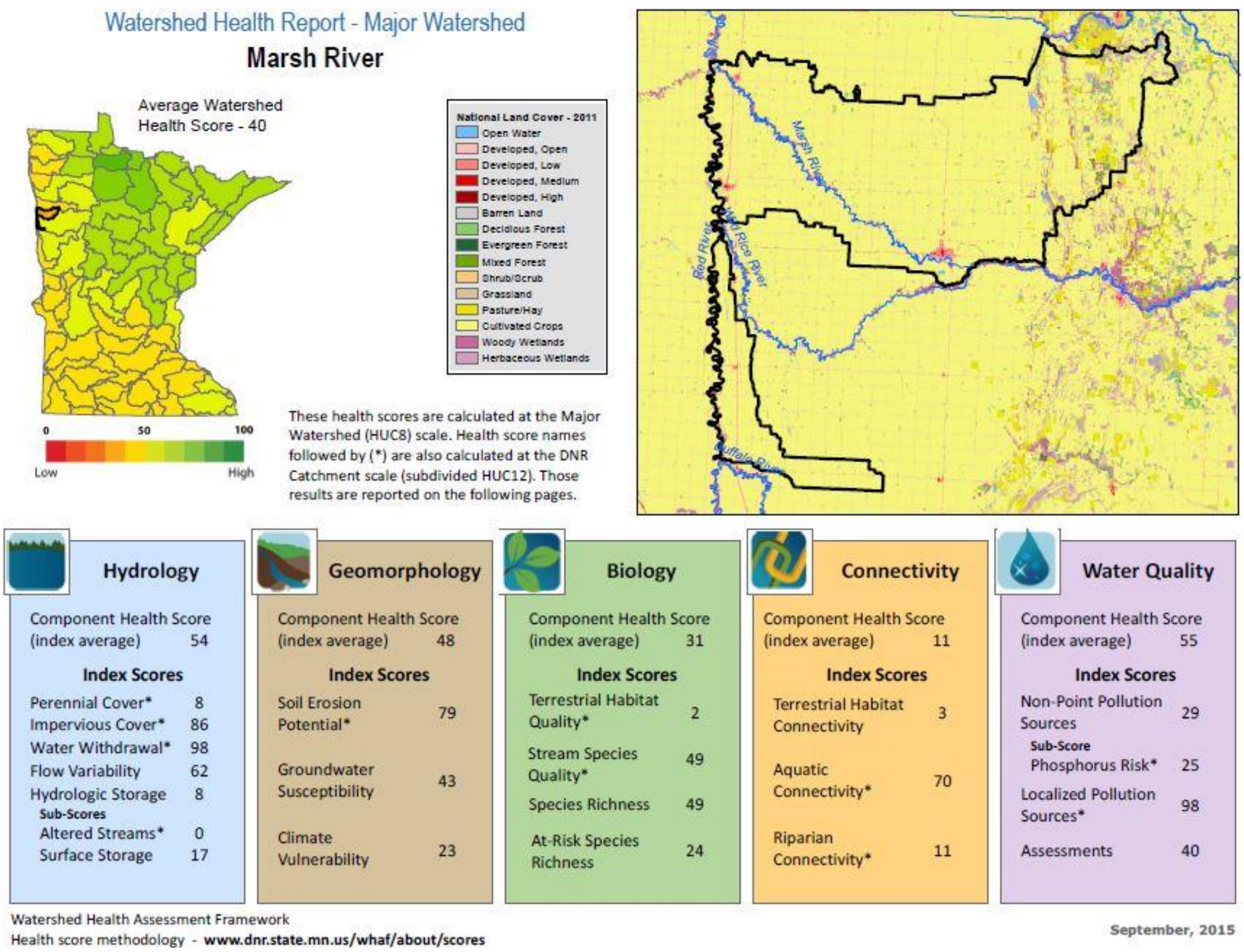


Figure 2.1. DNR Watershed Health Assessment Framework for the Marsh River Watershed.

2.2. Monitoring overview

Minnesota's water quality assessment was established based on a watershed approach for monitoring all 80 watersheds across the state. The MPCA's IWM and assessment processes determine the overall health of the water resources, identify impaired waters, and identify waters in need of additional protection to prevent impairment. The IWM occurs in each watershed for a two year period, once every 10 years. This process involves the collection of fish, macroinvertebrate, fish contaminates, and water chemistry data. Stream sites are selected near the outlet of each watershed scales (8-HUC, 12-HUC, and 14-HUC). Specifically, HUC 8 outlets are sampled for fish, macroinvertebrates, fish contaminates, and water chemistry. HUC 12 outlets are sampled for fish, macroinvertebrates, and water chemistry and HUC 14 outlets are only sampled for fish and macroinvertebrates. The biological community provides an indication of overall stream health when compared to the IBI. Water chemistry data are paired with the biological community data to assess whether the waterbody is impaired. Each waterway is assessed based on the opportunity for the use it provides (i.e., fishing, swimming, support aquatic insects and fish communities). For additional information see: Watershed Approach to Condition Monitoring and Assessment (MPCA, 2008). (http://www.pca.state.mn.us/publications/wq-s1-27.pdf). The Marsh River Watershed IWM was conducted in the summer of 2014 and 2015. An overview of the Marsh River Watershed biological monitoring stations is outlined below (MPCA, 2017).

Table 2.1. List of biological monitoring stations in the Marsh River Watershed.

AUID suffix	AUID	Name	Monitoring station(s)
503	09020107-503	Marsh River	05RD113, 14RD061, 14RD072
508	09020107-508	Spring Creek	14RD071
510	09020107-510	County Ditch 45	14RD075
516	09020107-516	County Ditch 66	07RD008
517	09020107-517	County Ditch 11	14RD060
518	09020107-518	Judicial Ditch 51	05RD055
521	09020107-521	County Ditch 45	14RD075

2.3. Summary of biological impairments

The approach used to identify biological impairments includes assessment of fish and aquatic macroinvertebrates communities and related habitat conditions at sites throughout a watershed. The resulting information is used to develop an IBI. The IBI scores can then be compared to a range of thresholds with upper and lower confidence intervals (Table 2.2 and Table 2.3). The range of thresholds and confidence intervals are based on their location in the state of Minnesota along with the type of stream (e.g. headwater, riffle/run habitats). For the Marsh River Watershed, there are several different classes of streams. It is important to note that Southern Streams were named for their common occurrence in the southern part of the state, but can be found at any latitude in the state.

Table 2.2. Minnesota statewide F-IBI threshold and confidence limits for the classes found in the Marsh River Watershed.

Class	Class name[1]	General Use[3] threshold	Modified Use[3] threshold	Confidence limit
2	Southern Streams	50	35	± 9
6	Northern Headwaters	42	23	± 16
7	Low Gradient Streams	42	15	± 10

[1] F-IBI classes: Low Gradient Streams (LGS), Northern Headwaters (NH), Southern Streams (SS)
[3] Tiered aquatic life use (TALU) Framework designation: General Use (G), Modified Use (M)

Table 2.3. Minnesota statewide M-IBI threshold and confidence limits for the classes found in the Marsh River Watershed.

Class	Class name[2]	General Use[3] threshold	Modified Use[3] threshold	Confidence limit
5	Southern Streams RR	37	24	± 13
7	Prairie streams GP	41	22	± 14

[2] M-IBI 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)

The fish and macroinvertebrates within each AUID were compared to a regionally developed threshold and confidence intervals. These thresholds and confidence intervals utilize a weight of evidence approach that takes into account the biological response, water chemistry, physical habitat, and exposure indicators when making decisions. IBI scores provide a measurement tool to assess the health of the aquatic communities. IBI scores higher than the impairment threshold indicate that the stream reach supports aquatic life. Conversely, scores below the impairment threshold indicate that the stream reach does not support aquatic life. Confidence limits around the impairment threshold help to ascertain where additional information may be considered to help inform the impairment decision. When IBI scores fall within the confidence interval, interpretation and assessment of the waterbody condition involves consideration of potential stressors, and draws upon additional information regarding water chemistry, physical habitat, land use, etc.

Figure 2.2 displays the monitoring stations that were sampled for fish and macroinvertebrates. The results from the biological samples are outlined in Table 2.4; based on these results, two AUIDS were listed for impairment. AUID 503 is classified as non-supporting for fish and macroinvertebrate communities based on IBI scores below the Southern Streams General Use threshold. AUID 517 is the second reach indicating non-supporting for fish community based on an IBI scores below the Southern Streams Modified Use threshold.

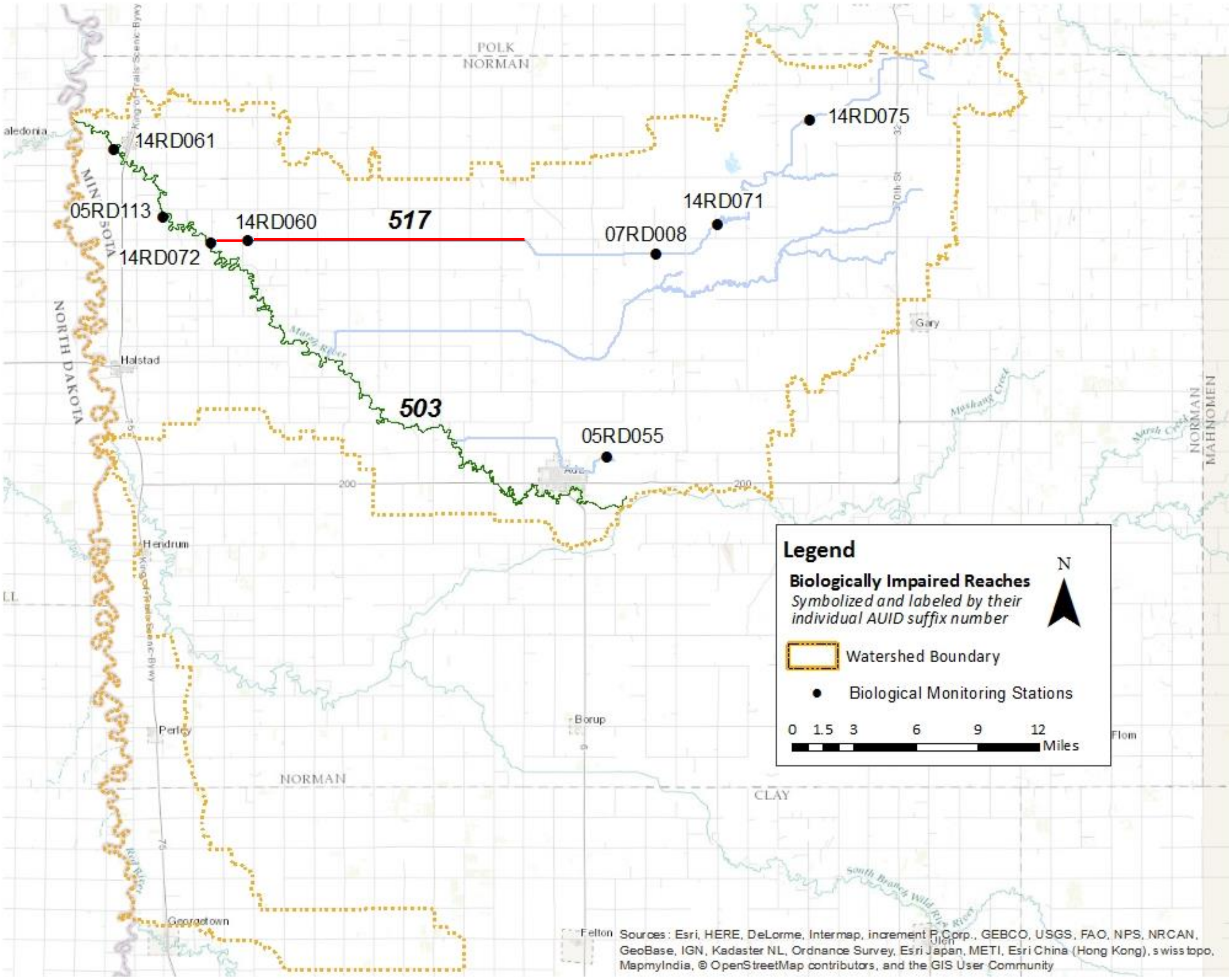


Figure 2.2. Map of the two biologically impaired AUIDS in the Marsh River Watershed. Three impairments were determined for this particular watershed. AUID 517 (County Ditch 11), displayed in red, is listed as impaired for fish bioassessment. AUID 503 (Marsh River), displayed in green, is listed as impaired for fish and macroinvertebrate bioassessment.

Table 2.4. Biological index (F-IBI and M-IBI) scores for AUIDs in the Marsh River Watershed (MPCA, 2017). Text in red indicates biological impairment. Text in blue indicates at-risk for biological impairment.

Fish					Macroinvertebrate				
AUID	Station	F-IBI class[1] (Use[3])	F-IBI impairment threshold	F-IBI score (mean)	AUID	Station	M-IBI Class[2] (Use[3])	M-IBI impairment threshold	M-IBI score (mean)
HUC 12: 0902010705-01 (Marsh River)									
503	05RD113	SS(G)	50	47.65	503	05RD113	PGP(G)	41	20.9
503	05RD113	SS(G)	50	53.20	503	05RD113	PGP(G)	41	17.9
503	14RD061	SS(G)	50	55.34	503	14RD061	PGP(G)	41	34.9
503	14RD072	SS(G)	50	39.39	503	14RD072	PGP(G)	41	13.0
518	05RD055	LG(M)	15	50.39	*Not Sampled*				
HUC 12: 0902010705-02 (County Ditch 11)									
521	14RD075	NH(G)	42	41.94	521	14RD075	SRR(G)	37	41.2
508	14RD071	NH(G)	42	35.76	508	14RD071	PGP(G)	41	45.1
508	14RD071	NH(G)	42	47.79	*Not Sampled*				
516	07RD008	NH(M)	23	41.42	516	07RD008	PGP(M)	22	36.9
517	14RD060	SS(M)	35	0	517	14RD060	PGP(M)	22	34.7
517	14RD060	SS(M)	35	0	*Not Sampled*				

[1]F-IBI Classes: Southern Streams (SS), Low Gradient Streams (LG), Northern Headwaters (NH)
[2]M-IBI Classes: Prairie Streams GP (PGP), Southern Streams RR (SRR).
[3]Tiered aquatic life use (TALU): General Use (G), Modified Use (M)

2.4. Hydrological Simulation Program - FORTRAN Model

The Hydrological Simulation Program - FORTRAN (HSPF) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates watershed-scale Agricultural Runoff Model and Non-Point Source (NPS) models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at the outlet of any subwatershed. HSPF simulates three sediment types (sand, silt, and clay) in addition to a single organic chemical and transformation products of that chemical.

The HSPF watershed model contains components to address runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/transformation of chemical constituents in stream reaches. Primary external forcing is provided by the specification of meteorological time series. The model operates on a lumped basis within subwatersheds. Upland responses within a subwatershed are simulated on a per-acre basis and converted to net loads on linkage to stream reaches within each subwatershed and the upland areas are separated into multiple land use categories.

A HSPF watershed model was computed for the Marsh River Watershed to predict water quality conditions throughout the watershed on an hourly basis from 1996-2009. The model used subwatersheds associated with the impaired reaches to estimate the probability of exceeding a state standard threshold for dissolved oxygen, total suspended solids, and flow. The Southern Streams threshold was used for both total suspended solids (65 mg L^{-1}) and dissolved oxygen (5 mg L^{-1}) along with estimating flow under 1 cfs in both AUID 503 and 517. Specifically, the Marsh River model included 10 subwatersheds along the impaired stream length, while County Ditch 11 included one subwatershed in the model. Results of the model assisted the process of stressor identification with the occurrence of state standard threshold exceedances along with the degradation of the biological effect.

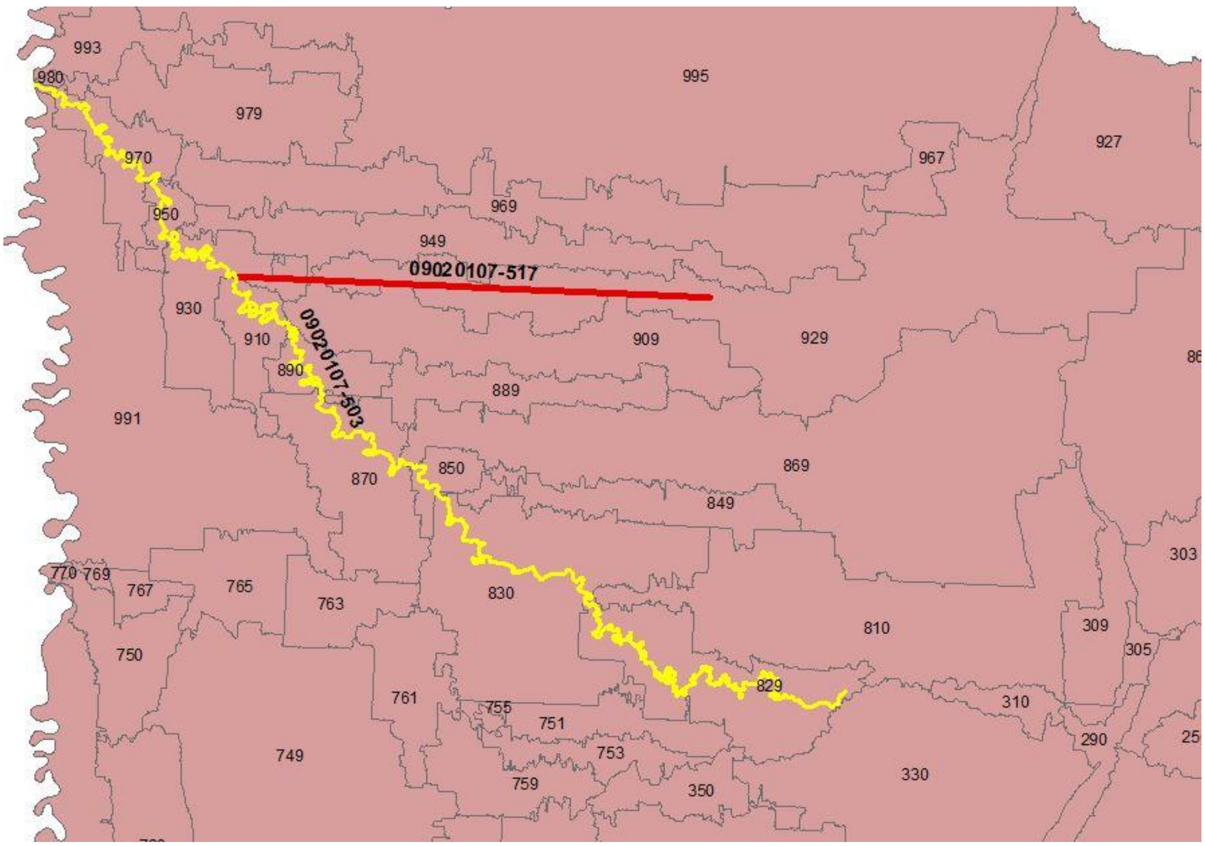


Figure 2.3. HSPF model of the Marsh River Watershed. Reaches used in the model were the Marsh River (AUID 503) and County Ditch 11 (AUID 517). Ten subwatersheds were used for the Marsh River model (829, 830, 580, 870, 890, 910, 930, 950, 970, 980, and 929) and one subwatershed was used for County Ditch 11 model (929).

3. Possible stressors to biological communities

A comprehensive list of potential stressors to aquatic biological communities compiled by the EPA can be found here (https://www.epa.gov/caddis-vol1/caddis-volume-1-stressor-identification-step-2-list-candidate-causes). This comprehensive list serves two purposes. First, it can serve as a checklist for investigators to consider all possible options for impairment in the watershed of interest. Second, it can be used to identify potential stressors that can be eliminated from further evaluation. In some cases, the data may be inconclusive and limit the ability to confidently determine if a stressor is causing impairment to aquatic life. It is imperative to document if a candidate cause was suspected, but there was not enough information to make a scientific determination of whether or not it is causing harm to aquatic life. In this case, management decisions can include modification of sampling plans and future evaluation of the inconclusive case. Alternatively, there may be enough information to conclude that a candidate cause is not causing biological impairment and therefore can be eliminated. The inconclusive or eliminated causes will be discussed in more detail in the following section.

3.1. Eliminated causes

Biological stressors within a body of water are directly associated with the surrounding land use within the drainage area, including NPS overland runoff and point sources. Anthropogenic alterations of the natural landscape along with quality and quantity of water causes an accelerated evolutionary shift in the biological community in aquatic ecosystems. Analysis of the land use that surrounds adjacent freshwater ecosystems can lead to causal analysis of stressors identification. Figure 3.1 displays the Marsh River Watershed land use map, and shows that the watershed is dominated by cultivated crops (88%) with a small fraction of the watershed comprised of urbanization (5%), wetlands (4%), forest (2%), and open water (1%) (USGS, 2011). The following stressor were eliminated as candidate causes given the absence of the source within the drainage area:

- Urbanization: impervious surfaces, specific conductivity from road salts and effluent discharges, residential chemical use.
- Industrial stressors: Chemical, high conductivity discharges.
- Mining stressors.

Data collected for certain parameters over an extended period of time can be analyzed for quick analysis of potential to cause stress to the biological community.

- High nitrate-nitrite: nitrogen levels along the impaired reaches never exceeded the threshold to cause stress to aquatic life (<10 mg L^{-1}).
- Temperature: all temperatures measured in impaired reaches never exceeded the state standard (30 °C).
- Potential of hydrogen (pH): all pH values in the impaired reaches were within the state standard range (6.5-9.0).

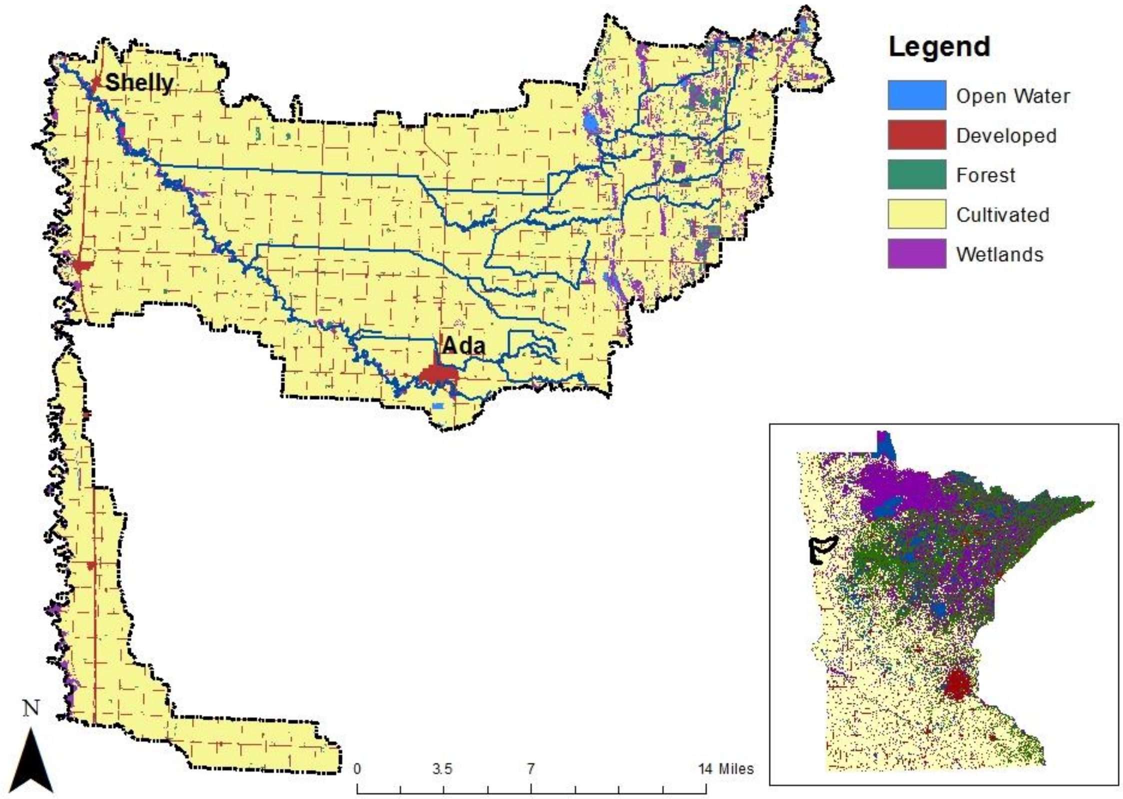


Figure 3.1. Land use map of the Marsh River Watershed (NLCD, 2011). Developed land use includes low, medium, and high intensity. Forest includes deciduous forest, evergreen forest, and mixed forest. Cultivated includes pasture, hay, and cultivated crops. Wetlands include woody wetlands and emergent herbaceous wetlands.

3.2. Summary of candidate causes in the Marsh River Watershed

Background information specific to candidate causes/stressors in Minnesota can be found here. This information provides an overview of the pathway and effects of each candidate stressor considered in the biological stressor identification process with relevant data and water quality standards specific to Minnesota. The EPA has additional information, conceptual diagrams of sources and causal pathways, and publication references for numerous stressors on its CADDIS website.

The initial list of candidate causes was narrowed down by reviewing data. After elimination, the following five candidate causes were selected as possible stressors for the three biological impairments in AUIDs 503 and 517 of the Marsh River Watershed.

- Loss of connectivity
- Flow regime instability
- Insufficient physical habitat
- High suspended sediment
- Low dissolved oxygen

4. Evaluation of candidate causes

4.1. Marsh River (AUID 503)

4.1.1. Overview

AUID 503 (hereafter referred as the Marsh River) includes 51 miles of stream length from the beginning of the reach near the town of Ada to its confluence with the Red River of the North (Figure 4.1.1). The watershed has a drainage area of 362 square miles. Land use in this area is dominated by extensive agriculture (88%), with the remainder comprised of developed (5%), wetlands (4%), forest (2%), and open water (1%) (USGS, 2011). The soil type in this region that support agricultural development consists of clay and silty clay with low infiltration rates and potential for runoff and erosion. Altered stream channels are common in this watershed with 67% of stream length hydrologically channelized, ditched, or impounded (MPCA, 2013). Even though the Marsh River itself still has 61% of naturally meandering stream channel, drainage on the landscape (e.g. drainage systems) can contribute to the Marsh River degradation.

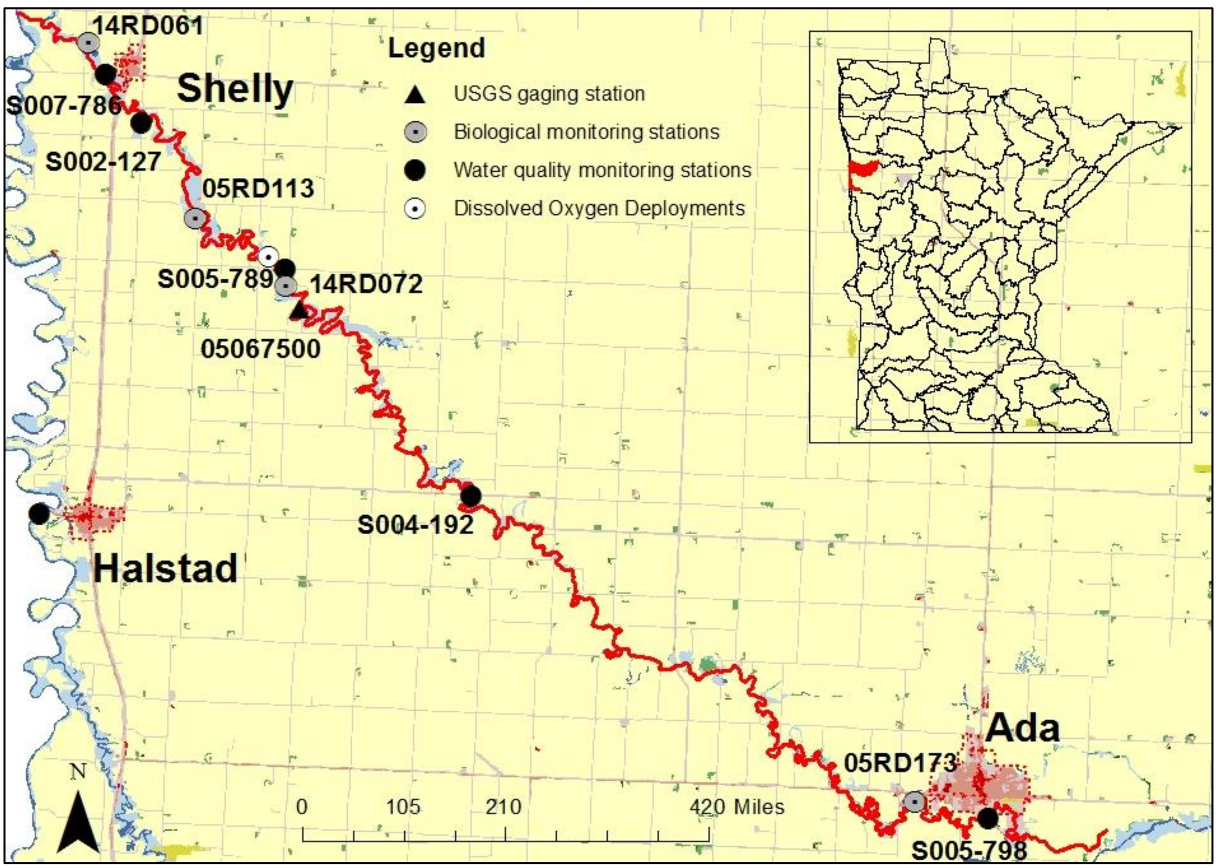


Figure 4.1.1. Marsh River (HUC 09020107) impaired reach 51 miles from the town of Ada to the confluences with the Red River of the North.

4.1.2. Biological impairments

Fish (F-IBI)

The Marsh River is classified as a class two southern stream providing General Use habitat with an F-IBI threshold of 50. Three biological monitoring stations were sampled during the summer of 2014. The most upstream site, 14RD072, was sampled twice in 2014. The first sampling event yielded results below the threshold and lower confidence interval with an F-IBI of 39. The second sampling event had an F-IBI of 54, which is above the threshold but lower than the upper confidence interval. This station had a biological condition gradient (BCG) level six fish assemblage suggesting that there were extreme changes in structure and ecosystem function causing changes in taxonomic composition. The other two sites in the Marsh River, 05RD113 and 14RD061, had F-IBI scores above the General Use threshold but not above the upper confidence interval (05RD113 F-IBI =53; 14RD061 F-IBI= 55). Both of these stations scored a BCG level 4 assemblage indicating moderate changes in structure due to replacement of sensitive species with a robust sample of tolerant taxa. These results indicate an increase level of exposure to stressors resulting in a decline of biological condition.

Macroinvertebrate (M-IBI)

The Marsh River is classified as a class seven Prairie Streams GP providing General Use habitat with an M-IBI threshold of 41. Three biological monitoring stations were sample one time in 2014. All three stations were below the threshold and classified with a BCG level 4/5. This BCG level indicates habitats that are dominated by tolerant taxa with sensitive species either declining or completely diminished. Site 14RD072 received an M-IBI score of 12, which is below the threshold and lower confidence interval. This site only had 13 different taxa sampled that were mostly comprised of snails and scuds. This indicated lack of diversity and abundance with the majority of the sample comprised of tolerance species. 14RD061 had an M-IBI score of 34, which is below the threshold but within the lower confidence interval. This sample was dominated by tolerant taxa with some flow dependent species. 05RD113 also had an M-IBI score of 34, which is below the threshold but within the confidence interval limits. In summary, these three stations all scored below the threshold and one station (14RD072) dropped below the lower confidence interval. Scores below the threshold indicate a community dominated by tolerant taxa with some erratic sensitive species. These results indicate an increase level of exposure to stressors resulting in a decline of biological condition.

4.1.3. Stressor pathway

Connectivity

Connectivity does not seem to be a significant stressor in the Marsh River. The biological monitoring crew did not observe any connectivity issues during any visits to stations 14RD072, 05RD113, and 14RD061. According to the DNR, there are no dams large enough for regulatory action along the Marsh River (DNR, 2014). MPCA monitoring staff and stressor identification staff completed a longitudinal survey of the Marsh River on August 4, 2016, and observed no apparent barriers upstream and downstream of road crossings. Stressor Identification staff completed the Marsh River site reconnaissance using Google Earth on January 18, 2017, and found no major barriers that would cause a disconnect in either flow or biological passage along the Marsh River. However, there is insufficient data to make any conclusions on velocity barriers caused by poorly constructed culverts along the reach. Overall, there are no apparent man made longitudinal connectivity stressors along the Marsh River.

Biological response: Fish

The fish community does not strongly indicate stressors caused by connectivity related impairments (Table 4.1.1). A waterway that is not longitudinally connected results in an inability for migratory fish to gain access to spawning grounds or different suitable habitats required for certain life history stages (Saunders, 2007). Dams often result in changes to the natural habitat, causing sensitive species to decline in abundance along with the overall diversity (Poole, 2002; Aadland, 2010; Gardner, et al. 2013; Cross et al., 2013). Large bodied and long-lived species (e.g. Walleye, Sauger, Channel Catfish, Redhorses) require a strongly connected habitat for various life history stages including spawning and fixed retreats. Table 4.1.1 explains that the Marsh River is lower than the basin wide averages in migratory taxa and mature females; however, the scores are within confidence limits. With no evidence of barriers along the Marsh River and the biological data within confidence limits of stressors caused by connectivity related issues, it is unlikely that the connectivity is a related stressor to the biological community. The available data neither supports nor weakens the case for connectivity as a stressor to the fish community of the Marsh River.

Table 4.1.1. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
MgrTxPct	Relative abundance of taxa that are migratory	24 ± 8	17 ± 5	05RD113 (19), 14RD072 (13), 14RD072* (14), 14RD061 (23)
MA>3-TolTxPct	Relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa	22 ± 11	18 ± 14	05RD113 (31), 14RD072 (0), 14RD072* (14), 14RD061 (27)

[1]Basin wide averages for reaches that meet General Use habitat.

* Second sampling event for 14RD072. First sample at 14RD072 was on July 7, 2014 and the second sample at 14RD072* was on July 30, 2014.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Biological response: Macroinvertebrate

Given the limitations of the macroinvertebrate community to migrate along a river continuum, there is no evidence for analysis of connectivity as a stressor. Macroinvertebrate populations have been documented to re-establish in a segmented stream channel to reflect stable community composition upstream and downstream of a man-made barrier. However, barriers related to altered hydrology, specifically drought conditions, can cause direct or indirect changes in sensitive macroinvertebrate populations (see altered hydrology section).

Flow regime instability

The Marsh River Watershed has a USGS flow-monitoring site (05067500) near Shelly, Minnesota that was established in 1944. The historical records of continuous flow data allows for trend analysis over time. According to the Wild Rice Watershed District (2003), the Marsh River Watershed experiences undulating flow regimes. The Marsh River experiences prolonged periods of unsustained baseflow during vulnerable occasions in late summer. The Marsh River Watershed HSPF model estimates that the reach had minimal (< 1 cfs) to no flow from 18% to 62% during 1996-2009. The Marsh River receives significant amounts of flow from a diversion of the Wild Rice River southeast of Ada. During storm events, the Marsh River experiences high peak flows and vulnerability to flooding. Undulating flow regimes have been associated with anthropogenic alterations of stream channel and land use drainage (Groshens, 2007). Transition of native grassland to row crop agriculture aids in the accelerated movement of water off the terrestrial land into waterways, exacerbating flow instability. The MPCA biological monitoring staff encountered slow flow to even stagnant conditions on biological monitoring station 14RD072. However, the biological monitoring staff documented more stable flows at 05RD113 and 14RD061 because of flow contributions from County Ditch 11. The MPCA SID staff conducted reconnaissance along the reach on three different dates: August 4, 2016, August 17, 2016, and October 12, 2016. Stagnant conditions were observed and specifically a dry stream was documented on August 17, 2016, at County State Aid Highway (CSAH) 17, about four stream miles upstream up biological monitoring station 14RD113 (Figure 4.1.2).

Figure 4.1.2. Marsh River documentation of no flow at CSAH 17 on August 17, 2016.

Biological response: Fish

The fish community indicates stressors caused by flow regime instability related impairments (Table 4.1.2). Flow regime instability has been documented to limit the potential for the number of species along with the diversity of species, given the limited abilities for adaption to extreme flow regime fluctuation. Drastic fluctuations have been shown to limit diversity and favor species that are generalists, early maturing and short lived, pioneering, and intolerant to disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). The Marsh River fish community is limited in the diversity of fish species. Specifically, the fish community is comprise of mainly two taxa (Spotfin Shiner and Black Bullheads). These taxa are relatively tolerant species that are typically abundant in areas with poor habitat and flow instability. The available data convincingly supports the case for flow regime instability as a stressor to the fish community of the Marsh River.

Table 4.1.2. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
DomTwoPct	Relative abundance of the two most abundant taxa	47 ± 12	71 ± 9	05RD113 (73), 14RD072 (59), 14RD072* (80), 14RD061 (71)
GeneralTxPct	Relative abundance of individual that are generalists	32 ± 8	23 ± 5	05RD113 (19), 14RD072 (25), 14RD072* (29), 14RD061 (18)
MA<2TxPct	Relative abundance of taxa with a female mature age equal to or less than two years	62 ± 10	63 ± 9	05RD113 (56), 14RD072 (75), 14RD072* (57), 14RD061 (64)
NumPerMeter-Tol	Number of individuals per meter of stream sampled, excluding tolerant species	1 ± 1	0.3 ± 0.4	05RD113 (0.5), 14RD072 (0.0), 14RD072* (0.0), 14RD061 (0.8)
PioneerTxPct	Relative abundance of taxa that are pioneers	18 ± 7	10 ± 6	05RD113 (13), 14RD072 (13), 14RD072 (0), 14RD061 (14)
SLvdPct	Relative abundance of individuals that are short-lived	16 ± 12	7 ± 9	05RD113 (3), 14RD072 (21), 14RD072* (0), 14RD061 (4)
SensitiveTxPct	Relative abundance of sensitive taxa	27 ± 14	16 ± 9	05RD113(13), 14RD072 (13), 14RD072* (29), 14RD061 (9)

[1]Basin wide averages for reaches that meet General Use habitat.

* Second sampling event for 14RD072. First sample at 14RD072 was on July 7, 2014 and the second sample at 14RD072* was on July 30, 2014.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Biological response: Macroinvertebrate

The macroinvertebrate community indicates stressors caused by flow regime instability related impairments (Table 4.1.3). Flow regime instability has been documented to limit diversity and taxa richness of macroinvertebrates and favor tolerant individuals that can adapt to disturbances. Instability can lead to the decline in long-lived individuals given the vulnerability of the stream to dry out towards the end of the growing season. Ephemeroptera, Plecoptera, and Trichoptera are indicator species that require stable flow conditions. Many authors have documented an inverse relationship with flow regime instability and benthic aquatic insects, particularly Trichoptera (Bunn and Arthington, 2002; Bragg et al., 2005; Dewson et al., 2007). The Marsh River, is dominated by scuds (Hyalella), snails (Physella; Gyraulus), and midges (Polypedilum). Specifically, at stations 05RD113 and 14RD072, over half the sample was dominated by scuds and snails (73% and 63%, respectively). However, at station 14RD061, less than half the sample was comprised of the tolerant taxa scuds and snails displaying increasing diversity with samples of mayflies (Caenis, Stenacron) and several different midges. 14RD061 is the furthest downstream biological monitoring station on the Marsh River and specifically was documented on having more stable flow conditions by stressor identification staff and biological monitoring staff. Thus, upstream of the confluence with County Ditch 11, flow instability appears to be limiting the biological community. The available data convincingly supports the case for flow regime instability as a stressor to the macroinvertebrate community of the Marsh River.

Table 4.1.3. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for macroinvertebrate class 7 streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
EPTPct	Relative abundance of Ephemeroptera, Plecoptera, and Trichoptera	38 ± 20	10 ± 9	05RD113 (12), 14RD072 (0.6), 14RD061 (19)
LongLivedPct	Relative abundance of long-lived individuals	8 ± 9	0.3 ± 0.5	05RD113 (0), 14RD072 (0), 14RD061 (0.9)
TaxaCountAllChir	Total taxa richness of macroinvertebrates	37 ± 8	24 ± 10	05RD113 (27), 14RD072 (13), 14RD061 (32)
Tolerant2ChTxPct	Relative percentage of taxa with tolerance values equal to or greater than six	82 ± 8	82 ± 2	05RD113 (81), 14RD072 (85), 14RD062 (81)
TrichwoHydroPct	Relative abundance of non-hydrospsychid Trichoptera individuals	4 ± 5	3 ± 3	05RD113 (6), 14RD072 (1), 14RD062 (1)

[1]Basin wide averages for reaches that meet General Use habitat.

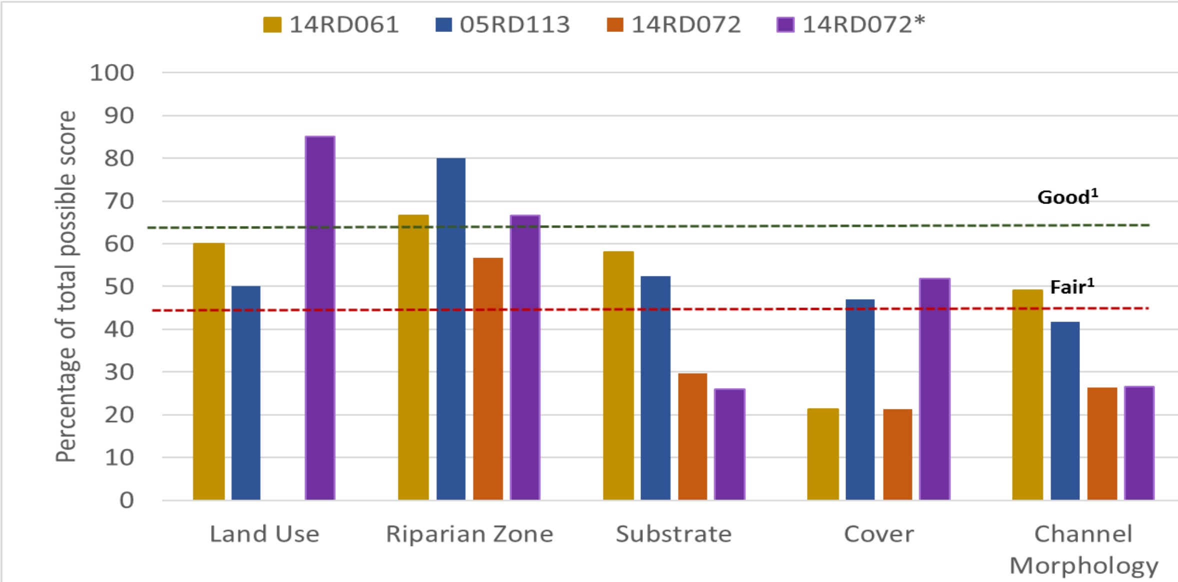
■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Insufficient physical habitat

The physical habitat along the Marsh River has major alternations in the riparian and instream characteristics with a cumulative MPCA Stream Health Assessment (MSHA) score of 45 out of 100 (n= 4 sampling events in 2015) (Figure 4.1.3). The lowest score was channel morphology, which is limited by channel instability derived from high erosion, bedload alterations, and the effects of wide fluctuations in water level (Figure 4.1.4). Instream habitat is limited by moderate amounts of embeddedness and sparse cover type, which leads to lack of protection from stream current or concealment from predators. The highest category score for Marsh River is the riparian zone, which consists of around 50 m to over 100 m of mature woody vegetation providing bank stability and canopy cover for substantial shading.



[1] Good: MSHA score above the median of the least-disturbed sites (MSHA > 66). Fair: MSHA score below the median of the most disturbed sites MSHA < 45).

* Second sampling event for 14RD072. First sample at 14RD072 was on July 7, 2014 and the second sample at 14RD072* was on July 14, 2014.

Figure 4.1.3. MSHA scores for the Marsh River. Stations for MSHA scoring are displayed in Figure 4.1.1.

Figure 4.1.4. Photo documentation of channel instability on the Marsh at biological monitoring station 05RD113 (top left, May 19, 2014) (bottom left and bottom right, July 7, 2014) and station 14RD061 (top right, July 30, 2014). Photos were taken by the MPCA biological monitoring crew.

Biological response: Fish

The fish community indicates stressors caused by insufficient physical habitat related impairments (Table 4.1.4). Loss of physical habitat has a wide range of effects on the biological community with instream and riparian zone degradation. Loss of instream zone stability and channel morphology will limit the potential for organisms that favor riffle habitat, lithophilic spawners, and benthic insectivores (Frimpong et al., 2005; Aaland and Kuitunen, 2006). The degradation of streambed composition and morphology will favor organisms that feed on detritus because of the shift in organic matter arrangement (Culp et al., 1986). The Marsh River biological scores below the basin averages but within confidence limits, with a substantially higher abundance of insectivores than the basin average. The available data somewhat supports the case for insufficient physical habitat as a stressor to the fish community of the Marsh River.

Table 4.1.4. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
RiffleTxPct	Relative abundance of taxa that predominately utilize riffle habitats	27 ± 13	11 ± 4	05RD113 (13), 14RD072 (13), 14RD072* (14), 14RD061 (5)
SLithopTx Pct	Relative abundance of taxa that are simple lithophilic spawning species	34 ± 12	19 ± 6	05RD113 (25), 14RD072 (13) 14RD072* (14), 14RD061 (23)
Insect-TolPct	Relative abundance of individuals that are insectivorous excluding tolerant species	35 ± 19	46 ± 37	05RD113 (79), 14RD072 (24), 14RD072* (6), 14RD061 (77)
BenInsect-TolTxPct	Relative abundance of taxa that are benthic insectivores, excluding tolerant species	29 ± 11	11 ± 8	05RD113 (13), 14RD072 (0), 14RD072* (14), 14RD061 (18)
DetNWQT xPct	Relative abundance of taxa that are detritivorous	20 ± 7	23 ± 11	05RD113 (25), 14RD072 (38), 14RD072* (14), 14RD061 (14)
DarterScul pTxPct	Relative abundance of taxa that are darters and sculpins	15 ± 6	4 ± 5	05RD113 (6), 14RD072 (0), 14RD072* (0), 14RD061(9)

[1]Basin wide averages for reaches that meet General Use habitat.

* Second sampling event for 14RD072. First sample at 14RD072 was on July 7, 2014 and the second sample at 14RD072* was on July 30, 2014.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Biological response: Macroinvertebrate

The macroinvertebrate community indicates stressors caused by insufficient physical habitat related impairments (Table 4.1.5). Loss of physical habitat will limit the streambed composition and morphology overall affecting the species adapted for specific microhabitats. The effects of erosion and sedimentation will decrease the species that cling onto hard surfaces while promoting species adapted for burrowing into sediments, legless, and species that sprawl onto bottom sediments (Culp et al., 1986; Gore et al., 2001). The Marsh River has a substantial decrease in the clinger taxa resulting from limited environments for clingers to attach onto hard-aerated surfaces (e.g. riffles). The amount of sediment and embeddedness in the Marsh River substantially increases the potential for sprawlers to live on surfaces of aquatic plants or fine sediments given their modifications for staying on top of substrate and keeping respiratory surfaces free of silt (Merritt and Cummins, 1995). The Marsh River has over two times the amount of sprawlers compared to the Red River basin average and a 4 fold decrease in the amount of clinger species compared to the Red River basin average. The drastic deviation from the basin wide average indicates stress to the biological community. The available data strongly supports the case for insufficient physical habitat as a stressor to the macroinvertebrate community in the Marsh River.

Table 4.1.5. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for macroinvertebrate class 7 streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
BurrowerPct	Relative percentage of burrower individuals	8 ± 8	8 ± 10	05RD113 (5), 14RD072 (0), 14RD061 (20)
ClingerPct	Relative percentage of clinger individuals	39 ± 18	9 ± 5	05RD113 (13), 14RD072 (4), 14RD061 (11)
LeglessPct	Relative percentage of legless individuals	40 ± 19	48 ± 6	05RD113 (41), 14RD072 (49), 14RD061 (53)
SprawlerPct	Relative percentage of sprawler individuals	21 ± 12	44 ± 6	05RD113 (50), 14RD072 (39), 14RD061 (43)

[1]Basin wide averages for reaches that meet General Use habitat.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

High suspended sediment

The Marsh River experiences vulnerability to remaining clay and fine sediments left over by Lake Agassiz, which are easily erodible. The Marsh River has an existing turbidity impairment that was listed in 2008. TSS has been sampled along Marsh River from 2003-2016 (Table 4.1.6). Over the years, the Marsh River has shown to be most vulnerable to excess sediment in the water column during the spring months (March-June) due to snow melt and spring runoff (Figure 4.1.5). During spring sampling (March-June), TSS averages 66 mg L^{-1}, which is over the threshold of impairment and even reached a maximum of 890 mg L^{-1} on May 13, 2004. The Marsh River Watershed HSPF model estimates that the TSS standard of 65 mg L^{-1} was exceed 19 – 23% during 1996-2009. Specifically, the Marsh River Watershed receives majority of flow contributions from County Ditch 11 (AUID 517); therefore, downstream of the confluence with County Ditch 11, the Marsh River experiences degraded habitat from sediment loading during high flows. Figure 4.1.6 displays visual documentation of excessive sediment loading from County Ditch 11 at the confluence with the Marsh River during the spring of 2017.

Table 4.1.6. Total suspended sediment data on the Marsh River. Stations are displayed in Figure 4.1.1.

		TSS mg L^{-1}				
Station	**Years collected**	**n**	**min**	**max**	**average**	**Percentage exccedance[1]**
S007-786	2014	11	6	79	29	9
S002-127	2003-2016	244	1	890	59	20
S005-789	2010-2016	60	2	360	34	17
S005-798	2009	4	19	49	32	0

[1]percentage of samples that exceed the Southern Streams TSS standard of 65 mg L^{-1}

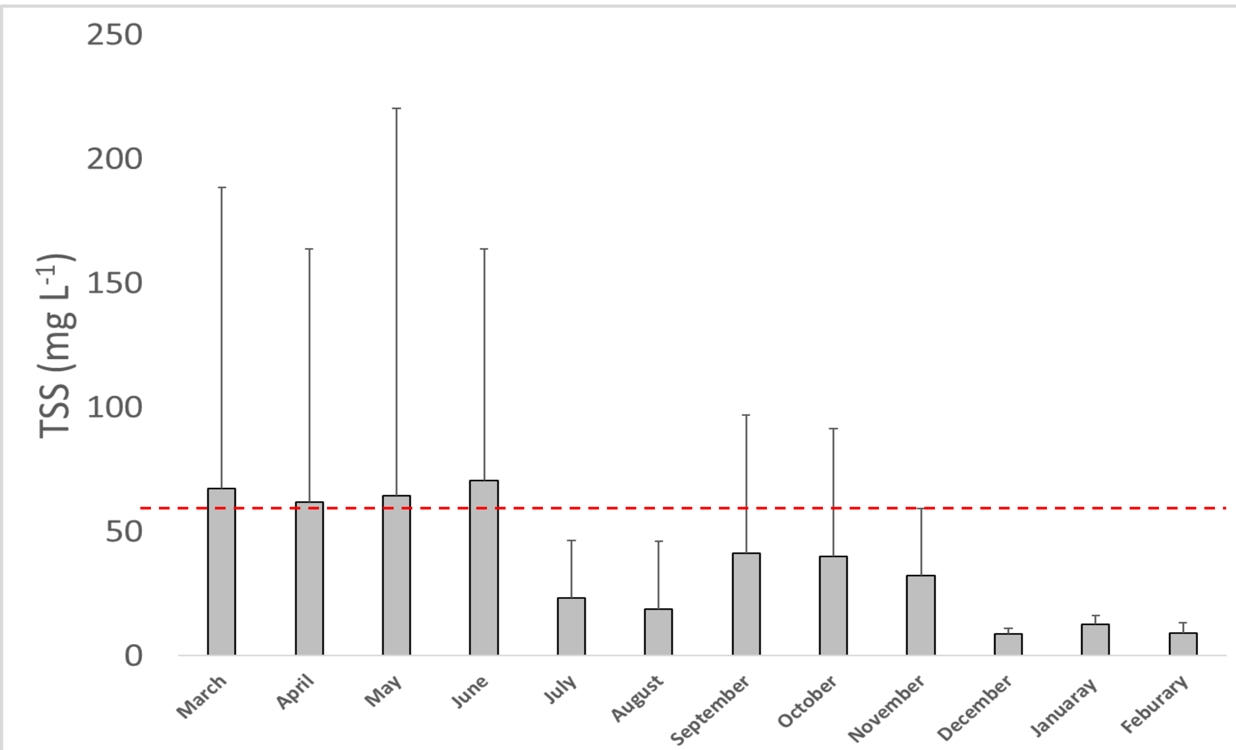


Figure 4.1.5. Monthly TSS on the Marsh River Watershed collected at stations S007-786, S002-127, S005-789, S005-798 in 2003-2016 (see Table 4.1.6. for site specific years). Stations locations are displayed in Figure 4.1.1. Red line indicates the TSS threshold for Southern Streams (65 mg L^{-1}).

Figure 4.1.6. The confluence of the Marsh River and County Ditch 11 near Shelly on 129th Avenue. This photo was taken on April 7, 2017, during a stressor identification site reconnaissance.

Biological response: Fish

The fish community indicate stressors caused by high suspended sediment related impairments (Table 4.1.7). Excessive suspended sediment can affect the fish community in various ways depending on the amount of suspended sediment, duration of exposure to excessive suspended sediment, and the chemical composition of the colloidal fraction of suspended sediment. High suspended sediment often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b). Sediment deposition fills interstitial space in riffles and coarse substrate that is utilized by sensitive lithophilic spawning fish (Bilotta and Brazier, 2008). The deposited material blocks the pores in the streambed, preventing the exchange within the hyporheic zone (Greig et al., 2005). Sedimentation can also degrade the macroinvertebrate community, which will lead to (or "result in") overall reduced insectivore fish species. The Marsh River biological community is representing a decline in taxa that are sensitive to TSS relative to the basin averages. The available data strongly supports the case for high-suspended sediment as a stressor to the fish community of the Marsh River.

Table 4.1.7. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
TSS TIV	Mean TSS tolerance indicator value	18 ± 7 (mg L^{-1})	17 ± 5 (mg L^{-1})	05RD113 (29), 14RD072 (16), 14RD072* (21), 14RD061 (27)
CondProb	Probability of meeting the TSS standard	60 ± 28 (%)	30 ± 28 (%)	05RD113 (6), 14RD072 (65) 14RD072* (38), 14RD061 (9)
SLithopTxPct	Relative abundance of taxa that are simple lithophilic spawning species	34 ± 12	19 ± 6	05RD113 (25), 14RD072 (13) 14RD072* (14), 14RD061 (23)
BenInsectPct	Relative abundance of benthic insectivores individuals	23 ± 14	6 ± 7	05RD113 (4), 14RD072 (0) 14RD072* (3), 14RD061 (16)

[1]Basin wide averages for reaches that meet General Use habitat.
* Second sampling event for 14RD072. First sample at 14RD072 was on July 7, 2014 and the second sample at 14RD072* was on July 30, 2014.
■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.
■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.
■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Biological response: Macroinvertebrate

The macroinvertebrate community indicates stressors caused by high suspended sediment related impairments (Table 4.1.8). Excessive suspended sediment can affect the macroinvertebrate community in various ways depending on the amount of suspended sediment, duration of exposure to excessive suspended sediment, and the chemical composition of the colloidal fraction of suspended sediment. High suspended sediment often results in a limited macroinvertebrate community that is dominated by tolerant taxa (Henley et al., 2000; EPA, 2012; Jones et al., 2012). Sediment suspended in the water column will limit collector species and species that filter using a net-spinning casing. The amount of sediment in the Marsh River substantially increases the potential for sprawlers to live on surfaces of fine sediments given their modifications for staying on top of substrate and keeping respiratory surfaces free of silt (Merritt and Cummins, 1995). Marsh River is limited in clinger species indicating the degraded habitat of hard surfaces with high flows (e.g. riffles) covered by sediment loading. The available data strongly supports the case for high suspended sediment as a stressor to the macroinvertebrate community in the Marsh River.

Table 4.1.8. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for macroinvertebrate class 7 streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
Collector-filtererPct	Relative abundance of collector-filterer individuals	19 ± 15	3 ± 3	05RD113 (4), 14RD072 (0), 14RD061 (5)
TSS TIV	Mean TSS tolerance indicator value	18 ± 3	18 ± 1	05RD113 (18), 14RD072 (19), 14RD061 (17)
TolTSS	Relative abundance of high TSS tolerant taxa	48 ± 20	38 ± 6	05RD113 (38), 14RD072 (33), 14RD061 (44)
InTolTSS	Relative abundance of high TSS intolerant taxa	3 ± 5	0.2 ± 0.3	05RD113 (0.6), 14RD072 (0), 14RD061 (0)
SprawlerPct	Relative abundance of sprawler individuals	21 ± 12	44 ± 6	05RD113 (50), 14RD072 (39), 14RD061 (43)
ClingerPct	Relative percentage of clinger individuals	39 ± 18	9 ± 5	05RD113 (13), 14RD072 (4), 14RD061 (11)

[1]Basin wide averages for reaches that meet General Use habitat.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Low dissolved oxygen

The Marsh River was listed as impaired for dissolved oxygen in 2010. The Marsh River occasionally experiences low dissolved oxygen concentrations that drop below 5 mg L^{-1}. Specifically, the Marsh River Watershed HSPF model calculated that dissolved oxygen was below 5 mg L^{-1} 1% - 34% during 1996-2009. Dissolved oxygen has been sampled on the Marsh River in four different locations displayed in Figure 4.1.1 (S007-789, S002-127, S005-789, and S005-798). Occasionally, dissolved oxygen drops below 5 mg L^{-1} at three of the four sampling locations. However, the exceedances seem to be infrequent (Table 4.1.9). With all stations combined, dissolved oxygen exceedances appear to be common during low flow conditions in late summer (Figure 4.1.7). Stressor identification staff monitored dissolved oxygen during late summer over a 13 day period from August 4, 2016 – August 17, 2016 (Figure 4.1.8). During this time, dissolved oxygen concentrations never exceeded the Southern Streams standard for low dissolved oxygen (5 mg L^{-1}).

Stressors from eutrophication are determined using total phosphorus, chlorophyll *a*, biochemical oxygen demand (BOD), and dissolved oxygen flux. There were no BOD data for the Marsh River; however, total phosphorus, chlorophyll a, and DO flux were analyzed to determine eutrophication as a potential stressor. Phosphorus was sampled along the Marsh River from 2003-2016. Over the course of the sampling period, phosphorus exceeded the Southern Streams standard (150 µg L^{-1}) 81% of the time (n = 289). The average phosphorus concentration was 323 µg L^{-1} with a minimum concentration of 47 µg L^{-1} and a maximum concentration of 4,080 µg L^{-1}. Chl-a was sampled along the Marsh River from 2011-2015. Chl-a samples exceeded the Southern Streams threshold of 35 µg L^{-1} once on July 10, 2014 with 37 µg L^{-1} (n =23). The average chl a concentration was eight µg L^{-1} with a minimum concentration of one µg L^{-1} and a maximum concentration of 37 µg L^{-1}. From the stressor identification dissolved oxygen deployment from August 4, 2016 to August 17, 2016 (n = 13 days), DO flux never exceeded the standard of 4.5 mg L^{-1}. The average flux over the deployment period was 1.44 mg L^{-1} with a minimum of 0.88 mg L^{-1} and a maximum of 2.78 mg L^{-1}. The Marsh River is prone to high phosphorus concentrations, however, the limited response variable (i.e., Chl-a and DO flux) data and field observations do not suggest that eutrophication is adversely affecting the dissolved oxygen concentrations.

Table 4.1.9. Summary of the dissolved oxygen data collected on the Marsh River. Stations are displayed in Figure 4.1.1.

Station	Years	n	min	max	average	Percent exceedance[1]
S007-786	2014-2015	24	3.79	10.76	7.22	17
S002-127	2003-2016	233	0.44	13.38	8.39	4
S005-789	2010-2015	47	2.06	13.47	8.88	9
S005-798	2009	4	9.53	10.55	10.14	0

[1]percentage of samples that exceed the Southern Streams dissolved oxygen standard of 5 mg L^{-1}

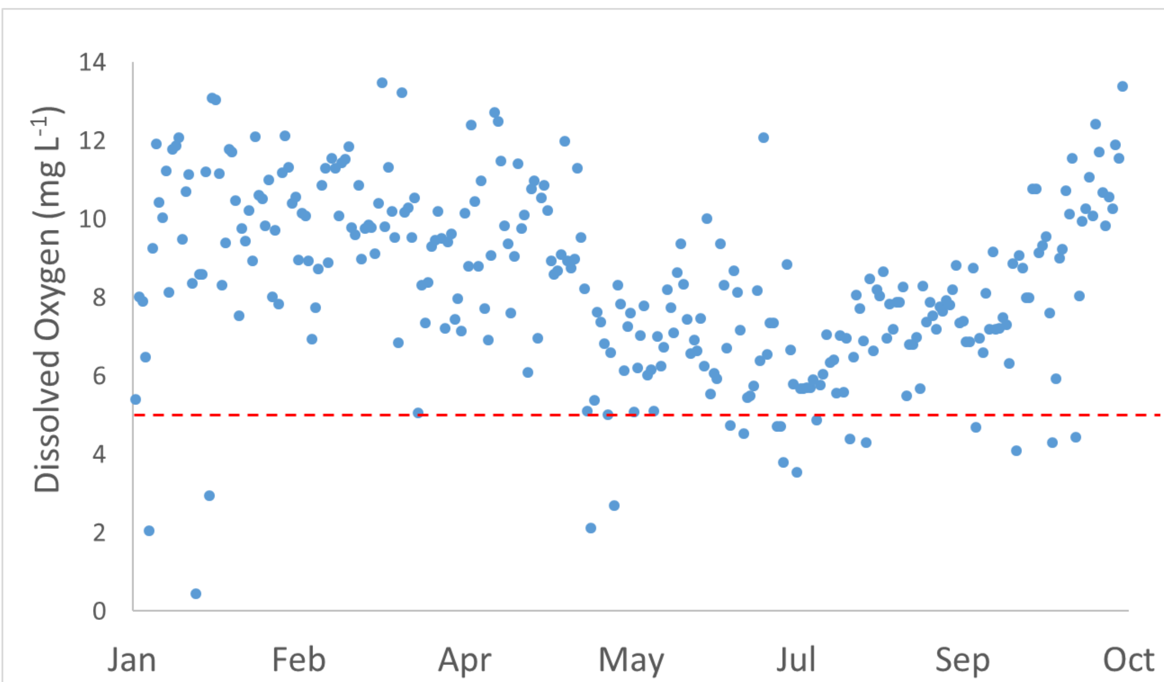


Figure 4.1.7. Monthly discrete dissolved oxygen measurements (mg L^{-1}) from water quality stations found in Figure 4.1.1 (S007-789, S002-127, S005-789, and S005-798). Years samples are from 2003-2016. No apparent trend was noticeable among monitoring stations. Red dashed line indicates the Southern Streams standard for low dissolved oxygen (5 mg L^{-1}).

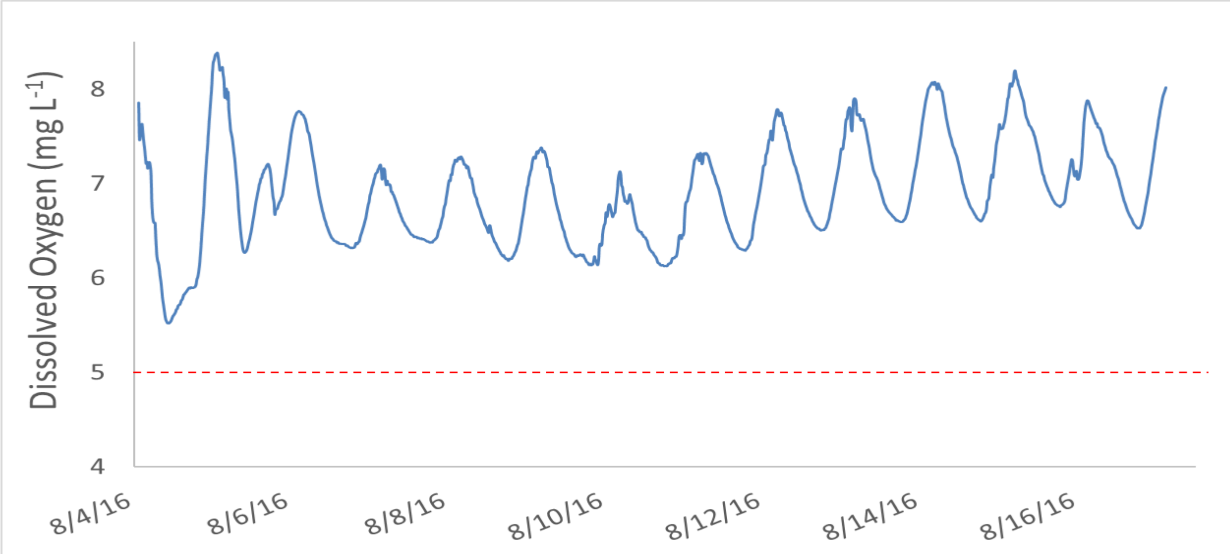


Figure 4.1.8. Dissolved oxygen deployments on the Marsh River. Deployment location is displayed in Figure 4.1.1. Red line indicates Southern Streams standard for dissolved oxygen (5 mg L^{-1})

Biological response: Fish

The fish community does not strongly indicate stressors caused by low dissolved oxygen related impairments (Table 4.1.10). Dissolved oxygen concentrations can alter the biological community by limiting species that are sensitive to dramatic shifts in dissolved oxygen along with species that are intolerant of low dissolved oxygen levels for an extended period of time (Davis, 1975; EPA, 2012). The available data neither supports nor weakens the case for low dissolved oxygen as a stressor to the fish community of the Marsh River.

Table 4.1.10. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
DO TIV	Mean DO tolerance indicator value	7 ± 0.5 (mg L^{-1})	6 ± 0.4 (mg L^{-1})	05RD113 (7), 14RD072 (7), 14RD072* (6), 14RD061 (7)
CondProb	Probability of meeting the dissolved oxygen standard	44 ± 21 (%)	36 ± 21 (%)	05RD113 (48), 14RD072 (33) 14RD072* (8), 14RD061 (57)
MA>3-TolTxPct	Relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa	22 ± 11	18 ± 14	05RD113 (31), 14RD072 (0), 14RD072* (14), 14RD061 (27)

[1]Basin wide averages for reaches that meet General Use habitat.
* Second sampling event for 14RD072. First sample at 14RD072 was on July 7, 2014 and the second sample at 14RD072* was on July 30, 2014.
■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.
■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.
■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Biological response: Macroinvertebrate

The macroinvertebrate community does not strongly indicate stressors caused by low dissolved oxygen related impairments (Table 4.1.11). Dissolved oxygen concentrations can alter the biological community by limiting species that are sensitive to dramatic shifts in dissolved oxygen along with species that are intolerant of low dissolved oxygen levels for an extended period of time (Davis 1975, EPA, 2012). Low dissolved oxygen will especially limit the taxa for the following orders, Ephemeroptera, Plecoptera, and Tricoptera (EPT). The EPT individuals will favors environments that provides high dissolved oxygen including riffles and swift aerated portions of the stream channel. Similar to TSS, the dissolved oxygen dynamics are dictated by the flow regime. Specifically, when the Marsh River gains flow from County Ditch 11, the macroinvertebrate community seems to display a positive response in metric scores. The biological monitoring station that consistently has the lowest metric scores is 14RD072, which is upstream of the confluence with County Ditch 11. The substantial flow contribution from County Ditch 11, aids in stabilizing the dissolved oxygen dynamics downstream of the confluence. Thus, the stressor is driven by flow regime instability rather than low dissolved oxygen. The available data somewhat supports the case for low dissolved oxygen as a stressor to the macroinvertebrate community of the Marsh River.

Table 4.1.11. Biological indices for the Marsh River compared with the basin wide averages that meet that state IBI threshold for macroinvertebrate class 7 streams providing General Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
DO TIV	Mean DO tolerance indicator value	7 ± 0.5 (mg L^{-1})	6 ± 0.3 (mg L^{-1})	05RD113 (6), 14RD072 (6), 14RD061 (6)
ChemTV DO % Tolerant	Relative abundance of low DO tolerant taxa	13 ± 14 (%)	56 ± 11 (%)	05RD113 (50), 14RD072 (69), 14RD061 (50)
ChemTV DO % Intolerant	Relative abundance of low DO intolerant taxa	9 ± 9	0.7 ± 1	05RD113 (2), 14RD072 (0), 14RD061 (0)
EPTPct	Percent of Ephemeroptera, Plecoptera, and Tricoptera	38 ± 20	10 ± 9	05RD113 (12), 14RD072 (1), 14RD061 (19)
Ephemeropte raPct	Percent of Ephemeroptera	25 ± 18	7 ± 9	05RD113 (4), 14RD072 (0), 14RD061 (16)

[1]Basin wide averages for reaches that meet General Use habitat.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Marsh River summary

The evidence for stressors causing impairment to the biological community are attributed to flow regime instability, insufficient physical habitat, high suspended sediment, and less strongly, dissolved oxygen. A detailed summary of the stressors associated with the Marsh River Watershed and recommended actions for mitigating stressors can be found in Section 5.1.

4.2. County Ditch 11 (AUID 517)

4.2.1. Overview

AUID 517 (hereafter referred as County Ditch 11) includes a 10-mile stream reach that flows east to west until it reaches the confluence with the Marsh River about five miles South East of Shelly, Minnesota (Figure 4.2.1). Land use surrounding County Ditch 11 is dominated by cultivated crops (88%), with small scattered portions of land use comprised of developed (5%), wetlands (4%), forest (2%), and open water (1%) (USGS, 2011). The entire length of County Ditch 11 has been ditched to promote drainage of agricultural land (MPCA, 2013). The impaired portion of the ditch is in the Lake Plain; therefore, the soils consists of clay and silty clay with low infiltration rates and potential for runoff and erosion.

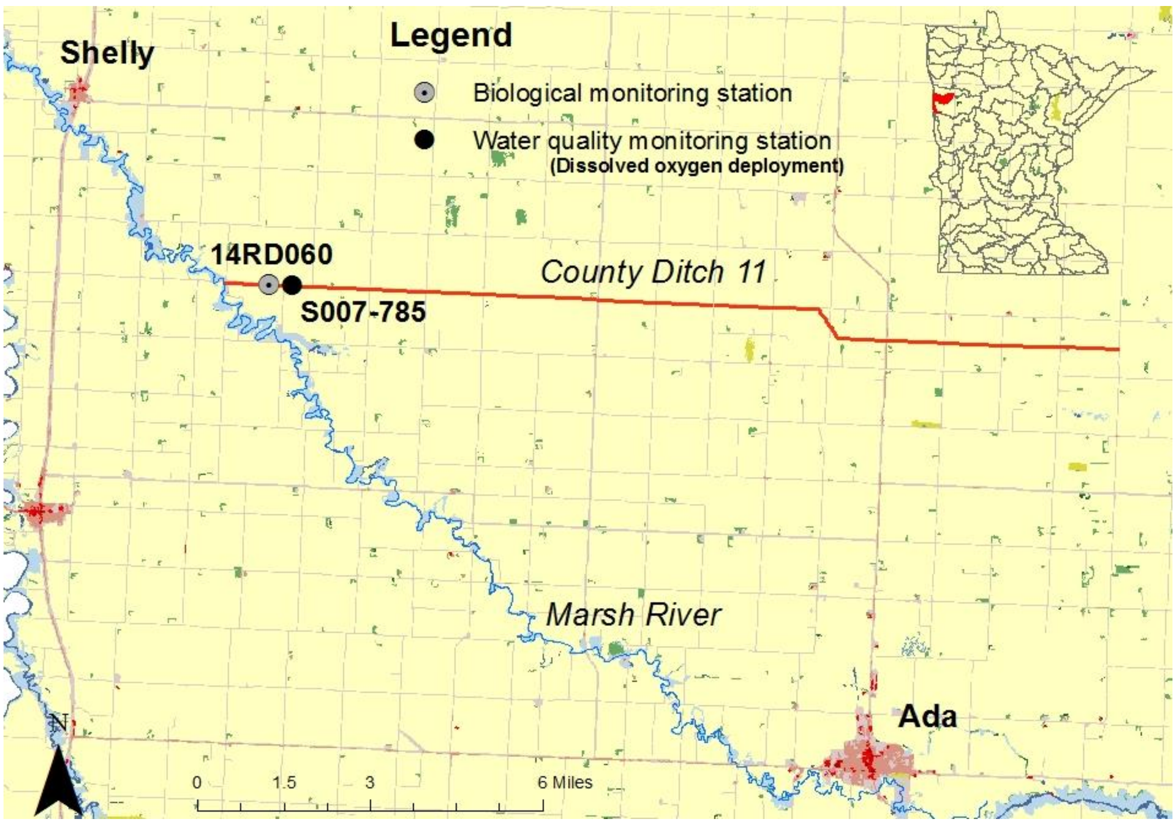


Figure 4.2.1. County Ditch 11 (AUID 09020107-517) 10 mile impaired reach offering Modified Use support, is displayed in red.

4.2.2. Biological impairments

Fish (F-IBI)

County Ditch 11 is classified as a class two Southern Stream providing Modified Use habitat with an F-IBI threshold of 35. One station (14RD060), displayed in Figure 4.2.1 was sampled twice in 2014. Both sampling events had an F-IBI score of zero, which is below the Modified Use threshold and confidence interval. County Ditch 11 is documented as having poor habitat that displays a BCG level five, with a trend towards six. BCG levels in this range show sensitive taxa diminished with extreme changes in density and diversity of taxa. The fish assemblage contains Fathead Minnow, Central Mudminnow, and Brook Stickleback. These species represent a fish community comprised of tolerant taxa. Overall, County Ditch 11 indicates non-support for aquatic life.

Macroinvertebrate (M-IBI)

County Ditch 11 is classified as a class seven Southern Stream providing Modified Use habitat with an M-IBI threshold of 22. One station (14RD060) was sampled in 2014 (Figure 4.2.1). This site received an M-IBI score of 34, which is above the Modified Use threshold with a BCG tier 5 community. Almost half (44%) of the sample was comprised of tolerant mayfly taxa. The remainder of the sample was comprised of scuds and midges. County Ditch 11 is supporting for aquatic life based on macroinvertebrates.

4.2.3. Stressor pathway

Connectivity

County Ditch 11 experiences loss of connectivity due to a high gradient culvert that is limiting the biological community (Figure 4.2.2). The culvert is located 350 feet upstream from the confluence with the Marsh River. The culvert has an elevation drop of 25 feet (IWI 2017, Figure 4.2.3). Therefore, this culvert will block fish passage during low flows and during high flows. Species seeking upstream tributary habitat will be unable to migrate into upper sections of the stream system. No other connectivity barriers were noted on County Ditch 11 during stressor identification reconnaissance on October 12, 2016, and April 7, 2017. Stressors Identification staff completed a site reconnaissance using Google Earth on January 18, 2017, and found no additional major barriers that would cause a disconnect in either flow or biological passage along County Ditch 11. However, there is insufficient data to make any conclusions on velocity barriers caused by poorly constructed culverts along the reach.

Figure 4.2.2. Pictures of a high gradient culvert on County Ditch 11 located 350 feet upstream of the confluence with the Marsh River. Stressor identification staff took the photos. The two right photos were taken on October 12, 2016, and the two left photos were taken on April 7, 2017.

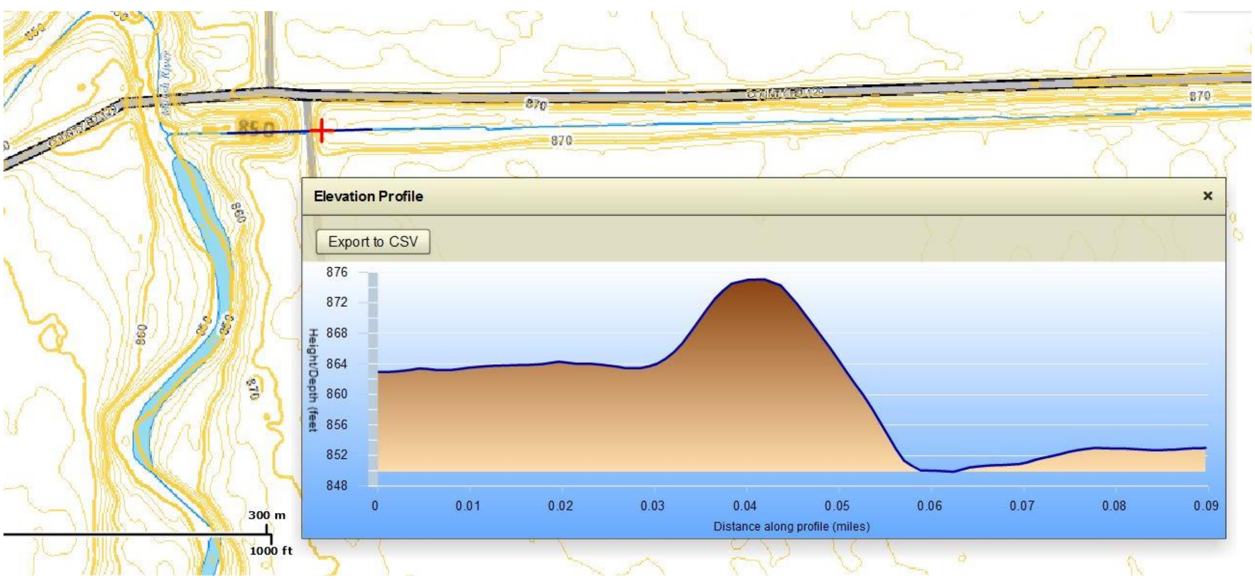


Figure 4.2.3. Elevation profile of the high gradient culvert on County Ditch 11 (IWI, 2017).

Biological response: Fish

The fish community indicate stressors caused by loss of connectivity related impairments (Table 4.2.1). A waterway that is not longitudinally connected will results in an inability for migratory fish to gain access to spawning grounds or different suitable habitats required for certain life history stages (Saunders, 2007). Dams often result in changes to the natural habitat causing sensitive species to decline in abundance along with the overall diversity (Poole, 2002; Aaland, 2010; Gardner et al., 2013; Cross et al., 2013). Specifically, barriers degrade habitat by altering dissolved oxygen, temperature, nutrient, and sediment concentrations. Large bodied and long-lived species (e.g. Walleye, Sauger, Channel Catfish, Redhorses) require a strongly connected habitat for various life history stages including spawning and fixed retreats. County Ditch 11 is completely deprived of species that are migratory insinuating complete loss of connectivity. The available data convincingly supports the case for connectivity as a stressor to the fish community of County Ditch 11.

Table 4.2.1. Biological indices for County Ditch 11 compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing Modified Use habitat.

Metric	Description	Basin average[1]	AUID 503 score	Station (count)
MgrTxPct	Relative abundance of taxa that are migratory	21 ± 8	0 ± 0	14RD060 (0), 14RD060* (0)
MA>3-TolTxPct	Relative abundance of taxa with a female mature age of equal to or greater than three years, excluding tolerant taxa	17 ± 10	0 ± 0	14RD060 (0), 14RD060* (0)

[1]Basin wide averages for reaches that meet Modified Use habitat.

* Second sampling event for 14RD60. First sample at 14RD060 was on June 11, 2014 and the second sample at 14RD060* was on July 7, 2014.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Flow regime instability

According to the Wild Rice Watershed District (2003), the Marsh River Watershed experiences undulating flow regimes. County Ditch 11 is susceptible to prolonged periods of unsustained baseflow during vulnerable occasions in late summer. The Marsh River Watershed HSPF model estimates that the reach had minimal (< 1 cfs) to no flow 43% of the time during 1996-2009. During storm events and spring runoff/snow melt, County Ditch 11 experiences high flows and high water depths with flooding tendencies. Undulating flow regimes have been associated with anthropogenic alterations of stream channel and land use drainage (Groshens, 2007). The MPCA biological monitoring staff documented no flow on August 18, 2015 at County Ditch 11. The MPCA SID staff conducted reconnaissance along the reach on four different dates: August 4, 2016, August 17, 2016, October 12, 2016, and April 7, 2017. Stagnant conditions were documented during reconnaissance on August 17, 2016 at CSAH 17 Figure 4.2.4). Following spring runoff, photos documented sustained baseflow on April 7, 2017 (Figure 4.2.4).

Figure 4.2.4. Pictures documenting variability in water depths on two different dates at County Ditch 11. The top two pictures were taken on April 7, 2017 and the bottom two pictures were taken on August 17, 2016. Stressor identification staff took the pictures during reconnaissance on CSAH 17.

Biological response: Fish

The fish community indicates stressors caused by flow regime instability related impairments (Table 4.2.2). Flow regime instability has been documented to limit the potential for the number of species along with the diversity of species, given the limited abilities for adaption to extreme flow regime fluctuation. Drastic fluctuations have been acknowledged to limit diversity and favor species that are generalists, early maturing and short lived, pioneering, and intolerant to disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). The available data strongly supports the case for flow regime instability as a stressor to the fish community of County Ditch 11.

Table 4.2.2. Biological indices for County Ditch 11 compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing Modified Use habitat.

Metric	Description	Basin average[1]	AUID 517 score	Station (count)
DomTwoPct	Relative abundance of the two most abundant taxa	53 ± 15	85 ± 4	14RD060 (82), 14RD060* (88)
GeneralTxPct	Relative abundance of individual that are generalists	35 ± 10	23 ± 4	14RD060 (25), 14RD060* (20)
MA<2TxPct	Relative abundance of taxa with a female mature age equal to or less than two years	62 ± 11	100 ± 0	14RD060 (100), 14RD060* (100)
NumPerMeter-Tol	Number of individuals per meter of stream sampled, excluding tolerant species	0.5 ± 0.4	0.1 ± 0.1	14RD060 (0.2), 14RD060* (0.1)
PioneerTxPct	Relative abundance of taxa that are pioneers	20 ± 9	23 ± 4	14RD060 (25), 14RD060* (20)
SLvdPct	Relative abundance of individuals that are short-lived	14 ± 14	98 ± 0	14RD060 (98), 14RD060* (98)

[1]Basin wide averages for reaches that meet Modified Use habitat.

* Second sampling event for 14RD60. First sample at 14RD060 was on June 11, 2014 and the second sample at 14RD060* was on July 7, 2014.

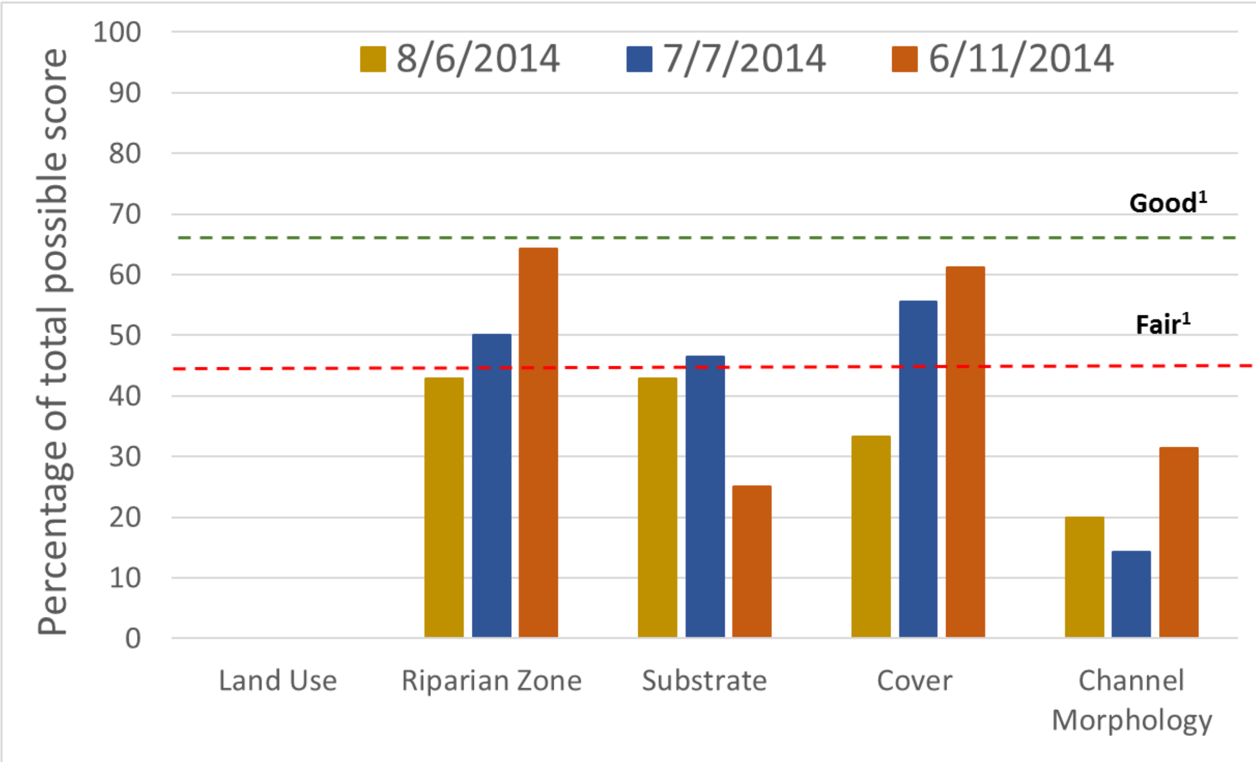
■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Insufficient physical habitat

The physical habitat along County Ditch 11 has major alternations in the riparian and instream habitat with an average cumulative MSHA score of 35 out of 100 (n=3 sampling events in 2014). The five categories used in the MSHA score were all well below the “good” threshold representing a disturbed system (Figure 4.2.5). The lowest overall categorical score was land use followed closely by channel morphology, which was limited by a homogenous agricultural row crop land use and ditched channel to promote drainage on the landscape. The channel morphology is indicative of poor channel development that includes 90-100% of the stream channel comprised of a run microhabitat with limited occurrences of riffle and pool habitat. Instream habitat was limited by moderate amounts of embeddedness caused by excessive fine sediment and sparse cover type, which leads to lack of protection from stream current or concealment from predators.



[1] Good: MSHA score above the median of the least-disturbed sites (MSHA > 66). Fair: MSHA score below the median of the most disturbed sites MSHA < 45).

Figure 4.2.5. MSHA scores for County Ditch 11.

Biological response: Fish

The fish community indicates stressors caused by insufficient physical habitat related impairments (Table 4.2.3). Loss of physical habitat has a wide range of effects on the biological community with instream and riparian zone degradation. Loss of instream zone stability and channel morphology will limit the potential for organisms that favor riffle habitat, lithophilic spawners that require clean gravel or cobble, and benthic insectivores (Frimpong et al., 2005). The degradation of streambed composition and morphology will favor organisms that feed on detritus because of the shift in organic matter arrangement. The available data convincingly supports the case for degraded physical habitat as a stressor to the fish community of County Ditch 11.

Table 4.2.3. Biological indices for County Ditch 11 compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing Modified Use habitat.

Metric	Description	Basin average	AUID 517 score	Station (count)
RiffleTxPct	Relative abundance of taxa that predominately utilize riffle habitats	18 ± 10	0 ± 0	14RD060 (0), 14RD060* (0)
SLithopTxPct	Relative abundance of taxa that are simple lithophilic spawning species	27 ± 14	0 ± 0	14RD060 (0), 14RD060* (0)
Insect-TolTxPct	Relative abundance of individuals that are insectivorous excluding tolerant species	37 ± 10	10 ± 14	14RD060 (0), 14RD060* (20)
BenInsect-TolTxPct	Relative abundance of taxa that are benthic insectivores, excluding tolerant species	23 ± 10	0 ± 0	14RD060 (0), 14RD060* (0)
DetNWQTxPct	Relative abundance of taxa that are detritivorous	21 ± 6	23 ± 4	14RD060 (25), 14RD060* (20)
DarterSculpTxPct	Relative abundance of taxa that are darters and sculpins	13 ± 6	0 ± 0	14RD060 (0), 14RD060* (0)

[1]Basin wide averages for reaches that meet Modified Use habitat.

* Second sampling event for 14RD60. First sample at 14RD060 was on June 11, 2014 and the second sample at 14RD060* was on July 7, 2014.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Excessive suspended sediment

County Ditch 11 experiences vulnerability to remaining clay and fine sediments left over by Lake Agassiz, which are easily erodible. TSS has been sampled along County Ditch 11 from 2014-2015 and there has been no documentation of exceedances of the Southern Streams threshold of 65 mg L^{-1} (Table 4.2.4, Figure 4.2.6). However, County Ditch 11 does not have a sufficient sample size of TSS water chemistry samples (n =13) and therefore yields low confidence in indictments of TSS impairment. Figure 4.2.7 displays visual documentation of excessive sediment loading during the spring of 2017 along with contributing areas of sediment with no vegetative buffer. The County Ditch 11 HSPF model estimates that the TSS standard of 65 mg L^{-1} was exceeded 25% of the time during 1996-2009. Additionally, the MSHA results (see insufficient physical habitat section) indicate that the deposition of excess sediment caused moderate level of embeddedness of coarse substrate documented at station 14RD060. Overall, the available data suggest that the reach experiences frequent periods of high suspended sediment.

Table 4.2.4. TSS sampling on County Ditch 11. Station is displayed in Figure 4.2.1.

		TSS mg L^{-1}				
Station	Years collected	n	min	max	average	Percentage exccedance[1]
S007-785	2014-2015	13	1	63	20	0

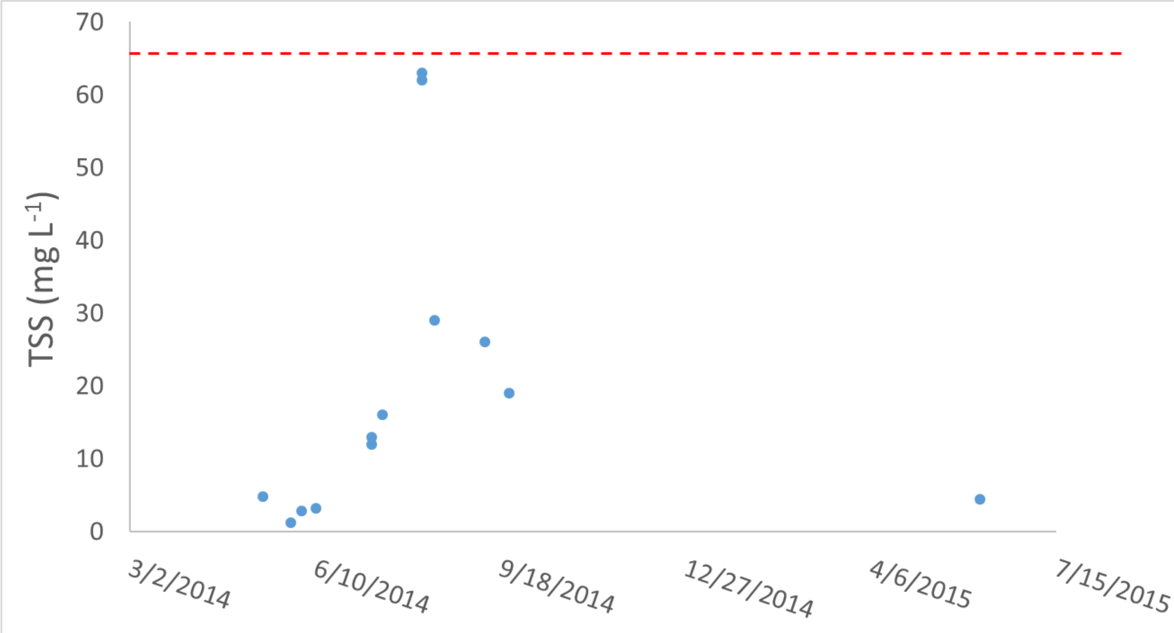


Figure 4.2.6. TSS samples on County Ditch 11 from station S007-785 during 2014-2015. Red line indicated TSS standard for Southern Streams (65 mg L^{-1}).

Figure 4.2.7. Pictures of County Ditch 11 near Shelly, Minnesota at 155th Street (top right and bottom right), and the confluence of the Marsh River and County Ditch 11 near Shelly on 129th Avenue (top left and bottom left). Red arrow in top left pictures showing excessive sediment deposited at the confluence of County Ditch 11 and Marsh River. These photos were taken on April 7, 2017, during a stressor identification site reconnaissance.

Biological response: Fish

The fish community indicates stressors caused by excessive suspended sediment related impairments (Table 4.2.5). Excessive suspended sediment can affect the fish community in various ways depending on the amount of suspended sediment, duration of exposure to excessive suspended sediment, and the chemical composition of the colloidal fraction of suspended sediment. Excessive suspended sediment fills interstitial space in riffles and coarse substrate that is utilized by sensitive lithophilic spawning fish (Bilotta and Brazier, 2008). The deposited material blocks the pores in the streambed, preventing the exchange within the hyporheic zone (Greig et al., 2005). High sedimentation can also negatively effect the macroinvertebrate community, which in turn can reduce insectivore fish species. High suspended sediment often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). The available data strongly supports the case for high suspended sediment as a stressor to the fish community of County Ditch 11 given the lack of data and ambiguity in the biological response.

Table 4.2.5. Biological indices for County Ditch 11 compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing Modified Use habitat.

Metric	Description	Basin average[1]	AUID 517 score	Station (count)
TSS TIV	Mean TSS tolerance indicator value	18 ± 6 (mg L^{-1})	18± 1 (mg L^{-1})	14RD060 (17), 14RD060*(19)
CondProb	Probability of meeting the TSS standard	59 ± 28 (%)	54 ± 9 (%)	14RD060 (60), 14RD060*(47)
SLithopTxPct	Relative abundance of taxa that are simple lithophilic spawning species	27 ± 14	0 ± 0	14RD060 (0), 14RD060*(0)
BenInsectTxPct	Relative abundance of benthic insectivores individuals	25 ± 11	0 ± 0	14RD060 (0), 14RD060*(0)

[1]Basin wide averages for reaches that meet Modified Use habitat.

* Second sampling event for 14RD60. First sample at 14RD060 was on June 11, 2014 and the second sample at 14RD060* was on July 7, 2014.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

Low dissolved oxygen

The dissolved oxygen dynamics in County Ditch 11 occasionally experience low dissolved oxygen concentrations that drop below the standard of 5 mg L^{-1}. Specifically, the County Ditch 11 HSPF model calculated that dissolved oxygen is below 5 mg L^{-1} 27% of the time in 1996-2009. Discrete dissolved oxygen measurements have been sampled on County Ditch 11 (Table 4.2.6). During the sampling period, there were nine exceedances of the threshold (n=23). Stressor identification staff monitored dissolved oxygen during late summer over a 13 day period from August 4, 2016 to August 17, 2016 (Figure 4.2.8). During the deployment period, the dissolved oxygen concentrations dropped below (i.e., exceeded) the standard of 5 mg L^{-1} for almost half of the deployment period (49%) with a minimum dissolved oxygen concentration of 3.29 mg L^{-1} and a maximum of 9.88 mg L^{-1}.

Stressors from eutrophication are determined using total phosphorus, chlorophyll *a*, biochemical oxygen demand (BOD), and dissolved oxygen flux. There were no BOD or chlorophyll *a* data for the County Ditch 11; however, total phosphorus was analyzed to determine eutrophication as a potential stressor.

Phosphorus was sampled along County Ditch 11 from 2014-2015. Over the course of the sampling period, phosphorus did not exceed the Southern Streams standard (150 µg L^{-1}) (n = 13). The average phosphorus concentration was 60 µg L^{-1} with a minimum concentration of 18 µg L^{-1} and a maximum concentration of 149 µg L^{-1}. From the stressor identification dissolved oxygen deployment from August 4, 2016 to August 17, 2016 (n = 13 days), DO flux exceeded the standard of 4.5 mg L^{-1} one time over the deployment period with a DO flux of 6 mg L^{-1} on August 5, 2016 (displayed in Figure 4.2.8 with a red arrow). The average flux over the deployment period was 2.87mg L^{-1} with a minimum of 1.26 mg L^{-1} and a maximum of 6.0 mg L^{-1}. August 4th was not included in the flux calculation because it did not include a complete 24-hour diurnal period. Given the available phosphorus concentrations, County Ditch 11 is currently meeting the standard for eutrophication.

Table 4.2.6. Summary of the dissolved oxygen data collect on County Ditch 11. Sampling location displayed in Figure 4.2.1.

Station	Years	n	min	max	average	Percent exceedance
S007-785	2014-2015	23	4.92	15.01	9.09	9

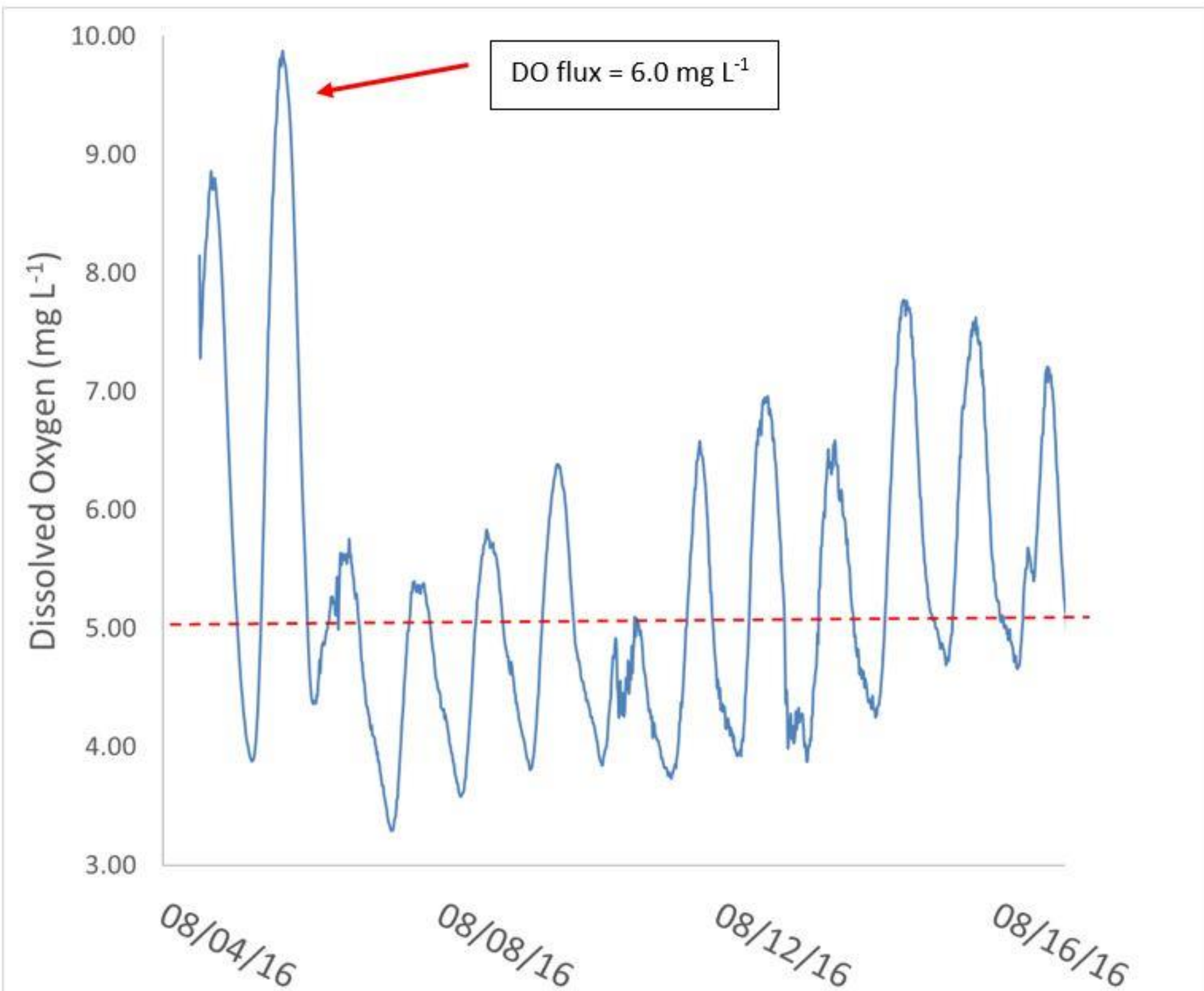


Figure 4.2.8. Dissolved oxygen deployed on County Ditch 11. Location of deployed displayed in Figure 4.2.1. Red line indicates dissolved oxygen standard (5 mg L^{-1}).

Biological response: Fish

The fish community indicates stressors caused by low dissolved oxygen related impairments (Table 4.2.7). Dissolved oxygen concentrations can alter the biological community by limiting species that are sensitive to dramatic shifts in dissolved oxygen along with species that are intolerant of low dissolved oxygen levels for an extended period of time (Davis, 1975; EPA, 2012). The available data strongly supports the case for low dissolved oxygen as a stressor to the fish community of County Ditch 11.

Table 4.2.7. Biological indices for County Ditch 11 compared with the basin wide averages that meet that state IBI threshold for the fish class two streams providing Modified Use habitat.

Metric	Description	Basin average[1]	AUID 517 score	Station (count)
DO TIV	Mean DO tolerance indicator value	7 ± 0.6 (mg L^{-1})	6 ± 0 (mg L^{-1})	14RD060 (6), 14RD060*(6)
CondProb	Probability of meeting the dissolved oxygen standard	46 ± 22 (%)	11 ± 2 (%)	14RD060 (10), 14RD060*(13)

[1]Basin wide averages for reaches that meet Modified Use habitat.

* Second sampling event for 14RD60. First sample at 14RD072 was on June 11, 2014 and the second sample at 14RD072* was on July 7, 2014.

■ Good: Biological monitoring score for the impaired reach is exceeding or equal to the basin wide average.

■ Fair: Biological monitoring score for the impaired reach is below the basin wide average but within the standard deviation range.

■ Poor: Biological monitoring score for the impaired reach is below the basin wide averages and below the standard deviation range.

County Ditch 11 Summary

The evidence for stressors causing impairment to the fish community are attributed to lack of connectivity, flow regime instability, insufficient physical habitat, and less strongly, high suspended sediment and dissolved oxygen. A detailed summary of the stressors associated with the Marsh River Watershed and recommended actions for mitigating stressors can be found in Section 5.1.

5. Conclusions and recommendations

5.1. Summary of probable stressors

Table 5.1 provides a summary of the stressors associated with the biologically impaired reaches in the Marsh River Watershed. Both biological impaired reaches (the Marsh River and County Ditch 11) are prone to disturbances causes by a high peak flows and periods of low to no flow. The undulating flow regime is a consequence of land use changes from native grassland to row crop agriculture and drainage patterns (e.g. channelization and ditching). Both reaches would benefit from detention/retention of water on the landscape in order to mitigate flashiness within the watershed. Instream habitat in both reaches has been degraded because of hydrologic alterations. The fine lacustrine sediment limits both reaches and specifically, excess suspended sediment appears to have an impact on the biological community. Soil erosion and channel degradation are believed to be the primary sources of sediment. The implementation of soil conservation practices would mitigate stressors caused by sedimentation. Low dissolved oxygen appears to be limiting both reaches, specifically County Ditch 11. Both reaches experience low dissolved oxygen in late summer during vulnerability to low flow or no flow conditions. Enhancing base flow during late summer and nutrient reductions appear to be the means of mitigating stressors associated with low dissolved oxygen. Lastly, connectivity is the primary stressors associated with County Ditch 11 fish impairment. One culvert in particular will completely block fish passage and limit the connectivity between County Ditch 11 and the Marsh River. Aside from the one known occurrence of connectivity stressors, there is no evidence that barriers are limiting the associated biotic communities. Further investigation is needed in the watershed to identify barriers to fish passage.

Table 5.1. Summary of probable stressors in the Marsh River Watershed.

			Stressors				
Stream name	**AUID**	**Biological impairment**	**Loss of longitudinal connectivity**	**Flow regime instability**	**Insufficient physical habitat**	**High suspended sediment**	**Low dissolved oxygen**
Marsh River	503	Fish	0	+++	+	++	0
		Macroinvertebrates	NE	+++	++	++	+
County Ditch 11	517	Fish	+++	++	+++	++	++

+++ 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.

5.2. Recommendations

The Marsh River Watershed has numerous areas in need of protection and restoration. The most feasible and simplistic area of focus should be concentrated on the connectivity barrier. Re-establishing one culvert on County Ditch 11 would provide the most influence on mitigating the declining biological integrity. With access into upper portions of the watershed, migratory fish species would be able to utilize upper portions of the stream system in order to gain access to spawning grounds and for certain life history traits that require for longitudinal connectivity.

For sediment loading, it is recommended to re-establish the riparian zone and use best management practices for cultivated crops within the Marsh River Watershed. Soil erosion and channel degradation are believed to be the primary sources of sediment. The implementation of soil conservation practices would mitigate stressors caused by sedimentation. Additionally, detention/retention of water over the landscape would especially help with flow regime instability and subsequently, sedimentation.

Eutrophication does not seem to be influencing dissolved oxygen dynamics in Marsh River Watershed; however, phosphorus levels have been documented at alarming levels that are well above the Southern Streams phosphorus standard. Augmenting baseflow and nutrient reduction would alleviate stressors caused by low dissolved oxygen. Further information and sampling is recommended to fully understand the response variables caused by elevated phosphorus in the Marsh River Watershed.

Table 5.2. Recommended prioritization of TMDLs relative to the stressors contributing to the biological impairment in the Marsh River Watershed.

Stressor	Priority	Comment
Sedimentation	High	TMDL should focus on reducing sediment input from riparian corridor and immediate stream channel (stream banks) in AUID 503 and 517.
Riparian disturbance	High	Restoration efforts should aim to re-establish quality riparian corridor to increase woody debris, CPOM inputs, and stream shading in County Ditch 11 (AUID 517).
Flow alteration	High	AUID 503 and 517 would benefit from detention/retention of water on the landscape in order to mitigate stressors caused by flow alteration.
Low DO	Medium	Low DO should be focused on AUID 517. Low dissolved oxygen does not appear to be limiting the biological community in AUID 503. More information and further sampling is recommended to determine the effects of eutrophication on low DO.

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7. Appendix

Table A1. Values used to score evidence in the Stressor Identification Process.

Rank	Meaning	Caveat
+++	*Convincingly supports*	*but other possible factors*
++	*Strongly supports*	*but potential confounding factors*
+	*Some support*	*but association is not necessarily causal*
0	*Neither supports nor weakens*	*(ambiguous evidence)*
-	*Somewhat weakens support*	*but association does not necessarily reject as a cause*
--	*Strongly weakens*	*but exposure or mechanism possible missed*
---	*Convincingly weakens*	*but other possible factors*
R	*Refutes*	*findings refute the case unequivocally*
NE	*No evidence available*	
NA	*Evidence not applicable*	
D	*Evidence is diagnostic of cause*	

Table A2. Strength of Evidence Scores for various types of evidence.

Types of Evidence	Possible values, high to low
Evidence using data from case	
Spatial / temporal co-occurrence	+, 0, ---, R
Evidence of exposure, biological mechanism	++, +, 0, --, R
Causal pathway	++, +, 0, -, ---
Field evidence of stressor-response	++, +, 0, -, --
Field experiments / manipulation of exposure	+++, 0, ---, R
Laboratory analysis of site media	++, +, 0, -
Temporal sequence	+, 0, ---, R
Verified or tested predictions	+++, +, 0, -, ---, R
Symptoms	D, +, 0, ---, R
Evidence using data from other systems	
Mechanistically plausible cause	+, 0, --
Stressor-response relationships in other field studies	++, +, 0, -, --
Stressor-response relationships in other lab studies	++, +, 0, -, --
Stressor-response relationships in ecological models	+, 0, -
Manipulation of exposure experiments at other sites	+++, +, 0, --
Analogous stressors	++, +, -, --
Multiple lines of evidence	
Consistency of evidence	+++, +, 0, -, --
Explanatory power of evidence	++, 0, -