# Rum River Watershed

# Stressor Identification Report

A study of the stressors limiting the aquatic biological communities in the Rum River Watershed.

Minnesota Pollution Control Agency

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## Cover Photo

Site 00UM102 (June 11, 2015)




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# Acronyms

| | |
|---|---|
| AUID | Assessment Unit Identification |
| BOD | Biochemical oxygen demand |
| CADDIS | Causal Analysis/Diagnosis Decision Information System |
| cfs | cubic foot per second |
| Chl-*a* | Chlorophyll-*a* |
| DNR | Department of Natural Resources |
| DO | Dissolved oxygen |
| EPA | U.S. Environmental Protection Agency |
| EPT | Ephemeroptera, Plecoptera, and Trichoptera |
| EQuIS | Environmental Quality Information System |
| F-IBI | Fish Index of Biological Integrity |
| GIS | Geographic information system |
| HSPF | Hydrological Simulation Program-FORTRAN |
| HUC | Hydrological unit code |
| IBI | Index of Biological Integrity |
| IMPLND | Impervious land surfaces |
| IWM | Intensive watershed monitoring |
| LIDAR | Light detection and ranging |
| LWD | Large woody debris |
| M-IBI | Macroinvertebrate-Index of Biological Integrity |
| MPCA | Minnesota Pollution Control Agency |
| MSHA | MPCA Stream Habitat Assessment |
| $NH_3$ | Un-ionized ammonia |
| $NH_4$ | Ionized ammonia |
| $NO_2$ | Nitrite |
| $NO_3$ | Nitrate |
| $NO_x$ | Nitrate-nitrite |
| NPS | Non-point source |
| P | Phosphorus |
| PERLND | Pervious land surfaces |
| POET | Plecoptera, Odonata, Ephemeroptera and Trichoptera taxa |

| | |
|---|---|
| QMH | Qualitative multi-habitat |
| RCHRES | Stream reaches |
| RRW | Rum River Watershed |
| SID | Stressor identification |
| SOE | Strength of evidence |
| TMDL | Total maximum daily load |
| TP | Total phosphorus |
| TSS | Total suspended solids |
| TSVS | Total suspended volatile solids |
| TVI | Tolerance Value Index |
| WRAPS | Watershed Restoration and Protection Strategy |

# 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 rivers and streams. The basic approach is to examine fish and aquatic macroinvertebrate communities at sites throughout a major watershed. From the data, an Index of Biological Integrity (IBI) score can be developed, which provides a measure of overall community health. If biological impairments are found, then the next step is to identify stressors to the aquatic community.

Stressor identification is a formal and rigorous process that identifies stressors causing biological impairment(s) of aquatic ecosystems, and provides a structure for organizing the scientific evidence supporting the conclusions (EPA, 2000). In simpler terms, it is the process of identifying the major factors causing harm to fish, macroinvertebrates and other aquatic organisms. Stressor identification is a key component in the development of Watershed Restoration and Protection Strategies (WRAPS) being carried out under Minnesota's Clean Water Legacy Act.

This report summarizes stressor identification work in the Rum River Watershed (RRW). The biologically impaired reaches, which are identified by their associated Assessment Unit Identification (AUID) number, are separated by aggregated Hydrologic Unit Code (HUC)-12 for this report. Figure E.S.-1 below shows the location of the biologically impaired stream reaches in the RRW. After examining many candidate causes for the biological impairments, the following stressors were identified for the biologically impaired streams in the RRW:

| | | Stressors | | | | |
|---|---|---|---|---|---|---|
| **Stream Name** | **AUID #** | **Low dissolved oxygen** | **Flow alteration** | **Elevated phosphorus** | **Elevated nitrogen** | **Lack of physical habitat** |
| Estes Brook | 07010207-679 | | X | X | X | |
| Trott Brook | 07010207-680 | X | X | X | | |
| Tibbetts Brook | 07010207-677;676 | | X | | | X |
| West Branch Rum River | 07010207-525 | | X | X | | |
| Tributary to West Branch Rum River | 07010207-667 | | X | | | X |
| Vondell Brook | 07010207-567;687 | | X | X | | X |
| Stanchfield Creek | 07010207-520 | X | X | X | | |
| Isanti Brook | 07010207-592 | X | X | | | |
| Washburn Brook | 07010207-641 | | X | | | X |
| Mahoney Brook | 07010207-682 | X | | X | | |

**X** – Stressor to biological community

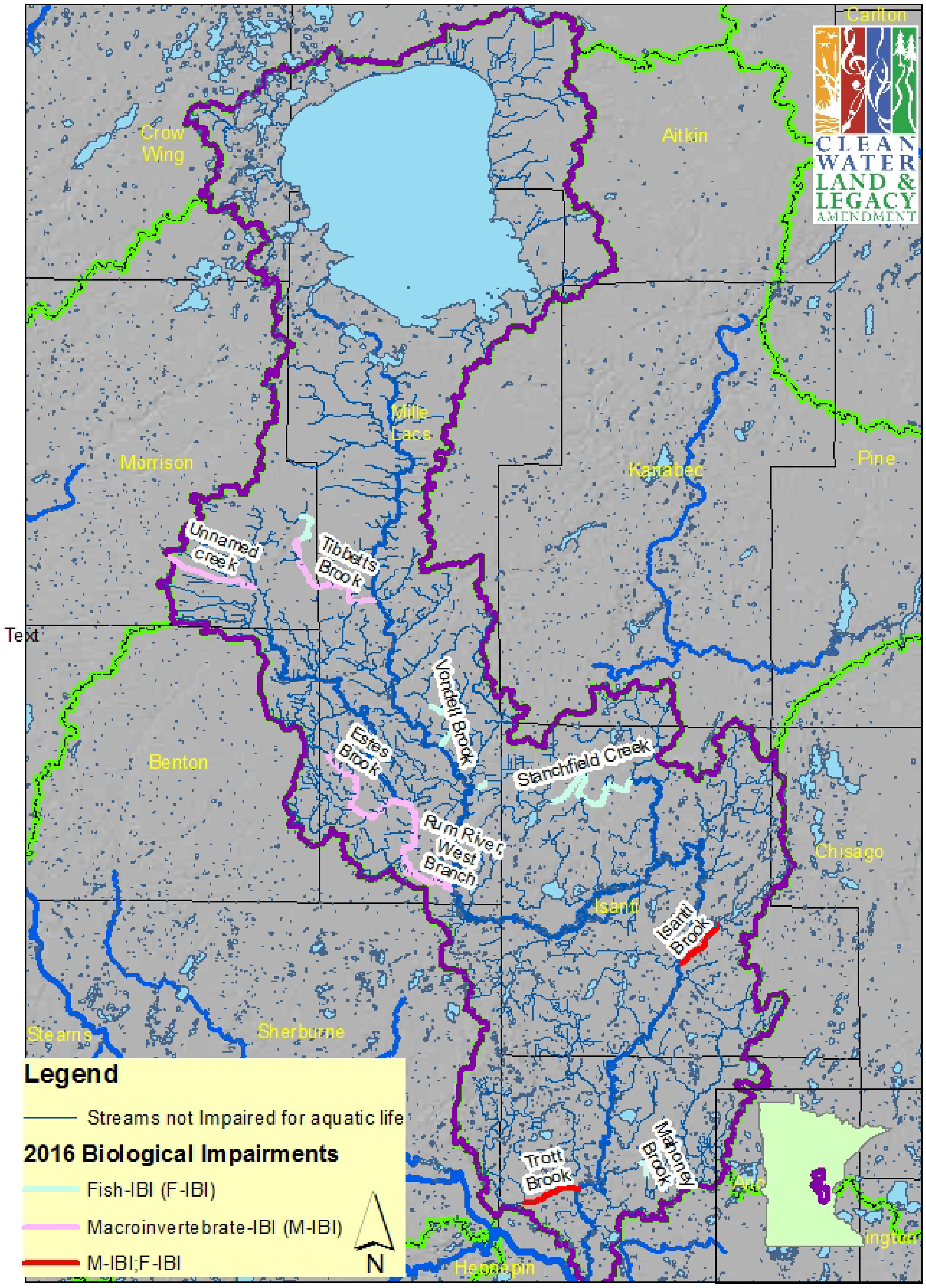



**Figure E.S 1: RRW map of biological impairments for 2016.**

Poor habitat quality is a common theme in the impaired AUID's throughout the RRW. Lack of physical habitat is a concern to the impaired biotic communities. The habitat tool used to evaluate this stressor is the Minnesota Stream Habitat Assessment (MSHA) score. The MSHA score is used to classify the stream into three use categories: exceptional, general and modified. Most streams in the RRW are general use streams, meaning that the habitat scores from the MSHA scored high enough to assess the AUIDs as natural channel. The MSHA score was poor to good at the impaired stream stations sampled in each impaired AUID. The AUIDs that were evaluated as having poor habitat were missing certain habitat features therefore restricting the potential for biotic communities.

Eutrophication was also a common theme throughout the impaired AUIDs. Elevated algal or submerged plant growth was common as a result of elevated total phosphorus concentrations. This often led to an increase in daily dissolved oxygen (DO) flux. DO flux is a measure of the daily difference in minimum and maximum DO readings at a stream site.

Significant portions of streams within the Rum Watershed have been channelized. This can lead to lack of baseflow as water storage in the landscape is reduced and can also lead to increased peak flows during high precipitation periods. A significant amount of the pre-settlement wetlands appear to have been partially or fully drained. The associated nutrient export is being delivered downstream and causing elevated plant growth and wide fluctuations in daily DO.

Altered hydrology was analyzed using the results from the Hydrological Simulation Program – FORTRAN (HSPF) model along with a select number of stream gages located within the watershed. The HSPF model results are from 1999 through 2013 and give a 14 year record of simulated runoff for each stream reach. Analysis of the model data showed extended periods of low baseflow which affected habitat availability and stream biology.

Upon completion of the stressor identification process a WRAPS report will be developed. This report is developed by local partners, MPCA, and other state agencies and groups and will be the report that identifies restoration and protection activities within the RRW. Upon completion of the WRAP report an implementation plan (County Water Plan or One Watershed One Plan (1W1P)) is developed to help guide restoration and protection work within the watershed. Total Maximum Daily Loads (TMDLs) for impaired reaches/water bodies, are also developed and submitted to the U.S. Environmental Protection agency (EPA) for approval.

# 1. Introduction

## 1.1. Monitoring and assessment

Water quality and biological monitoring in the Rum River Watershed (RRW) has been active from 2013 through 2015. As part of the MPCAs Intensive Watershed Monitoring (IWM) approach, monitoring activities increased in rigor and intensity during the years of 2013-2014 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 2013, were used to identify stream reaches that were not supporting healthy fish and macroinvertebrate assemblages (Figure 1.1-1).

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 TMDL study. The result of the SID process is the identification of the stressor(s) for which the TMDL may be developed. For example, the SID process may diagnose excess fine sediment as the cause of biological impairment, but a separate effort is then required to determine the TMDL, and implementation goals needed to restore the impaired condition.

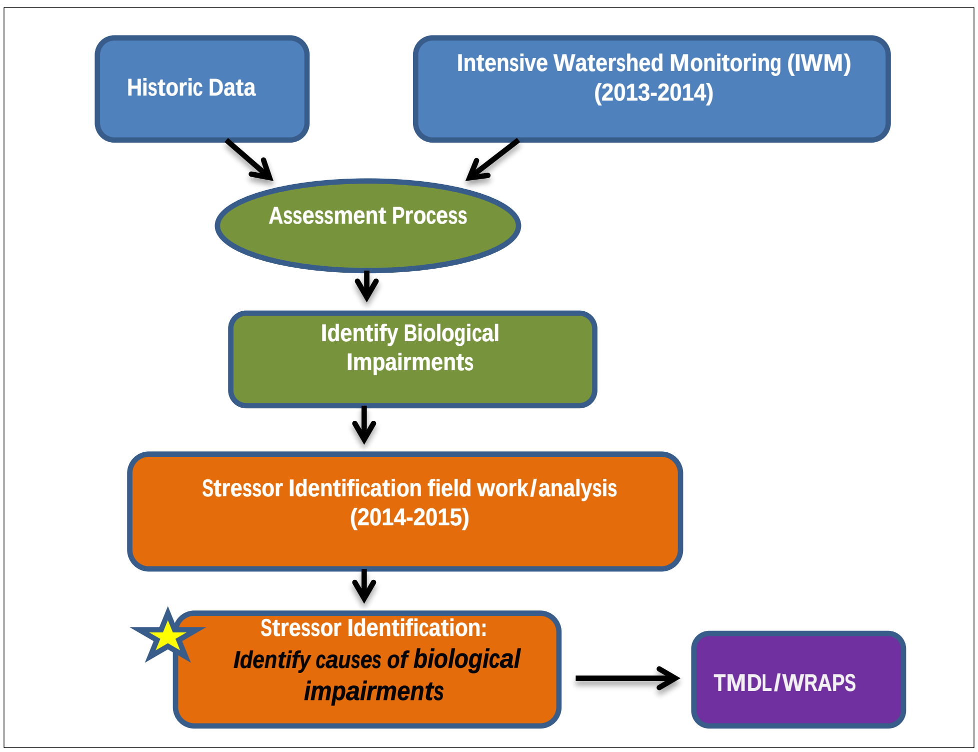



**Figure 1.1-1: Process map of Intensive Watershed Monitoring, Assessment, Stressor Identification, and TMDL processes.**

## 1.2. Stressor identification process

The MPCA follows the EPA process of identifying stressors that cause biological impairment, which has been used to develop the MPCA 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 Watershed Restoration and Protection Strategies (WRAPS) being carried out under Minnesota's Clean Water Legacy Act. Stressor identification 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 1.2-1. 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.

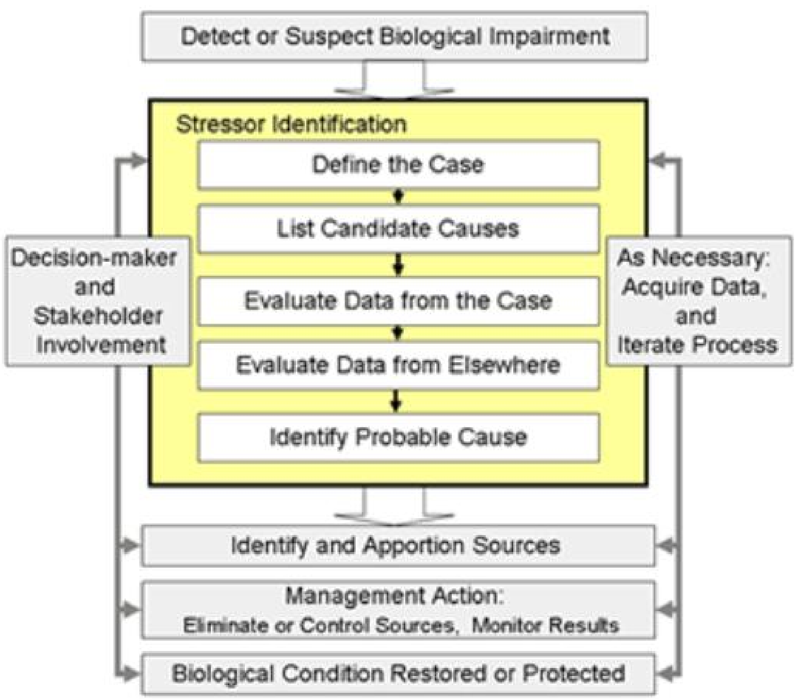



**Figure 1.2-1: Conceptual model of Stressor Identification process.**

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 outside the study area).

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 included 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 A1. 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(s).Additional detail on the various types of evidence and interpretation of findings can be found here: http://www.epa.gov/caddis/si_step_scores.html

## 1.3. Common stream stressors

The five major elements of a healthy stream system are stream connections, hydrology, stream channel morphology, water chemistry, and stream biology. If one or more of the components are unbalanced, the stream ecosystem can fail to function properly and is then listed as an impaired water body. Table 1.3.1 lists the common stream stressors to biology relative to each of the major stream health categories.

**Table 1.3-1: Common streams stressors to biology (i.e. fish and macroinvertebrates).**

| Stream health | Stressor(s) | Link to biology |
|---|---|---|
| **Stream connections** | **Loss of Connectivity**<br>· Dams and culverts<br>· Lack of Wooded riparian cover<br>· 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**<br>**Loss of habitat due to channelization**<br>**Elevated Levels of TSS**<br>· Channelization<br>· Peak discharge (flashy)<br>· 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 morphology** | **Loss of Habitat due to excess sediment**<br>· Loss of dimension/pattern/profile<br>· Bank erosion from instability<br>· Loss of riffles due to accumulation of fine sediment<br>· 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 DO Concentrations**<br>**Elevated levels of TSS**<br>· Increased nutrients from human influence<br>· Widely variable DO levels during the daily cycle<br>· Increased algal and or periphyton growth in stream<br>· Increased nonpoint pollution from urban and agricultural practices<br>· Increased point source pollution from urban treatment facilities | There is a loss of intolerant species and a loss of species diversity, due to conditions that favor species that can breathe air or survive under low DO concentrations. Biology tends to be dominated by a few tolerant species. |

| Stream health | Stressor(s) | Link to biology |
|---|---|---|
| **Stream biology** | **Aquatic Invasive species**<br>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. |

## 1.4. Report format

This report will be organized by Assessment Unit Identification (AUID). AUID are assigned to stream reaches to identify each stream reach with a unique number. This number is used to track the stream reach through protection and restoration projects. Each AUID that has a biological impairment will be discussed in detail in Chapter 4 of this report. The candidate stressors that were considered during the stressor identification process will be reviewed and discussed in Chapter 3 of this report.

# 2. Overview of Rum River Watershed

## 2.1. Background

From its source at Mille Lacs Lake in Aitkin County (approximately 0.5 miles east of Garrison), the Rum River flows southeast to its confluence with the Mississippi River in Anoka, Minnesota. Many tributary creeks flow into the Rum River from the east and west parts of which extend into seven Minnesota Counties. The biological stream impairments are located in the southern ⅔ of the watershed (Figure 2.1-1). The northern half of the watershed is predominately forest and wetland with scattered agricultural lands. The southern portion of the watershed is opposite, with predominately developed land (both residential and commercial), forest, agricultural lands and scattered wetlands, and small lakes (Figure 2.1-2). The biological impairments are located in the transitional zone between forested land and mixed developed and agricultural landuse.

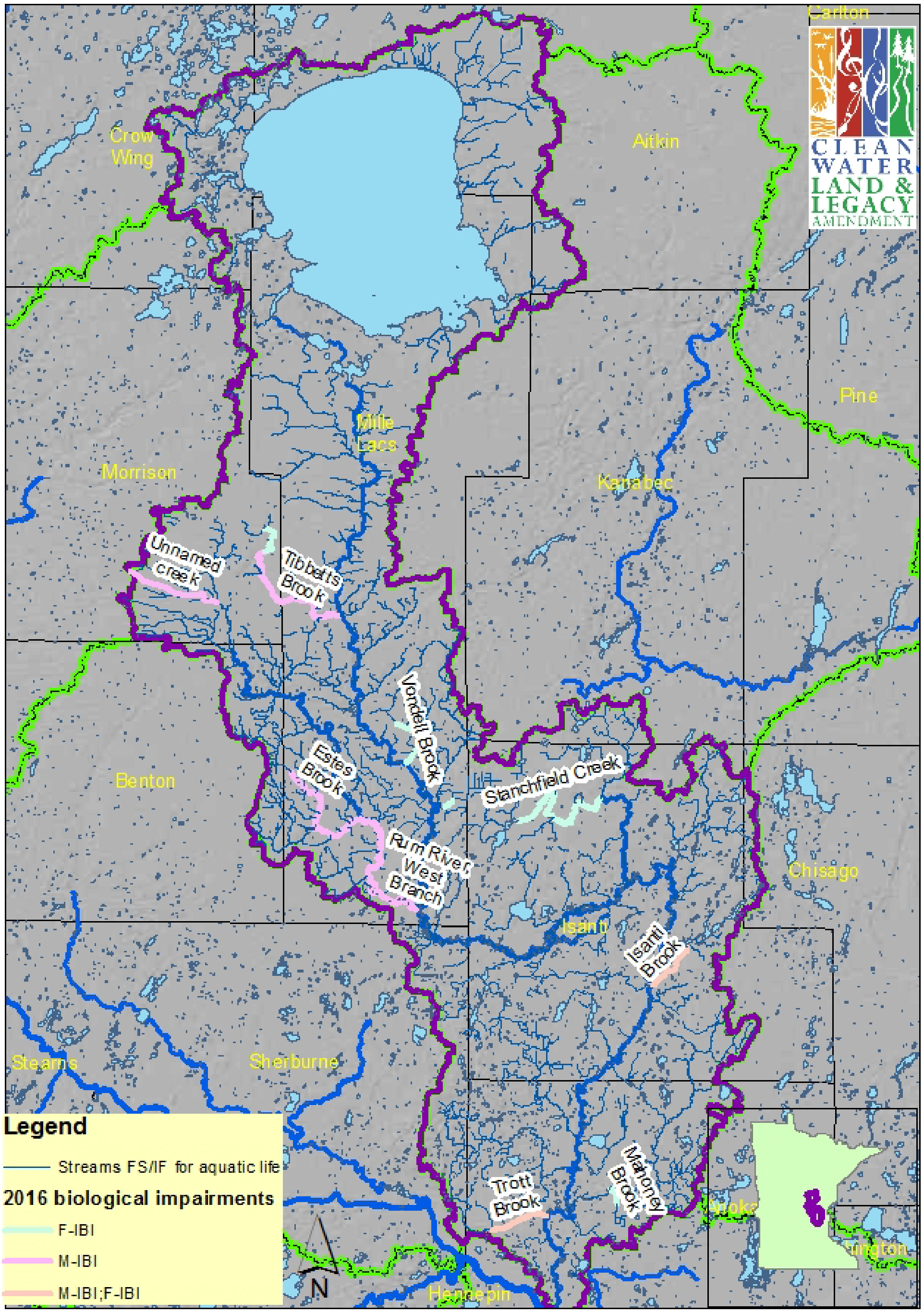



**Figure 2.1-1: Location of biologically impaired streams within the RRW (07010207).**

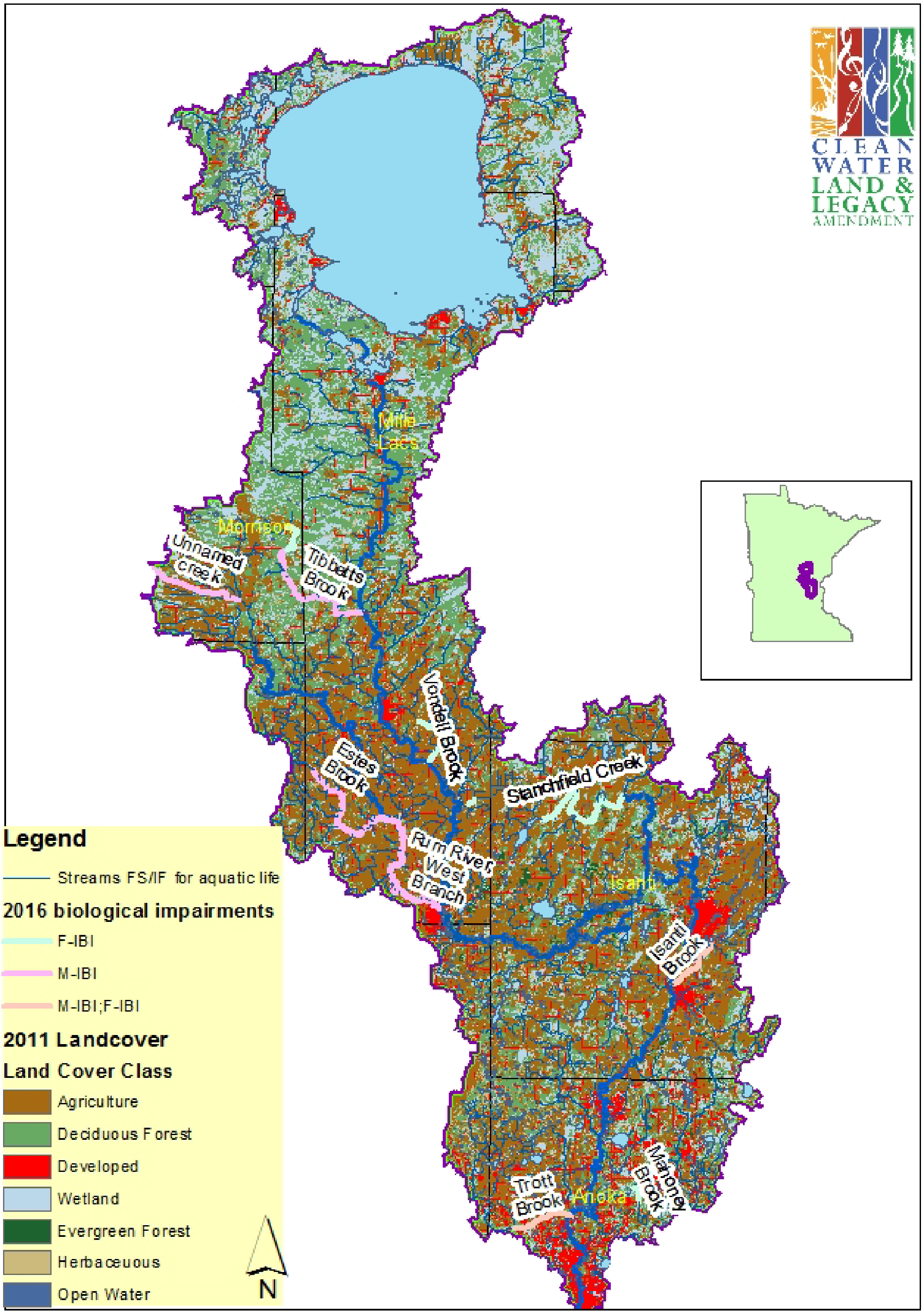



**Figure 2.1-2: RRW 2011 Land Cover Map**

### 2.1.1 Subwatersheds

Due to the sheer size of the watershed it is difficult to evaluate potential stressors to aquatic life without further stratifying the Rum River drainage into smaller sections. Although there may be some consistent chemical and physical stressors found throughout the Rum River Watershed (RRW), some are likely acting locally, driven by landscape characteristics specific to a certain region of the watershed. For the purpose of addressing biological impairments in the RRW, the watershed was stratified into aggregated 12-digit Hydrologic Unit Code (HUC) units. Figure 2.1-2 below shows the watershed boundaries used in this report. The RRW has 14 HUC-12 subwatershed units. Ten stream AUIDs were impaired for biology in seven different HUC-12 units. Two of the impaired HUC-12s have a significant amount of agricultural land use occurring in the subwatershed. This report will discuss the stream reach AUID that is impaired as part of the subwatershed that it resides in.

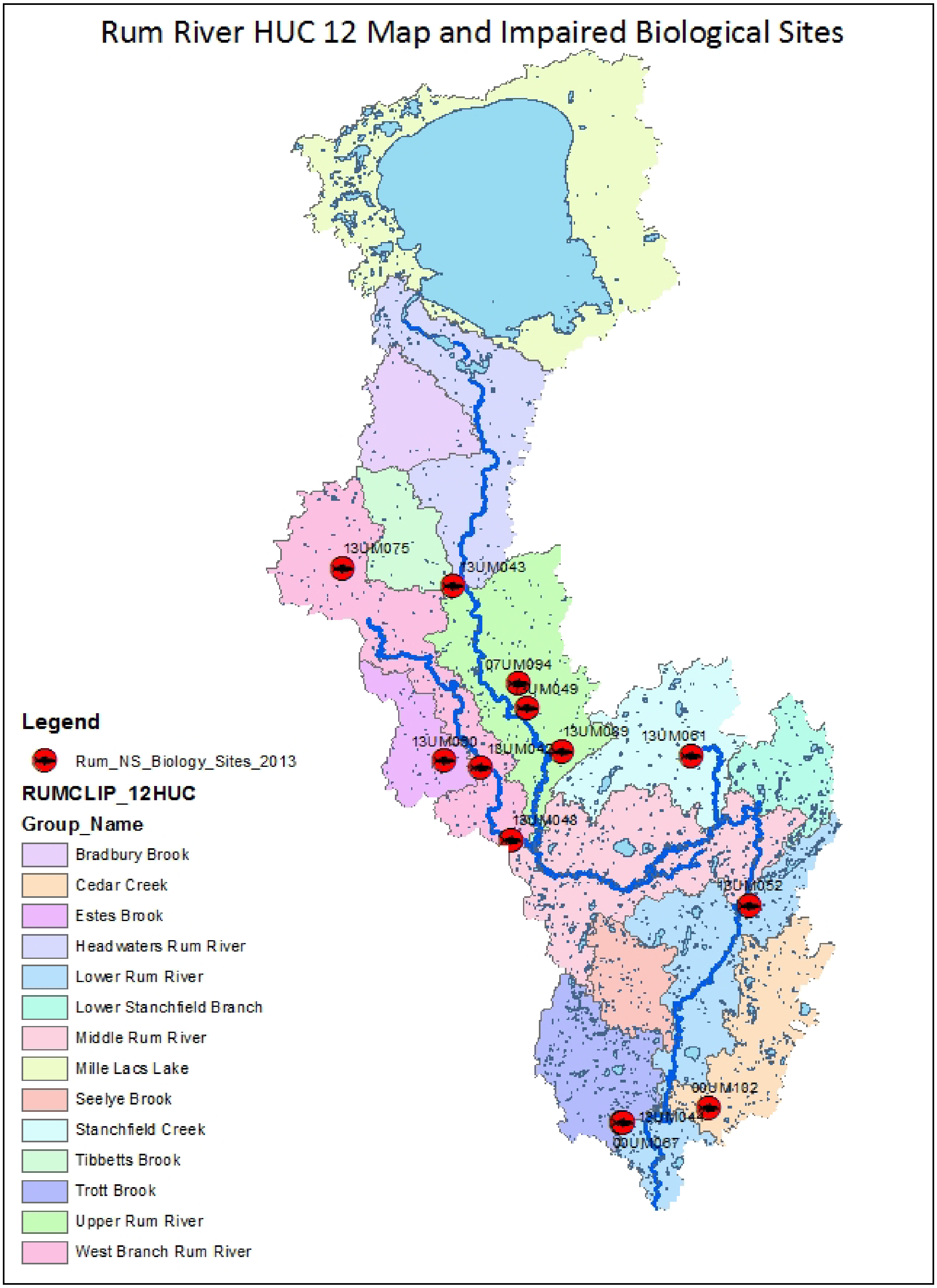



**Figure 2.1-3: RRW with HUC 12 boundaries and impaired biological stations.**

## 2.2. Monitoring and assessment status

The RRW was assessed in 2015. For the full assessment report, the Rum River monitoring and assessment report located https://www.pca.state.mn.us/water/watersheds/rum-river. The RRW has 10 AUIDs that are impaired for fish, macroinvertebrates, or both. The watershed was initially sampled in 2013 with follow up biological sampling occurring in 2014 at select locations to verify initial results.

Water chemistry data used in the stressor identification (SID) report comes from EQuIS sites. These sites can have data ranging from the 1990s through 2014. The locations on the above map were created and sampled in response to poor biological monitoring data or to answer questions about the water quality in a stream reach. This data was collected in 2015. The data analyzed for this report is from 2002 through 2015. Nutrient concentrations and sediment concentration data is stored in Environmental Quality Information System (EQuIS) and can be accessed through the EQuIS website located at http://pca-gis02.pca.state.mn.us/eda_surfacewater/index.html. This website also contains biological monitoring site information as well.

## 2.3. Summary of biological impairments

The approach used to identify biological impairments includes assessment of fish and aquatic macroinvertebrate communities and related habitat conditions at sites throughout a watershed. The resulting information is used to develop an Index of Biological Integrity (IBI). The IBI scores can then be compared to a range of thresholds.

The fish and macroinvertebrate IBI scores within each Assessment Unit Identification AUID were compared to a regionally developed threshold and confidence interval, utilizing a weight of evidence approach. Within the RRW, 10 AUIDs are biologically impaired or fail to support the aquatic life designated use (Table 2.3.1).

**Table 2.3-1: Biologically impaired AUIDs in the RRW.**

| | | | Impairments | |
|---|---|---|---|---|
| **Stream Name** | **AUID #** | **Reach Description** | **Biological** | **Water Quality** |
| Estes Brook | 07010207-679 | *-93.7502, 45.7028 to W Br Rum R* | Macroinvertebrate | E. coli |
| Trott Brook | 07010207-680 | *CD 51 to Rum R* | Fish/Invert | DO |
| Tibbetts Brook | 07010207-677,676 | *T40 R28W S35, east line to Rum R* | Macroinvertebrate/Fish | |
| West Branch Rum River | 07010207-525 | *Estes Bk to Rum R* | Macroinvertebrate | E. coli |
| Tributary to West Branch Rum River | 07010207-667 | *Headwaters to W Br Rum R* | Macroinvertebrate | |
| Vondell Brook | 07010207-567;687 | *Unnamed cr to Rum R* | Fish | |
| Stanchfield Creek | 07010207-520 | *Headwaters (North Stanchfield Lk 30-0143-00) to Stanchfield Bk* | Fish | |
| Isanti Brook | 07010207-592 | *Florence Lk outlet to Rum R* | Macroinvertebrate/Fish | |
| Washburn Brook | 07010207-641 | *Unnamed ditch to Unnamed cr* | Fish | |

| | | | Impairments | |
|---|---|---|---|---|
| **Stream Name** | **AUID #** | **Reach Description** | **Biological** | **Water Quality** |
| Mahoney Brook | 07010207-682 | *T33 R24W S34, south line to Cedar Cr* | Fish | |

The assessment process uses a weight of evidence approach when considering the status of the biological community. Water chemistry, IBI scores for both fish and macroinvertebrates, along with the current land use and potential for pollutant transport are all reviewed when determining the status of the biological community. The IBI score is used as an indicator to the overall biological health of the stream but it is often not the only factor used on which to base the decision to call a site impaired.

Each IBI is comprised of metrics that are based on community structure and function, the sum of which produces an overall score scaled 0 to 100 points. The number of metrics that make up an IBI will determine the metric score scale. For example, an IBI with eight metrics would have a scale from 0-12.5 and an IBI with 10 metrics would have a scale from 0-10.

The purpose of SID is to interpret the data collected during the biological monitoring and assessment process. Trends in the IBI scores can help to identify causal factors for biological impairments. The ten AUIDs that are impaired for biology did not meet the expected aquatic life scores in the respective IBI.

Overall the biological communities had passing IBI scores for both fish and macroinvertebrates during the 2013 sampling cycle in the RRW. Many of the passing IBI scores were well above the threshold and were near or above the upper confidence interval.

## 2.4 Hydrological Simulation Program - FORTRAN (HSPF) 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 (ARM) 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 (PERLNDs), runoff and constituent loading from impervious land surfaces (IMPLNDs), and flow of water and transport/transformation of chemical constituents in stream reaches (RCHRESs). 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, the upland areas are separated into multiple land use categories.

An HSPF watershed model was run for the Rum watershed to predict water quality condition throughout the watershed on an hourly basis from 1996-2015.

# 3. Possible stressors to biological communities

A comprehensive list of potential stressors to aquatic biological communities compiled by the U.S. Environmental Protection Agency (EPA) can be found here (http://www.epa.gov/caddis/si_step2_stressorlist_popup.html). This comprehensive list serves two purposes. First, it can be 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 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. 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

Initially nine candidate causes were evaluated to address the biological impairments found in the ten impaired AUIDs in the RRW. The following sections of the report will describe the reasoning behind either including the candidate causes for further analysis or placing the candidate causes into the inconclusive candidate portion of the report. At this point there are no eliminated candidate causes.

## 3.2. Inconclusive causes

Elevated stream temperature was deemed to be inconclusive as a stressor to aquatic life in the RRW. Warm water streams are not to exceed 30°C in any given day as a daily maximum temperature. Temperature data is readily available through much of the RRW. Most of the temperature data is instantaneous data and was collected sporadically over the course of 2002 through 2014. The temperature data that was reviewed showed no exceedances of the 30°C daily maximum, however; temperature data is limited and a more in depth collection of temperature data would be required to eliminate elevated temperature as a stressor. The highest temperature recorded in 2015 was 26.7 °C in Mahoney Brook.

Ammonia toxicity can be detrimental to aquatic life when the concentrations of un-ionized ammonia ($NH_3$) exceed 0.040 mg/L. There currently is limited data on either ionized ($NH_4$) or un-ionized ammonia ($NH_3$). Additional data collection would be required to adequately assess the impact that ammonia is having on the aquatic life in the RRW.

## 3.3. Summary of candidate causes in the Rum River Watershed

The initial list of candidate/potential causes was narrowed down after the initial data evaluation/data analysis resulting in seven candidate causes for final analysis in this report.

### 3.3.1. Candidate cause: dissolved oxygen

Dissolved oxygen (DO) refers to the concentration of oxygen gas within the water column. Oxygen diffuses into water from the atmosphere (turbulent flow enhances this diffusion) and from the release of oxygen by aquatic plants during photosynthesis. DO concentrations in streams are driven by several factors. Large-scale factors include climate, topography, and hydrologic pathways. These in turn influence smaller scale factors such as water chemistry and temperature, and biological productivity. As water temperature increases, its capability to hold oxygen is reduced. Low DO can be an issue in streams with slow currents, excessive temperatures, high biochemical oxygen demand (BOD), and/or high groundwater seepage (Hansen, 1975). In most streams and rivers, the critical conditions for stream DO usually occur during the late summer season when water temperatures are at or near the annual high and stream flow volumes and rates are generally lower. DO concentrations change hourly, daily, and seasonally in response to these driving factors.

Human activities can alter many of these driving factors and change the DO concentrations of water resources. Increased nutrient content of surface waters is a common human influence, which results in excess aquatic plant growth. This situation often leads to a decline in daily minimum oxygen concentrations and an increase in the magnitude of daily DO concentration fluctuations due to the decay of the excess organic material, increased usage of oxygen by plants at night, and their greater oxygen production during the daytime. Humans may directly add organic material by municipal or industrial effluents. Other human activities that can change water temperature include vegetation alteration and changes to flow patterns.

Aquatic organisms require oxygen for respiration. Inadequate oxygen levels can alter fish behavior, such as moving to the surface to breathe air, or moving to another location in the stream. These behaviors can put fish at risk of predation, or may hinder their ability to obtain necessary food resources (Kramer, 1987). Additionally, low DO levels can significantly affect fish growth rates (Doudoroff and Warren, 1965). Fish species differ in their preferred temperature ranges (Dowling, 1986), so alterations in water temperature (and DO) from the natural condition will alter the composition of fish communities. Low or highly fluctuating concentrations of DO can have detrimental effects on many fish and macroinvertebrate species (Davis, 1975) (Nebeker, 1991). Heiskary et al. (2013) observed several strong negative relationships between fish and macroinvertebrate metrics and higher daily DO fluctuations. Increased water temperature raises the metabolism of organisms, and thus their oxygen needs, while at the same time, the higher-temperature water holds less oxygen. Some aquatic insect species have anatomical features that allow them to access atmospheric air, though many draw their oxygen from the water column. Macroinvertebrate groups (Orders) that are particularly intolerant to low DO levels include mayflies (with a few exceptions), stoneflies, and caddis flies.

For more detailed information on DO as a stressor go to the EPA Causal Analysis/Diagnosis Decision Information System (CADDIS) webpage following this link. (U.S.EPA, 2013)

#### 3.3.1.1. Minnesota DO standards

The DO standard (as a daily minimum) is 5 mg/L for class 2B (warmwater) streams and 7 mg/L for class 2A (coldwater). Additional stipulations have been recently added to this standard. The following is from the Guidance Manual for Assessing the Quality of Minnesota Surface Waters (MPCA, 2009).

*Under revised assessment criteria beginning with the 2010 assessment cycle, the DO standard must be met at least 90 percent of the time during both the 5-month period of May through September and the 7-month period of October through April. Accordingly, no more than 10 percent of DO measurements can violate the standard in either of the two periods.*

*Further, measurements taken after 9:00 in the morning during the 5-month period of May through September are no longer considered to represent daily minimums, and thus measurements of > 5 DO later in the day are no longer considered to be indications that a stream is meeting the standard.*

*A stream is considered impaired if 1) more than 10 percent of the "suitable" (taken before 9:00) May through September measurements, or more than 10 percent of the total May through September measurements, or more than 10 percent of the October through April measurements violate the standard, and 2) there are at least three total violations.*

#### 3.3.1.2. Types of dissolved oxygen data

1. **Point measurements**
   Instantaneous (one moment in time) DO data was collected at many locations and used as an initial screening for low DO reaches. Because DO concentrations can vary significantly with changes in flow conditions and time of sampling, conclusions using instantaneous measurements need to be made with caution and are not completely representative of the DO regime at a given site.
2. **Longitudinal (synoptic)**
   This sampling method involves collecting simultaneous (or nearly so) readings of DO from several locations along a significant length of the stream path. It is best to perform this sampling in the early morning in order to capture the daily minimum DO readings.
3. **Diurnal (continuous)**
   Short interval, long time period sampling using deployed YSIä water quality sondes (a submerged electronic sampling devise) provides a large number of measurements to reveal the magnitude and pattern of diurnal DO flux at a site. This sampling captures the daily minimum DO concentration, and when deployed during the peak summer water temperature period, also allows an assessment of the annual low DO levels in a stream system.

#### 3.3.1.3. Sources and causal pathways model for low dissolved oxygen

DO concentrations in streams are driven by a combination of natural and anthropogenic factors. Natural background characteristics of a watershed, such as topography, hydrology, climate, and biological productivity can influence the DO regime of a waterbody. Agricultural and urban land uses, impoundments (dams), and point-source discharges are just some of the anthropogenic factors that can cause unnaturally high, low, or volatile DO concentrations. The conceptual model for low DO as a candidate stressor is shown in EPA CADDIS website by following this link: Dissolved oxygen simple conceptual diagram | CADDIS: Sources, Stressors & Responses | EPA

### 3.3.2. Candidate cause: flow alteration

Flow alteration is the change of a streamflow volume and/or flow pattern caused by anthropogenic activities, which include channel alteration, water withdrawals, land cover alteration, wetland drainage, agricultural tile drainage, and impoundment. Changes in landscape vegetation, pavement, and drainage can increase how fast rainfall runoff reaches stream channels. This creates a stronger pulse of flow, followed later by decreased baseflow levels. According to the authors of a review on flow effects (Poff, 1997), "Streamflow quantity and timing are critical components of water supply, water quality, and the ecological integrity of river systems. Indeed, streamflow, which is strongly correlated with many critical physicochemical characteristics of rivers, such as water temperature, channel geomorphology, and habitat diversity, can be considered a 'master variable'…"

### *Reduced flow or baseflow reduction*

Fish and macroinvertebrate species have many habits and traits that can either be helpful or detrimental in different flow conditions and will either respond positively or negatively with reduced flow. Across the conterminous U.S., Carlisle et al. (2011) found that there is a strong correlation between diminished streamflow and impaired biological communities. Habitat availability can be scarce when flows are interrupted, low for a prolonged duration, or extremely low, leading to decreased wetted width, cross sectional area, and water depth. Flows that are reduced beyond normal baseflow decrease living space for aquatic organisms and competition for resources increases. Pollutant concentrations can increase when flows are lower than normal, increasing the exposure dosage to organisms. Tolerant organisms can out-compete others in such limiting situations and will thrive. Low flows of prolonged duration lead to macroinvertebrate and fish communities comprised of generalist species or that have preference for standing water (U.S.EPA, 2012a). Changes in fish community can occur related to factors such as species' differences in spawning behavior (Becker, 1983), flow velocity preference (Carlisle et al., (2011)), and body shape (Blake, 1983). When baseflows are reduced, nest-guarding fish species increase and simple nesters, which leave eggs unattended, are reduced (Carlisle et al., (2011)). Nest-guarding increases reproductive success by protecting eggs from predators and providing "continuous movement of water over the eggs, and to keep the nest free from sediment" (Becker, 1983). Active swimmers, such as the green sunfish, contend better under low velocity conditions (Carlisle et al., (2011)). In their review paper on low-flow effects on macroinvertebrates, Dewson et al. (2007) found that responses were complex, and not easy to generalize. Some cited studies showed increased density, and others decreased. More often, the behavior called drift (using the current to be transported to a new location) increased. Many studies reported that species composition changed, and taxonomic richness generally decreased in streams experiencing prolonged low flows. Those invertebrates that filter food particles from the water column have shown negative responses to low flows. EPA CADDIS website (U.S.EPA, 2012a) lists the responses of reduced flow as lower total stream productivity, elimination of large fish, changes in taxonomic composition of fish communities, fewer migratory species, fewer fish per unit area, and more-concentrated aquatic organisms, potentially benefiting predators.

### *Increased flow or Channelization*

Increasing surface water runoff and seasonal variability in stream flow have the potential for both indirect and direct effects on fish populations (Schlosser, 1990). Indirect effects include alteration in habitat suitability, nutrient cycling, production processes, and food availability. Direct effects include decreased survival of early life stages and potentially lethal temperature and oxygen stress on adult fish (Bell, 2006). Increased flow volume increases channel shear stress, which results in increased scouring and bank destabilization. This subsequently has a negative impact on the fish and macroinvertebrate communities via loss of habitat, including habitat smothering by excess sediment. High flows and the associated increased flow velocities can cause displacement of fish and macroinvertebrates downstream, and mobilization and possible removal to the floodplain of habitat features such as woody debris, which are important as flow refugia for fish and living surfaces for clinging invertebrates. Macroinvertebrate types may shift from those species having long life cycles to shorter ones; species that can complete their life history within the bounds of the recurrence interval of the elevated flow conditions (U.S.EPA, 2012a). Fish species that have streamlined body forms experience less drag under high velocities and will have advantage over non-streamlined fish species (Blake, 1983).

Increased flows may directly impair the biological community or may contribute to additional stressors. Increased channel shear stresses, associated with increased flows, often cause increased scouring and bank destabilization. With these stresses added to the stream, the fish and macroinvertebrate community may be influenced by the negative changes in habitat and sediment. To learn more about flow alteration as a stressor go to the EPA CADDIS webpage here.

The following is an excerpt from a DNR (Minnesota Department of Natural Resources) (Missouri River Watershed Hydrology, Connectivity, and Geomorphology Assessment Report., 2014) publication and contains a more detailed discussion on various aspects of connectivity and flow alteration effects:

*Lateral connectivity represents the connection between a river and its floodplain. The dynamic relationship amongst terrestrial and aquatic components of a river's floodplain ecosystem comprises a spatially complex and interconnected environment (Ickes et al. 2005). The degree to which lateral connectivity exists is both a time-dependent phenomenon (Tockner, 1999) and dependent upon the physical structure of the channel. Rivers are hydrologically dynamic systems where their floodplain inundation relates to prevailing hydrologic conditions throughout the seasons. Riverine species have evolved life history characteristics that exploit flood pulses for migration and reproduction based on those seasonally predictable hydrologic conditions that allow systems to access their floodplains (Weclomme 1979, McKeown 1984, Scheimer 2000). When a system degrades to a point where it can no longer access its floodplain, the system's capacity to dissipate energy is lost. Without dissipation of energy through floodplain access, sheer stress on streambanks builds within the channel causing channel widening. Channel widening reduces channel stability and causes loss of integral habitat that in turn reduces biotic integrity of the system until the stream can reach a state of equilibrium once again.*

#### 3.3.2.1. Water quality standards

There currently is no applicable standard for flow alteration.

The standard for minimum streamflow, according to Minn. Stat. § 7050.0210, subp. 7 is:
Point and nonpoint sources of water pollution shall be controlled so that the water quality standards will be maintained at all stream flows that are equal to or greater than the $7Q_{10}$ [the lowest streamflow for 7 consecutive days that occurs on average once every 10 years] for the critical month or months, unless another flow condition is specifically stated as applicable in this chapter.

#### 3.3.2.2. Types of Flow Alteration Data

Stream gaging stations are located in each major watershed of the state. The stations have differing lengths of monitoring history, and some are very new. If there is sufficient monitoring data, detailed hydrologic analysis can be used to help analyze for flow alteration. In addition, hydrologic models can be used to predict flows in a watershed or subwatershed when measured data are not available. An indirect determination of flow alteration can be found via geomorphological measurements, as channel form and dimensions are related to flow volumes.

#### 3.3.2.3. Sources and Causal Pathways Model for Flow Alteration

The conceptual model for flow alteration can be found on the EPA webpage. The causes and potential sources for altered flow are modeled at EPA CADDIS Flow Alteration webpage.

### 3.3.3. Candidate cause: total suspended sediment (TSS)

Sediment and turbidity have been shown to be among the leading pollutant issues affecting stream health in the United States (U.S.EPA, 2012a). Recent studies in Minnesota have demonstrated that human activities on the landscape have dramatically increased the sediment entering our streams and rivers since European settlement (Triplet, 2009);(Engstrom, 2009). Sediment can come from land surfaces (e.g., exposed soil) or from unstable stream banks. The soil may be unprotected for a variety of reasons, such as construction, mining, agriculture, or insufficiently-vegetated pastures. Human actions on the landscape, such as channelization of waterways, riparian land cover alteration, and increased impervious surface area can cause stream bank instability leading to sediment input from bank sloughing. Although sediment delivery and transport are an important natural process for all stream systems, sediment imbalance (either excess suspended sediment or lack of sediment) can be detrimental to aquatic organisms.

As described in a review by Waters (1995), excess suspended sediments cause harm to aquatic life through two major pathways: (1) direct, physical effects on biota (i.e., abrasion of gills, suppression of photosynthesis, avoidance behaviors); and (2) indirect effects (i.e., loss of visibility, increase in sediment oxygen demand). Elevated total suspended solids (TSS) concentrations can reduce the penetration of sunlight and can thwart photosynthetic activity and limit primary production (Munawar et al., 1991; Murphy et al., 1981). Sediment can also cause increases in water temperature as darker (turbid) water will absorb more solar radiation.

Organic particles (including algae) can also contribute to TSS. Testing for Total Suspended Volatile Solids (TSVS) allows for the determination of the particle type, and provides information on the source of the problem. High percentages of TSVS in relation to TSS concentrations can be indicative of excess nutrients (causing algal growth) and an unstable DO regime. Determining the type of suspended material (mineral vs organic) is important for proper conclusions about the stressor and source (erosion vs. nutrient enrichment vs. a wastewater discharge). More information on sediment effects can be found on the EPA CADDIS webpage: http://www.epa.gov/caddis/ssr_sed_int.html.

#### 3.3.3.1. Water Quality Standards

The new TSS standard in Minnesota is stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. For the central region the TSS standard has been set at 65 mg/L for warmwater streams and 10 mg/L for coldwater streams. For assessment, this concentration is not to be exceeded in more than 10% of samples within a 10-year data window. There is currently no standard for TSVS in Minnesota.

#### 3.3.3.2. Types of Suspended Sediment Data

Particles suspended in the water column can be either organic or mineral. Generally, both are present to some degree and measured as TSS. Typically, fine mineral matter is more concerning and comes from soil erosion of land surfaces or stream banks. TSS is determined by collecting a stream water sample and having the sample filtered and weighed to determine the concentration of particulate matter in the sample. To determine the mineral component of the suspended particles, a second test is run using the same procedure except to burn off the organic material in an oven before weighing the remains, which are only mineral material.

#### 3.3.3.3. Sources and Causal Pathways Model for Suspended Sediment

High TSS occurs when heavy rains fall on unprotected soils, dislodging the soil particles, which are transported by surface runoff into the rivers and streams (MPCA and MSUM, 2009). The soil may be unprotected for a variety of reasons, such as construction, mining, agriculture, or insufficiently vegetated land. Decreases in bank stability may also lead to sediment loss from the stream banks, often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, and increases in impervious surfaces.

Rangeland and pasture are also common landscape features in Minnesota. In some areas, the riparian corridor has been cleared for pasture and is heavily grazed, resulting in a riparian zone that lacks deep-rooted vegetation necessary to protect streambanks and provide shading. Exposures of these areas to weathering, trampling, and shear stress (water friction) from high flow events are increasing the quantity and severity of bank erosion. Additional causes and potential sources for increases in sediment are modeled at EPA CADDIS Sediments webpage.

### 3.3.4. Candidate cause: physical habitat

Habitat is a broad term encompassing all aspects of the physical, chemical, and biological conditions needed to support a biological community. This section will focus on the physical habitat structure including geomorphic characteristics and vegetative features (Griffith, Rashleigh, & Schofield, 2010). Physical habitat is often interrelated to other stressors (e.g., sediment, flow, DO).

Excess fine sediment deposition on benthic habitat has been proven to adversely impact fish and macroinvertebrate species that depend on clean, coarse stream substrates for feeding, refugia, and/or reproduction (Newcombe & MacDonald, 1991). Aquatic macroinvertebrates are generally affected in several ways: (1) loss of certain taxa due to changes in substrate composition (Erman, 1988); (2) increase in drift (avoidance) due to sediment deposition or substrate instability (Rosenberg & Wiens, 1978); and (3) changes in the quality and abundance of food sources such as periphyton and other prey items (Peckarsky, 1984). Fish communities are typically influenced through: (1) a reduction in spawning habitat or egg survival (Chapman, 1988); and (2) a reduction in prey items as a result of decreases in primary production and benthic productivity (Bruton, 1985); (Gray & Ward, 1982).

Specific habitats that are required by a healthy biotic community can be minimized or altered by practices on our landscape by way of resource extraction, agriculture, forestry, silviculture, urbanization, and industry. These landscape alterations can lead to reduced habitat availability, such as decreased riffle habitat; or reduced habitat quality, such as embedded gravel substrates. Biotic population changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (Griffith, Rashleigh, & Schofield, 2010). Fish species that are simple lithophilic spawners require clean, coarse substrate for reproduction. These fish do not construct nests for depositing eggs, but rather broadcast them over the substrate. Eggs often find their way into interstitial spaces among gravel and other coarse particles in the stream bed. Increased sedimentation can reduce reproductive success for simple lithophilic spawning fish, as eggs become smothered by sediment and become oxygen deprived. In the past, it was common to remove large woody debris (LWD) from stream channels for various reasons. It has now been shown (Gurnell, 1995); (Cordova, 2006); and (Magilligan F.J., 2008) that LWD is very important in creating habitat (causes scour pools, provides cover for fish and creates pockets of protection from faster currents, and a living surface for macroinvertebrates that cling to hard objects).

Degraded physical habitat is a leading cause of impairment in streams on 303(d) lists. According to the EPA CADDIS website six attributes are the main features of physical habitat structure provided by a stream: *stream size and channel dimensions, channel gradient, channel substrate size and type, habitat complexity and cover, vegetation cover and structure in the riparian zone, and channel-riparian interactions*. Just like for terrestrial settings and those animals, aquatic population and community changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (U.S.EPA, 2012a). To learn more about physical habitat go to the EPA CADDIS webpage .

#### 3.3.4.1. Water quality standards

There is no standard for physical habitat.

#### 3.3.4.2. Types of physical habitat data

MPCA biological survey crews conduct a qualitative habitat assessment using the MPCA Stream Habitat Assessment (MSHA) protocol for stream monitoring sites. The MSHA protocol can be found here. MSHA scores can be used to review habitat conditions at biological sampling locations and compare those conditions against similar size streams and a variety of Index of Biological Integrity (IBI) scores.

MPCA and DNR partners are collecting stream channel dimension, pattern, and profile data at select stream locations of various sizes and biological condition. This data can be used to compare channel departure from a reference condition. Habitat features can be analyzed to determine if a stream is lacking pool depth, pool spacing, adequate cross sectional area to convey discharge, and various other physical habitat features. The applied river morphology method created by (Rosgen, 1996) is the accepted method of data collection by the MPCA and DNR.

Deposited sediment is visually estimated by measuring the degree to which fine material surrounds rock or woody substrate within the channel (embeddedness). Deposited sediment is also analyzed by randomly measuring numerous substrate particles (pebble count) and calculating the $D_{50}$ particle size.

#### 3.3.4.3. Sources and causal pathways for physical habitat

Alterations of physical habitat, defined here as changes in the structural geomorphic or vegetative features of stream channels, can adversely affect aquatic organisms. Many human activities and land uses can lead to myriad changes in in-stream physical habitat. Mining and resource extraction, agriculture, forestry and silviculture, urbanization, and industry can contribute to increased sedimentation (e.g., via increased erosion) and changes in discharge patterns (e.g., via increased stormwater runoff and point effluent discharges), as well as lead to decreases in streambank habitat and instream cover, including large woody debris (see the Sediment and Flow modules for more information on sediment- and flow-related stressors).

Direct alteration of stream channels also can influence physical habitat, by changing discharge patterns, changing hydraulic conditions (water velocities and depths), creating barriers to movement, and decreasing riparian habitat. These changes can alter the structure of stream geomorphological units (e.g., by increasing the prevalence of run habitats, decreasing riffle habitats, and increasing or decreasing pool habitats).

Typically, physical habitat degradation results from reduced habitat availability (e.g., decreased snag habitat, decreased riffle habitat) or reduced habitat quality (e.g., increased fine sediment cover). Bedded and deposited sediments are closely related to suspended sediments. Decreases in bank stability lead to sediment loss from the stream-banks, causing sediment loads in the water column, and deposition on the stream bed. Bank instability is often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration (e.g., loss of buffer vegetation), and increases in impervious surfaces. Decreases in habitat availability or habitat quality may contribute to decreased condition, altered behavior, increased mortality, or decreased reproductive success of aquatic organisms; ultimately, these effects may result in changes in population and community structure and ecosystem function. Narrative and conceptual model can be found on the U.S. Environmental Protection Agency (EPA) CADDIS webpage here.

## 3.3.5. Candidate cause: eutrophication (phosphorus)

Phosphorus (P), an important plant nutrient, is typically in short supply in natural systems, but human presence and activity on the landscape often exports phosphorus to waterways, which can impact stream organisms. Nutrient sources can include urban stormwater runoff, agricultural runoff, animal waste, fertilizer, industrial and municipal wastewater facility discharges, and non-compliant septic system effluents. Phosphorus exists in several forms; the soluble form, orthophosphorus, is readily available for plant and algal uptake. While phosphorus itself is not toxic to aquatic organisms, it can have detrimental effects via other follow-on phenomena when levels are elevated above natural concentrations. Increased nutrients cause excessive aquatic plant and algal growth, which alters physical habitat, food resources, and oxygen levels in streams. Excess plant growth increases dissolved oxygen (DO) during daylight hours and saps oxygen from the water during the nighttime. Additionally, DO is lowered as bacterial decomposition occurs after the abundant plant material dies. Streams dominated with submerged macrophytes experience the largest swings in DO and pH (Wilcox R. a., 2001). In some cases, oxygen production leads to extremely high levels of oxygen in the water (supersaturation), which can cause gas bubble disease in fish. The wide daily fluctuations in DO caused by excess plant growth are also correlated to degradation of aquatic communities (Heiskary, Bouchard, & Markus, 2013). More information on the effects of phosphorus can be found on EPA CADDIS webpage: http://www.epa.gov/caddis/ssr_nut_int.html.

### 3.3.5.1. Water quality standards

The MPCA has developed standards for phosphorus designed to protect aquatic life (Heiskary, Bouchard, & Markus, 2013). Total Phosphorus (TP) criteria were developed for three geographic regions (Table 3.3-1). The TP standard is a maximum concentration also requiring at least one of three related stressors above its threshold.

**Table 3.3-1 River eutrophication criteria ranges by River Nutrient Region for Minnesota. The MRW is placed in the South Region.**

| Region | TP µg/L | Related Stressor | | |
|---|---|---|---|---|
| | | Chl-a µg/L | DO flux mg/L | $BOD_5$ mg/L |
| North | ≤ 50 | ≤ 7 | ≤ 3.0 | ≤ 1.5 |
| Central | ≤ 100 | ≤ 20 | ≤ 3.5 | ≤ 2.0 |
| South | ≤ 150 | ≤ 35 | ≤ 4.5 | ≤ 2.0 |

### 3.3.3.2. Types of phosphorus data

Water samples were collected from streams and rivers throughout the state. The most common data is for TP, though orthophosphorus samples have also been collected in some cases. Related stressor parameters (Chlorophyll-*a* (Chl-*a*), DO flux, BOD) are analyzed in conjunction with TP to understand potential impacts and connections.

### 3.3.5.3. Sources and causal pathways for phosphorus

Phosphorus is delivered to streams by wastewater treatment facilities, urban stormwater, agricultural runoff, and direct discharges of sewage. Phosphorus bound to sediments in the river channel could be contributing to concentrations; however, there is no data available. Orthophosphorus is the form of phosphorus that is readily available for plant and algal uptake, and can influence excess algae growth.

While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from waste water treatment plants, noncompliant septic systems, and fertilizers in urban and agricultural runoff. The causes and potential sources for excess phosphorus are modeled at [EPA's CADDIS Phosphorus webpage].

### 3.3.6. Candidate cause: nitrogen (nitrate)

Nitrate ($NO_3$) and nitrite ($NO_2$) forms of nitrogen are components of the natural nitrogen cycle in aquatic ecosystems. $NO_2$ anions are naturally present in soil and water, and are readily converted to $NO_3$ by microorganisms as part of the denitrification process of the nitrogen cycle. As a result, nitrate is far more abundant than nitrite. Although the water test commonly used measures both nitrate and nitrite, because a very large percent is nitrate, this report will refer to this data as being nitrate. Nitrogen is commonly applied as a crop fertilizer. Nitrogen transport pathways can be different depending on geology and hydrology of the watershed. When water moves quickly through the soil profile (as in the case of watersheds with karst geology and heavily tiled watersheds) nitrate transport can become very significant.

A statewide nitrogen study in Minnesota found that the breakdown of cropland nitrogen sources was: 47% commercial fertilizer application, 21% from cropland legume fixation, 16% from manure application, and 15% from atmospheric deposition (MPCA, 2013). These land applications can reach waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013). Other nitrogen sources are non-compliant septic systems and municipal wastewater discharges. For more information on the sources and effects of nitrate, see the EPA Causal Analysis/Diagnosis Decision Information System (CADDIS) webpages: http://www.epa.gov/caddis/ssr_nut_int.html.

Apart from its function as a biological nutrient, some levels of nitrate can become toxic to organisms. Nitrate toxicity is dependent on concentration and exposure time, as well as the sensitivity of the individual organisms. The intake of nitrate by aquatic organisms converts oxygen-carrying pigments into forms that are unable to carry oxygen, thus inducing a toxic effect on fish and certain macroinvertebrates (Grabda et al., 1974). Certain species of caddisflies, amphipods, and salmonid fishes seem to be the most sensitive to nitrate toxicity according to Camargo and Alonso (2006), who cited a maximum level of 2.0 mg/L nitrate N as appropriate for protecting the most sensitive freshwater species and nitrate-N concentrations under 10.0 mg/L to protect several other sensitive fish and aquatic invertebrate taxa. For toxic effects of chemicals, see EPA CADDIS webpage: http://www.epa.gov/caddis/ssr_tox_int.html.

#### 3.3.6.1. Water quality standards

Minnesota currently does not have an aquatic life use nitrate standard, though MPCA is actively developing an aquatic life standard for nitrate toxicity.

Minnesota's Class 1 waters, designated for domestic consumption, have a nitrate water quality standard of 10 mg/L (Minn. Stat. § 7050.0222, subp. 3).

### 3.3.6.2. Types of nitrogen data

Stream and river water samples are collected at various locations throughout the 8HUC. Samples are sent to a state certified laboratory and analyzed for a number of water quality parameters including nutrients. Laboratory analytical data is then stored in the EQuIS database and can be accessed via the MPCA webpage here.

### 3.3.6.3. Sources and causal pathways for nitrogen

The conceptual model for nitrogen as a candidate stressor is modeled at EPA CADDIS Nitrogen webpage. Lefebvre et al. (2007) determined that fertilizer application and land-cover were the two major determinants of nitrate signatures observed in surface water and that nitrate signatures in surface waters increased with fertilization intensity. Nitrogen is commonly applied as a crop fertilizer, predominantly for corn. A statewide nitrogen study found that cropland commercial fertilizers make up 47% of nitrogen added to the landscape, 21% occurs through cropland legume fixation, 16% from manure application, and 15% from atmospheric deposition (MPCA, 2013). These land applications can reach waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013).

## 3.3.7. Candidate cause: pH

Acidity is measured on a scale called pH, ranging from 0 to 14, with values of 0 to 6.99 being acidic, 7.0 neutral and above 7 being basic. Human effects on pH values can result from agricultural runoff, urbanization, and industrial discharges. Some geology produces naturally high hydrogen ions that can leach into surface water, but it would be rare for this to be the only cause when pH is a stressor. Photosynthesis from unnaturally-abundant plants or algae removes carbon dioxide from the water, causing a rise in pH. As pH increases, unionized ammonia (the toxic form of ammonia) increases, and may reach toxic concentrations (U.S.EPA, 2012a). Low pH values contribute to elevated ionic strength of water (more dissolved minerals). High or low pH effects on biology include decreased growth and reproduction, decreased biodiversity, and damage to skin, gills, eyes, and organs. Values of pH outside the range of 6.5 - 9 or highly fluctuating values are stressful to aquatic life (U.S.EPA, 2012a). For additional information on pH as a stressor, see EPA CADDIS webpage: http://www.epa.gov/caddis/ssr_ph_int.html#highph.

### 3.3.7.1. Water quality standards

The pH standard for Class 2B (warmwater) streams is within the range of 6.5 as a daily minimum and 9 as a daily maximum (Minn. Stat. § 7050.0222, subp. 4).

### 3.3.7.2. Types of pH data

Like DO, pH readings can be collected by deployed devices at defined time intervals, or a single, instantaneous reading taken during a site visit.

### 3.3.7.3. Sources and causal pathways for pH

The conceptual model for pH as a candidate stressor is modeled at EPA CADDIS pH webpage.EPA's CADDIS pH webpage. Human effects on pH values can result from agricultural runoff, urbanization, and industrial discharges. Some geology has naturally high hydrogen ions that can leach into surface water, but it would be rare for this to be the only cause. Photosynthesis of overabundant macrophytes and algae can remove carbon dioxide from the water, causing a higher pH. Effects on biology include decreased growth and reproduction, decreased biodiversity, and damage to skin, gills, eyes, and organs.

Concentrations of nutrients (especially nitrogen) also play a significant part in pH dynamics, as nitrification and respiration both produce hydrogen ions (U.S.EPA, 2013).

### 3.3.8. Candidate cause: physical connectivity (fish passage)

Connectivity in river ecosystems refers to how water features are linked to each other on the landscape or how locations within a feature (i.e., a stream) are connected. Connectivity also pertains to locations adjacent to a stream, such as a stream's connectivity to its floodplain, or the groundwater system.

Humans can alter the degree of connectivity within stream systems. In Minnesota, there are more than 800 dams on streams and rivers for a variety of purposes, including flood control, maintenance of lake levels, wildlife habitat, and hydroelectric power generation. Dams change stream habitat by altering streamflow, water temperature, and sediment transport (Cummins M.J., 1979); (Waters, 1995). Dams also directly block fish migration. Both mechanisms can cause changes in fish and macroinvertebrate communities and greatly reduce or even extirpate local populations (Brooker, 1981); (Tiemann, Gillette, Wildhaber, & Edds, 2004).

DNR has conducted numerous dam removal projects in recent years which have demonstrated benefits to fish populations. A more detailed presentation of the effects of dams on water quality and biological communities can be found in the DNR publication "Reconnecting Rivers: Natural Channel Design in Dam Removals and Fish Passage" (Aadland, 2010).

Culverts at road crossings can also be significant barriers to fish passage if they are installed or sized incorrectly. Culverts can be perched above the downstream water level, have too high an angle, resulting in high velocity flow which many species cannot traverse, or be undersized for the stream size, which also results in high velocity within the culvert. An excellent review of studies regarding culvert impacts to fish migration, including information specifically from Minnesota, has been conducted by the Minnesota Department of Transportation (MNDOT, 2013).

The following is an excerpt from a DNR (2014)publication and contains a more detailed discussion on various aspects of connectivity:

*Connectivity is defined as the maintenance of lateral, longitudinal, and vertical pathways for biological, hydrological, and physical processes within a river system (Annear 2004). Connectivity is thus the water-mediated transfer of energy, materials, and organisms across the hydrological landscape (Pringle 2003). The transport of these integral components within a river travel in four dimensions: longitudinal, upstream and downstream; lateral, channel to floodplain; vertical, hyporheic to groundwater zones; and temporal, continuity of transport over time (Annear 2004). Due to the objectives of this study, vertical connectivity was not directly assessed.*

*Longitudinal connectivity of flowing surface waters is of the utmost importance to fish species. Many fish species' life histories employ seasonal migrations for reproduction or overwintering. Physical barriers such as dams, waterfalls, perched culverts and other instream structures disrupt longitudinal connectivity and often impede seasonal fish migrations. Disrupted migration not only holds the capacity to alter reproduction of fish, it also impacts mussel species that utilize fish movement to disperse their offspring. Structures, such as dams, have been shown to reduce species richness of systems, while also increasing abundance of tolerant or undesirable species* (Winston, 1991), (Santucci V.A., 2005).

*Longitudinal connectivity of a system's immediate riparian corridor is an integral component within a healthy watershed. Continuous corridors of high quality riparian vegetation work to sustain stream stability and play an important role in energy input and light penetration to surface waters. Riparian* *connectivity provides habitat for terrestrial species as well as spawning and refuge habitat for fish during periods of flooding. Improperly sized bridges and culverts hinder the role of riparian connectivity as they reduce localized floodplain access, disrupt streambank vegetation, and bottle neck flows that can wash out down stream banks and vegetation.*

#### 3.3.8.1. Water Quality Standards

There is no applicable water quality standard for connectivity impacts, though new design guidelines for culverts have been developed by Minnesota Department of Transportation for fish passage http://www.dot.state.mn.us/research/TRS/2013/TRS1302.pdf.

#### 3.3.8.2. Types of Physical Connectivity Data

Locations for dams are available on DNR Geographic Information System (GIS) coverage. Aerial photos are viewed for unknown structures. Culverts are visited to determine their organism passage capability.

# 4.0 Evaluation of candidate causes

## 4.1. Estes Brook (AUID-07010207-679)

### 4.1.1. Biological communities

The macroinvertebrate community in Estes Brook is impaired. Two biological sampling sites (13UM060 and 13UM042) are located in this Assessment Unit Identification (AUID). Biological sampling site 13UM060 is in the Class 4 (Northern Forest Streams Glide/Pool Habitats) macroinvertebrate Index of Biological Integrity (IBI) class and biological sampling site 13UM042 is in the Class 3 (Northern Forest Streams Riffle/Run) macroinvertebrate Index of Biological Integrity (M-IBI) class. Table 4.3-1 below lists the M-IBI metrics for the IBI Class 4 sampling locations. Table 4.1-2 below lists the M-IBI metrics for the IBI Class 3 sites. The macroinvertebrate community scored a 50.4 at site 13UM060 with a threshold of 51. This site had all 20 samples come from undercut bank/overhanging vegetation. The fish communities were above their respective threshold during the 2013 sampling.

The mean metric score required to pass the M-IBI is 5.2 (Class 4) and 5.3 (Class3) per metric, meaning if the score is above that mean value the individual metric passes. Scores that are below that mean value bring the overall score down and are causing the low M-IBI score. Table 4.1-1 and Table 4.1-2 have the metric values highlighted in bold red that are below the mean value. Five of the 10 metrics used to calculate the M-IBI score are below the mean value of 5.2 for site 13UM060. There is a general lack of non hydropsychid trichoptera individuals, and a low taxa richness of POET (stoneflies, dragonflies, mayflies and caddisflies). A qualitative multi-habitat (QMH) sample was collected from available habitat within the reach. This indicates that there is a general lack of macroinvertebrate habitat in this reach. Macroinvertebrates could be sampled from many different habitat types, such as, aquatic macrophytes, rock substrate, undercut banks-overhanging vegetation and woody debris. Sampling one habitat type suggests there may be a lack of habitat diversity. Six of the 10 metrics used to calculate the M-IBI score at site 13UM042 are below the mean value of 5.3. There is a general lack of climber species, an absence of Plecoptera species, a lack of predator species and a low abundance of Trichoptera species. A QMH sample was collected from available habitat within the reach; this consisted of rocky substrate and undercut bank/overhanging vegetation habitats at 13UM042. Two potential habitat types were missed during sampling. The macroinvertebrate sample was skewed toward bank sampling with 14 bank samples and 6 rock substrate samples collected to composite into the macroinvertebrate sample. This may indicate that habitat is lacking in this reach as well.

**Table 4.1-1: Macroinvertebrate IBI metrics used to compute IBI scores for Northern Forest Streams (Macroinvertebrate Class 4). Sites are listed in order going upstream. Threshold is 51 for passing the MIBI.**

| Site ID | Date | MIBI Score | ClingerCh | Collector-filtererPct | DomFiveChPct | HBI_MN | Intolerant2Ch | POET | PredatorCh | TaxaCountAllChir | TrichopteraChTxPct | TrichwoHydroPct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13UM060 | Aug 14, 2013 | **50.4** | 6.66 | 7.39 | 5.99 | **5.00** | **5.00** | **2.86** | 7.14 | 7.66 | **2.70** | **0** |

**Table 4.1-2: Macroinvertebrate IBI metrics used to compute IBI scores for Northern Forest Streams (Macroinvertebrate Class 3). Threshold is 53 for passing the MIBI.**

| Site ID | Date | MIBI Score | ClimberCh | ClingerChTxPct | DomFiveChPct | HBI_MN | InsectTxPct | Odonata | Plecoptera | Predator | Tolerant2ChTxPct | Trichoptera |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13UM042 | Aug 14, 2013 | **43.3** | **4.61** | 7.53 | 6.68 | **0.97** | 6.86 | 6.13 | **0** | **2.31** | **3.63** | **3** |

## 4.1.2. Data analysis/evaluation for each candidate cause

### Low dissolved oxygen

Dissolved oxygen (DO) data was collected at one location in this AUID. The data was collected from Environmental Quality Information System (EQuIS) station S006-1014. An YSIä sonde was placed in Estes Brook for a 10-day period to document the diurnal fluctuation of DO and stream temperature. Figure 4.4-1 displays the continuous sonde data. The daily DO flux observed during the sampling period ranged from 2.5 to 4.5 mg/L. Figure 4.4-5 displays the DO sampling locations. With the current data DO does not appear to be a significant stressor to the biological community in the AUID. The macroinvertebrate DO Index value is 7.0 at biological site 13UM042 and 6.8 at site 13UM060. These values indicate that there is a 20% probability that the macroinvertebrate community is affected by low DO concentrations. There are more DO intolerant macroinvertebrate taxa than there are DO tolerant taxa in the sample and zero DO very tolerant taxa.

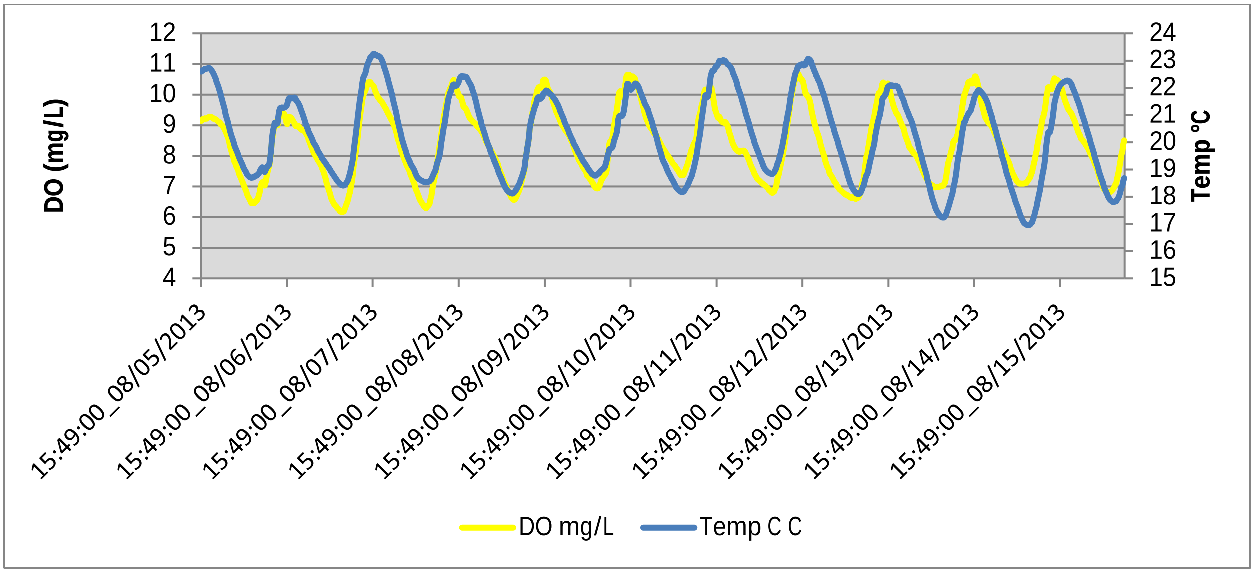



**Figure 4.1-1: Continuous DO and stream temperature data from Estes Brook during the assessment monitoring period for the Rum watershed. There are no periods of DO falling below the 5 mg/L standard. Daily DO flux ranges from 2.5 to 4 mg/L per day.**

Macroinvertebrate community tolerance indicator values have also been calculated by MPCA. These community tolerance indicator values can be compared against all samples collected for a given stream type. Estes Brook stations are in two macroinvertebrate stream classes; the northern stream glide pool (Class 4) and the northern stream riffle/run (Class 3). The sampling location (13UM060) on Estes Brook had higher than average Low DO index scores for macroinvertebrates (Figure 4.1-3). The HBI_MN score is a measure of organic pollution and was well below the class 4 statewide average for passing M-IBI scores.

**Table 4.1-3: Macroinvertebrate metrics that respond to low DO stress in the Estes Brook**

| Station (Year sampled) | TaxaCountAllChir | EPTCh | HBI_MN | Low DO Index Score | Low DO Intolerant Taxa | Low DO Tolerant Pct |
|---|---|---|---|---|---|---|
| **13UM060 (M-Class 4)** | 45 | 4.44 | 7.34 | 6.78 | 3 | 6.47 |
| **Statewide average for Northern Forest Stream GP that are meeting the MIBI Threshold (53)** | 47.3 | 12.4 | 6.45 | 6.62 | 3.9 | 22.9 |
| **Expected response to stress** | ↓ | ↓ | ↑ | ↓ | ↓ | ↑ |
| **13UM042 (M-Class 3)** | 43 | 16.28 | 8.02 | 7.045 | 11 | 1 |
| **Statewide average for Northern Forest Stream RR that are meeting the MIBI Threshold (56)** | 53.8 | 19.6 | 5.8 | 7.05 | 11.49 | 4.9 |
| **Expected response to stress** | ↓ | ↓ | ↑ | ↓ | ↓ | ↑ |

Based on the above data sets, low DO concentrations is not a stressor to the macroinvertebrate community in Estes Brook. Site 13UM042 could be experiencing some short duration periods of low DO stress that may be impacting the macroinvertebrate community. This is also supported by the current fish community. The fish community shows that there is a 51% probability of the DO meeting the standard based on the fish community present during sampling at both sites.

### Elevated nutrients

Estes Brook has one EQuIS station (S006-104) that has a limited amount of water chemistry data from the 2013 and 2015 sampling seasons. Water quality data was collected and analyzed for total phosphorus (TP), nitrite (NO2), nitrate (NO3), and un-ionized ammonia ($NH_3$). The majority of the nutrient concentrations were below the Ecoregion TP standard of 0.100 mg/L with the exception of three samples in June and July of 2013. The minimum TP sampled was 0.042 mg/L on 5/15/2013 and the maximum TP sampled was 0.192 mg/L on 7/11/2013. The average TP sample concentration was 0.083 mg/L for the 2013 monitoring season. Total P concentrations were slightly elevated during snowmelt and at the end of June (Figure 4.1-2).The daily DO flux as seen in Figure 4.1-1 is around 4mg/L per day. This suggests that nutrient enrichment may be causing an increase in primary production. Eutrophication caused by elevated TP concentrations does appear to be an issue in Estes Brook. Nitrite-nitrate ($NO_2NO_3$) concentrations are elevated in Estes Brook in relation to other observed $NO_2NO_3$ data in the Rum River Watershed (minimum of 0.46, maximum of 0.95, average of 0.712). Ammonia concentrations are also slightly elevated. Nitrogen levels are not high enough to alone be a source of stress to the macroinvertebrate communities, which is likely being affected by a combination of stressors as can be seen in Table 4.1-4below. The Index score is calculated by assigning a tolerance value to the individual macroinvertebrate taxa and looking at taxa abundance then using a weighted scoring system to develop the individual Index score. This work was conducted by the MPCA St. Paul biologists and the scores are calculated for all biological monitoring sites on an annual basis. The Class 3 and Class 4 Index scores for passing IBI sites was calculated by averaging all Index scores for the respective class that passed the IBI. The macroinvertebrate index score is above the Class 3 average but the percent tolerant taxa for nitrogen are over twice the Class average for both biological sites. It is recommended that additional data on nitrogen concentrations in Estes Brook be collected.

**Table 4.1-4: Macroinvertebrate Class 3 and Class 4 community metrics associated with a pollutant. Site metrics are calculated and compared to Class averages of sites scoring above the MIBI threshold. Yellow highlight shows metrics that indicate stress.**

| FieldNum | Parameter Name | Index Score | %Tolerant Individuals | %Very Tolerant Taxa | Class average for sites meeting IBI (%Tolerant Individuals) | Class average for sites meeting IBI (Index Score) |
|---|---|---|---|---|---|---|
| 13UM042 | DO | | 0.639 | 0.000 | 9.8 | 7.05 |
| 13UM060 | DO | 6.77 | 9.90 | 0.627 | 22.9 | 6.62 |
| 13UM042 | TSS | 4.4 | 38.8 | 12.9 | 25.36 | 16.3 |
| 13UM060 | TSS | 5.3 | 15.2 | 1.94 | 25.4 | 16.31 |
| 13UM042 | N | 0.90 | 67.97 | 53.59 | 36.13 | 0.23 |
| 13UM060 | N | 0.75 | 60.84 | 41.42 | 23.16 | 0.16 |

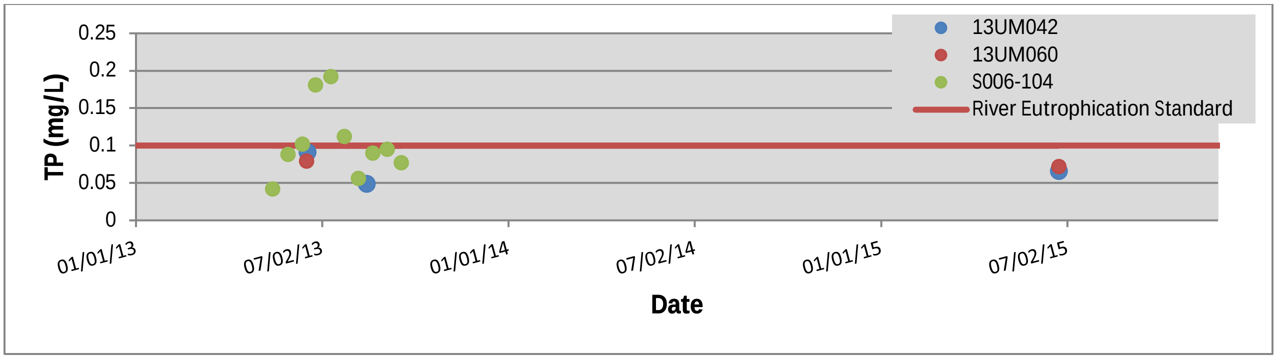



**Figure 4.1-2: Total Phosphorus concentrations at water quality sampling locations along the Estes Brook. Data was collected in 2013 and 2015.**

### Biotic response-macroinvertebrates

Eutrophication caused by TP does appear to be affecting the macroinvertebrate community. The DO flux is averaging approximately 4 mg/L/day which is above the expected 3.5 mg/L/day for the river nutrient standard. The relationship between elevated phosphorus and the M-IBI score in AUID 679 is not strong; however, it does appear to partially be stressing the macroinvertebrate community. With the limited nitrogen data that has been collected it is inconclusive to state whether nitrogen is a leading stressor to the macroinvertebrates. Macroinvertebrate metrics suggest that there is an abundance of nitrogen tolerant taxa; however, the nitrogen index score at both sites is above the mean nitrogen index score for sites meeting the M-IBI. Additional nitrogen samples should be collected at 13UM042 to further understand the concentrations in the stream at various times of the year.

### Lack of physical habitat

Habitat quality in Estes Brook (AUID 679) is good. Both the MPCA Stream Habitat Assessment (MSHA) scores in the lower to middle 60s and the scores are evenly distributed across the five major categories. Figure 4.1-3 below displays the scores from the MSHA. Land use is the one category that brings the score down.

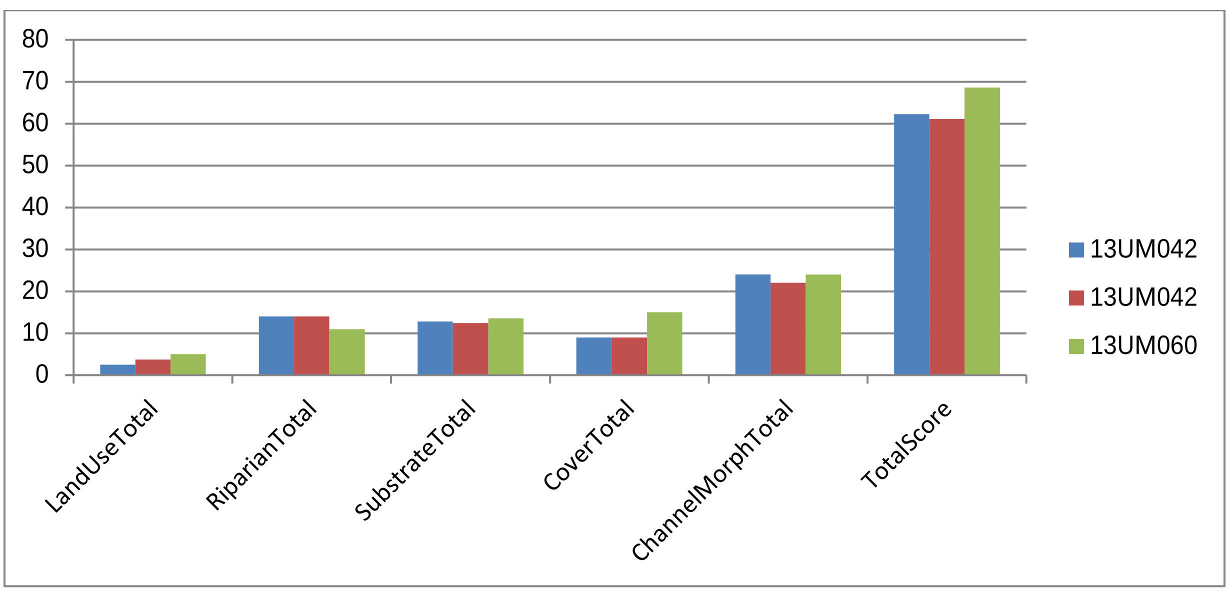



**Figure 4.1-3: MSHA scores at biologically impaired sites on Estes Brook. Site 13UM060 is a Class 4 Macroinvertebrate site and 13UM042 is a Class 3 Macroinvertebrate site.**

The M-IBI score at 13UM060 was 50.4 with a threshold of 51. This site does not appear to be habitat limited. Habitat at site 13UM042 does appear to be impacted by localized land use immediately upstream. This site is just below a cattle pasture that is experiencing bank erosion, and over widening of the channel. The lack of riparian cover may also be elevating stream temperatures in this reach. Figure 4.1-4 below is a google earth map showing the location of 13UM042 along with the upstream condition of the pasture. Habitat at site 13UM042 does not appear to be driving the macroinvertebrate score independently but the lack of coarse substrate and the upstream supply of fine sediment is impacting the community. The mean riffle particle size in this reach is 1.5 mm which is fine sand/silt substrate. The sand/silt is being exported from the upstream reach and embedding any coarse substrate. The Pfankuch channel stability rating at this site was fair (close to poor). This is a measure of both channel bank and stream channel conditions which reflect the condition of channel stability. A fair/poor condition indicates instability and sediment related problems. Sediment mobility and embeddedness of coarse substrate are affecting the macroinvertebrate community at 13UM042. Thirty-nine percent of the taxa sampled were legless and 36% of the individuals sampled were burrowers and legless. The stream longitudinal profile shows that pool depths are shallow (less than 1.5 times as deep as riffles). This shows that the pools are filling with sediment and stream power cannot scour out pools to maintain depth.

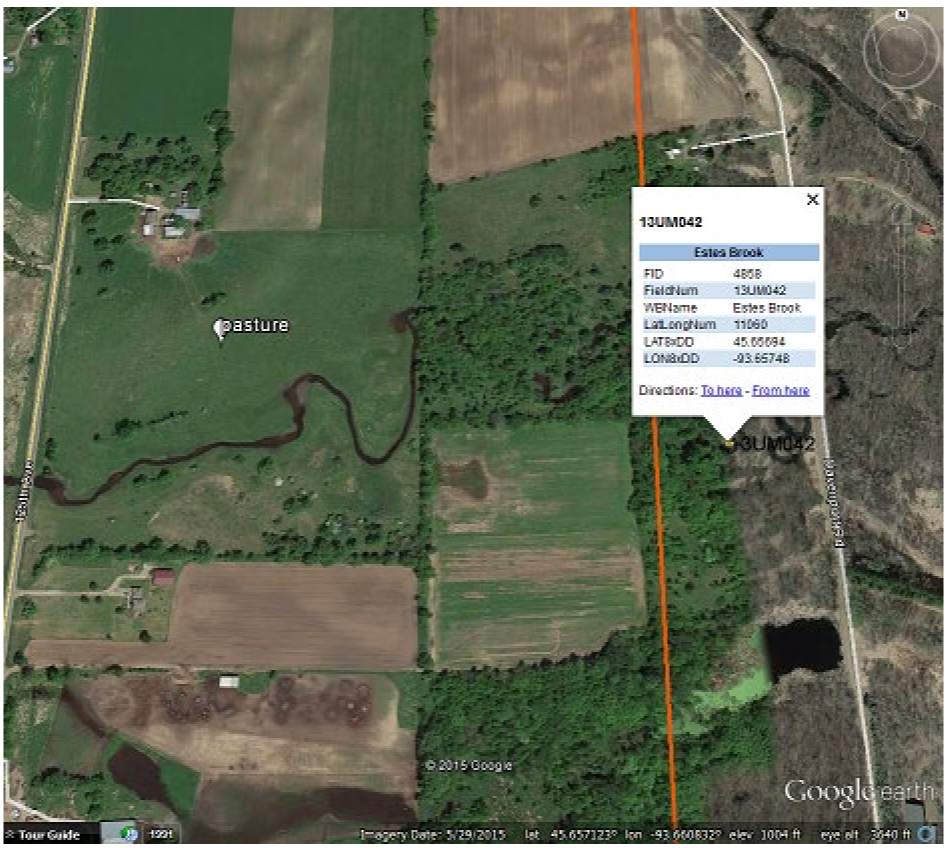



**Figure 4.1-4: Estes Brook sampling location at site 13UM042. Site is immediately downstream of a section of stream with no riparian cover and showing signs of over widening and bank erosion. This may be causing bedded sediment problems downstream.**

## Altered hydrology

Stream gage data was collected in Estes Brook from 2013 through 2015. Stage data was collected every 30 minutes and then a site specific rating curve was developed to convert stage to discharge. The discharge data shows that the stream flow is extremely flashy based on the precipitation. The discharge data confirms that in late summer at all three monitoring seasons, the stream discharge is low. The Department of Natural Resources (DNR) was asked to also look at the geomorphic characteristics of Estes Brook. There findings can be found in Estes Brook Site Summary report. A summary of the findings is presented in Table 4.1-5.

**Table 4.1-5: Geomorphic data summary for survey of Estes Brook (DNR collected data 2015 at 13UM042)**

| | | | |
|---|---|---|---|
| **Stream Type** | E5 | **Riffle D50 (mm)** | 1.5 |
| **Valley Type** | U-AL-FD | **Mean Riffle Depth (ft)** | 2.27 |
| **Sinuosity** | 1.8 | **Max Riffle Depth (ft)** | 2.77 |
| **Water Slope** | 0.0002 | **Bankfull Area (ft²)** | 59.91 |
| **Bankfull Width (ft)** | 26.37 | **Bank Erosion Estimates (tons/yr/ft)** | 0.0355 |
| **Entrenchment Ratio** | 6.83 | **Pfankuch Stability Rating** | Fair |
| **Width/Depth Ratio** | 11.62 | **Competence Condition** | NA |

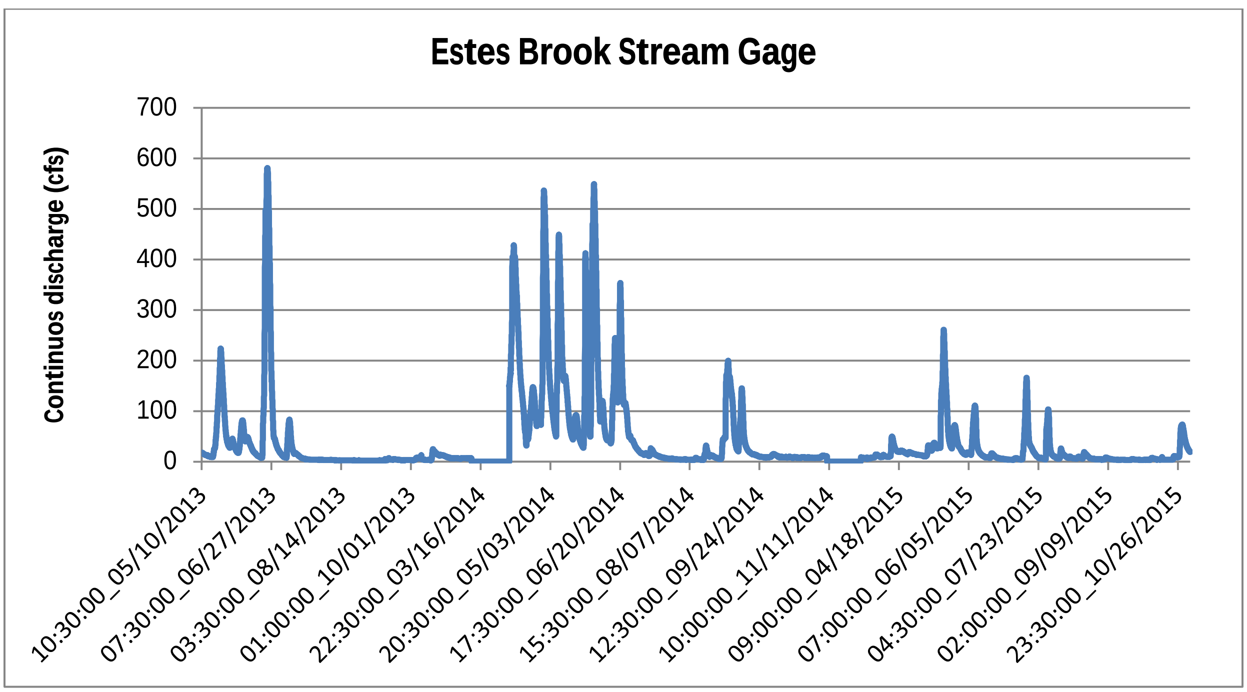



**Figure 4.1-5: Continuous stream discharge collected at Estes Brook in 2013 through 2015. Stage data was collected at this station and then converted using a site specific rating curve.**

A summary of the DNR data suggest that stream flow alteration is not driving the stream channel development. “E5 stream types in unconfined alluvial floodplains normally have very low width-to-depth ratios and are efficient at transporting sediment. These stream types are also resistant to change unless vegetation, sediment supply, or streamflow alterations occur. In this reach the width-to-depth ratio of 11.62 is high for an E stream type, indicating a suppressed ability to transport sediment. Historically unchanged riparian vegetation points to a possible increase in localized sediment contributions or streamflow alteration. One such source of sediment could be a pasture just upstream of the surveyed reach. Hoof shear stress is a well-documented phenomenon causing stream bank erosion.” This was taken directly from the DNR report.

Altered hydrology does appear to be a systemic problem in Estes Brook. A review of the Hydrological Simulation Program – FORTRAN (HSPF model output for hydrology show that Estes Brook at Reach 251 experiences flow less than 1 cfs for 21% of the modeling run. The model covers 1996 through 2009 and shows that, annually, the months of August and September have extended periods of flow less than 1 cfs. Based on the hydrograph and the HSPF modeling results, the flow regime appears altered. The hydrograph flashiness and extended periods of low flow will have an effect on macroinvertebrate taxa richness. At site 13UM042 there were 29 macroinvertebrate taxa present; of which 23 were tolerant taxa.

### 4.1.3. AUID summary

#### Stressor pathway discussion

The pasture immediately upstream of sampling site 13UM042 is exporting sediment to the downstream reach. Evidence of sand/silt substrate near 13UM042 was documented by the DNR during the geomorphic survey at this site. The Pfankuch stability rating is also fair/poor at this site which also reflects on channel bank conditions and channel substrate conditions. This is causing a change in the habitat available at 13UM042 and is inhibiting the macroinvertebrate community.

#### Stressor conclusions

Low DO is not a stressor to the biological communities in Estes Brook. Elevated nutrients do appear to be causing eutrophication in the stream as the response variables are showing an elevation of daily DO flux. TP concentrations are above the 0.1mg/L standard during June and July of 2013. Nitrogen also appears to be causing stress to the macroinvertebrate community based on comparative metrics used for Class 3 metric averages for sites meeting the M-IBI. Lack of habitat is a stressor at the downstream site 13UM042. It is immediately downstream of an active pasture that is exporting sediment to the downstream location which is filling pools, embedding riffles and causing a lack of macroinvertebrate habitat. The DNR Geomorph survey shows this in the longitudinal profile. Altered hydrology does appear to be impacting Estes Brook based on the geomorphic survey conducted and the stream hydrograph.

## 4.2. Trott Brook (07010207-680)

### 4.2.1. Biological communities

Trott Brook has two biological sampling locations: 00UM067 and 13UM044. The 00UM067 sample was collected in 2000 and passed both the fish and macroinvertebrate IBI’s with a Fish Index of Biological Integrity (F-IBI) of 49 and an M-IBI of 64.6. The 13UM044 sample was collected in 2013, with the fish failing the F-IBI with a score of 35 and macroinvertebrates failing the M-IBI with a score of 42.2. The drop of 22 points in the macroinvertebrate sample is a cause for concern in the IBI score. Trott Brook is a Class 6 macroinvertebrate stream type. The macroinvertebrate sample was dominated by *Hyalella sp.* ( a freshwater shrimp). *Hyalella sp.* is quite tolerant of a variety of stressors including low DO. Low DO may be a problem at this site based on the macroinvertebrate community tolerance metrics. In 2015 during higher August stream flow conditions macroinvertebrates were resampled and passed the M-IBI with scores of 54 and 63. The difference in M-IBI scores appear to be related to the flow conditions during late summer. Review of Rum River gage data (21095001) near St. Francis suggests that annually late summer flows are generally low. Fifteen years of data was reviewed. The mean August discharge in 2000 was 331 cfs and the mean August discharge in 2013 was 431.5 cfs. The mean for the 22 year record (19932015) in August was 571 cfs. Due to the fact that both monitoring years are below the mean August discharge for the 22 year record does indicate flows were low but there is not enough information to conclude that they were low enough to affect the macroinvertebrate sample collection.

### 4.2.2. Data analysis/evaluation for each candidate cause

#### Low dissolved oxygen

Low DO appears to be a stressor in Trott Brook. As Figure 4.2-1below shows there are extended periods of time during the last sixteen years that DO has been below the 5 mg/L standard. The macroinvertebrate community sampled also showed that low DO was a stressor. The macroinvertebrate sample was dominated by *Hyalella sp.;* these taxa are tolerant to a wide range of conditions and pollutants.

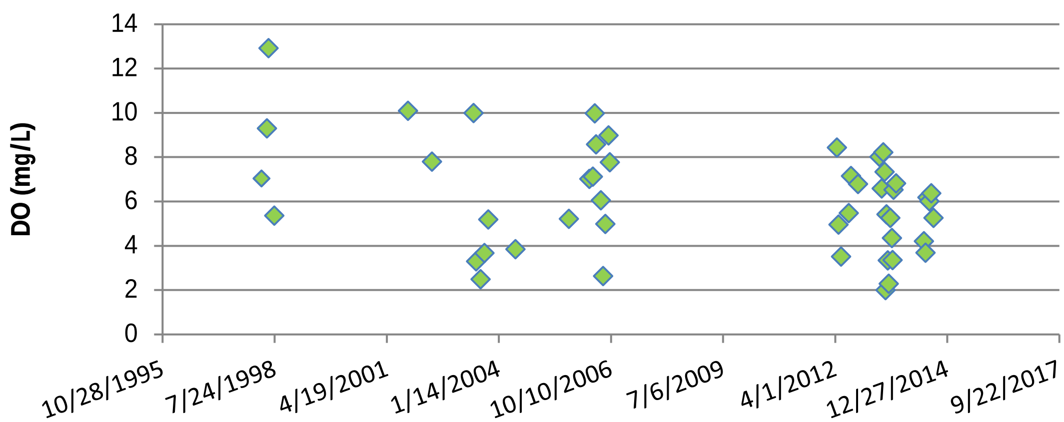



**Figure 4.2-1: DO data supplied by Anoka SWCD from Trott Brook at Highway 5. The data shows multiple DO data points below the 5 mg/L standard.**

Below in Table 4.2-1 is a summary of the macroinvertebrate DO metric data. This table shows that the macroinvertebrate sample was dominated by low DO tolerant taxa. With nearly 49% of the taxa sampled thriving in low DO conditions. A comparison of watershed averages for Class 6 macroinvertebrate metrics against the 13UM044 metrics can also be valuable to identify potential stressors based on macroinvertebrate data in Figure 4.2-2. Based on this information it appears that DO is a stressor.

**Table 4.2-1: Trott Brook site 13UM044 macroinvertebrate metric scores. This table shows the number and percent of macroinvertebrate metrics that are tolerant or intolerant to low DO.**

| Site ID | ChemTV_DO | # Intolerant Taxa | % Intolerant Individuals | # Very Intolerant Taxa | % Very Intolerant Individuals | # Tolerant Taxa | % Tolerant Individuals | # Very Tolerant Taxa | % Very Tolerant Individuals |
|---|---|---|---|---|---|---|---|---|---|
| 13UM 044 | 6.43 | 3 | 3.33 | 2 | 3.00 | 6 | 48.26 | 1 | 2.0 |

**Table 4.2-2: A comparison of site 13UM044 and the macroinvertebrate Class 6 averages for sites meeting the MIBI. Metric scores highlighted in yellow are indicative of potential stress to the biology.**

| | Parameter | Index Score | % Tolerant Individuals | Watershed average for Class 6 (Index Score) | Watershed average for Class 6 (%Tolerant Individuals) |
|---|---|---|---|---|---|
| 13UM044 | DO | 6.43 | 48.26 | 7.03 | 14.53 |
| 13UM044 | TSS | 4.0 | 9.72 | 16.36 | 25.82 |
| 13UM044 | N | 0.44 | 39.58 | 0.41 | 46.88 |

Fish Community Tolerance Value Index (TVI) scores also show that Trott Brook has shown a decline in water quality based on the scores. The 2013 sample data shows an 87% chance of failing the DO standard based on the fish sampled.

| FieldNum | WBName | Probability_TSSRA | probability_DO_earlyAM_RA |
|---|---|---|---|
| 00UM067 | Trott Brook | 0.783096707 | 0.515072165 |
| 13UM044 | Trott Brook | 0.840729203 | 0.133703147 |

A YSIä sonde was also deployed in Trott Brook during 2013 to evaluate the daily flux in DO data. The sonde recorded stream temperature, specific conductivity, pH and DO concentrations between July 25, 2013, to August 04, 2013. During this period DO concentrations fell below the 5 mg/L standard daily and have a daily flux of 4-8 mg/L. When a stream DO flux is greater than 3.5 mg/L it is indicative of eutrophication. More will be discussed in the elevated nutrient section of this report. Table 4.2-2below shows the continuous DO data collected during the 2013 deployment.

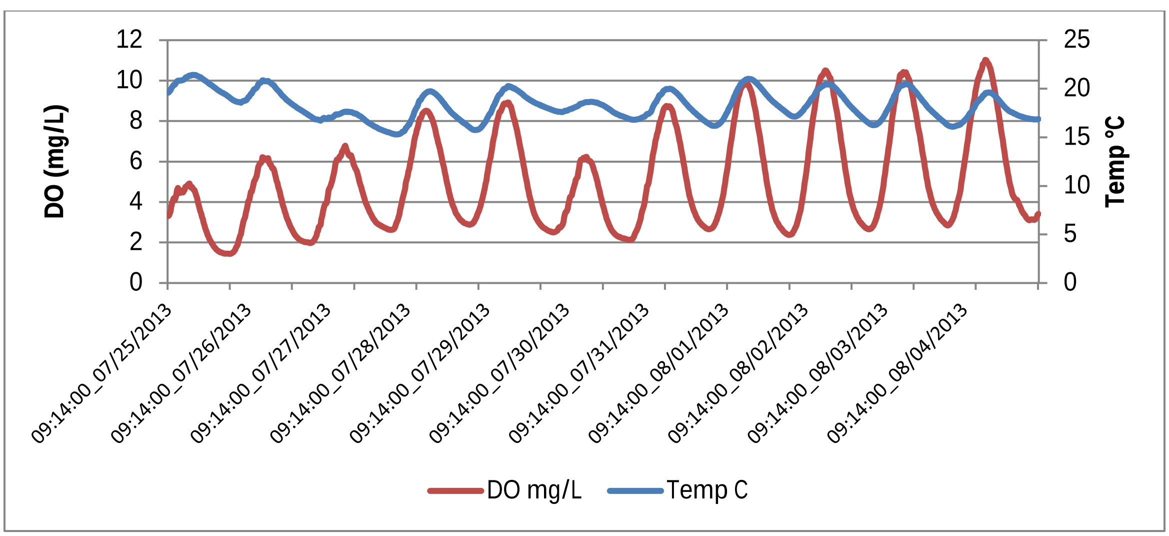



**Figure 4.2-2: Continuous DO data collected by a YSIä sonde that was deployed in the stream for 11 days in 2013.**

### Elevated nutrients

Elevated nutrients appear to be a stressor to the macroinvertebrate community in Trott Brook. As seen in Figure 4.2-3 below, phosphorus concentrations are often above the phosphorus standard of 100 ppb for central MN streams. The daily DO flux is above the standard of 3.5 mg/L and there is a response variable of increased peryphyton growth observed in the stream.

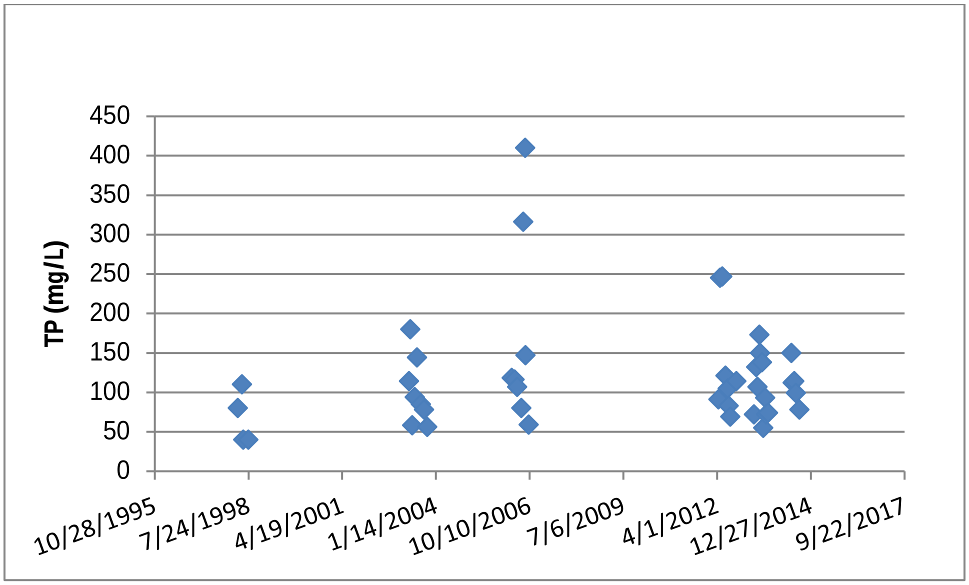



**Figure 4.2-3: Total phosphorus concentrations in Trott Brook at Highway 5 sampling site.**

There appears to be extensive submerged aquatic plant and periphyton growth (Figure 4.2-4) in the stream which is in response to the elevated TP concentrations. This plant growth is also leading to the daily flux in DO concentrations. An extensive portion of Trott Brook upstream of the sampling location has been channelized. This channelization appears to be draining a wetland complex and may be contributing to the elevated nutrient concentrations along with the low DO concentrations observed. Additional monitoring would be needed to estimate the main sources of the nutrients. As seen in Figure 4.2-2, there is a response in the biological community to low DO which, in part, is being caused by the elevated phosphorus concentrations.

**Figure 4.2-4: Trott Brook at sampling location 13UM042. Photo was taken during the SID visit in 2015. Photo shows rooted submerged vegetation along with extensive periphyton growth along the channel bottom.**

### Lack of physical habitat

Trott Brook scored a 67.1 in the MSHA. This score is calculated by MPCA biologists while biological sampling is occurring and is a reflection of the available habitat and its condition during sampling. There are five main categories that are calculated and then summed to receive a total. Figure 4.2-5 shows the MSHA score. The habitat in Trott Brook scores very well. Habitat does not appear to be a stressor in Trott Brook.

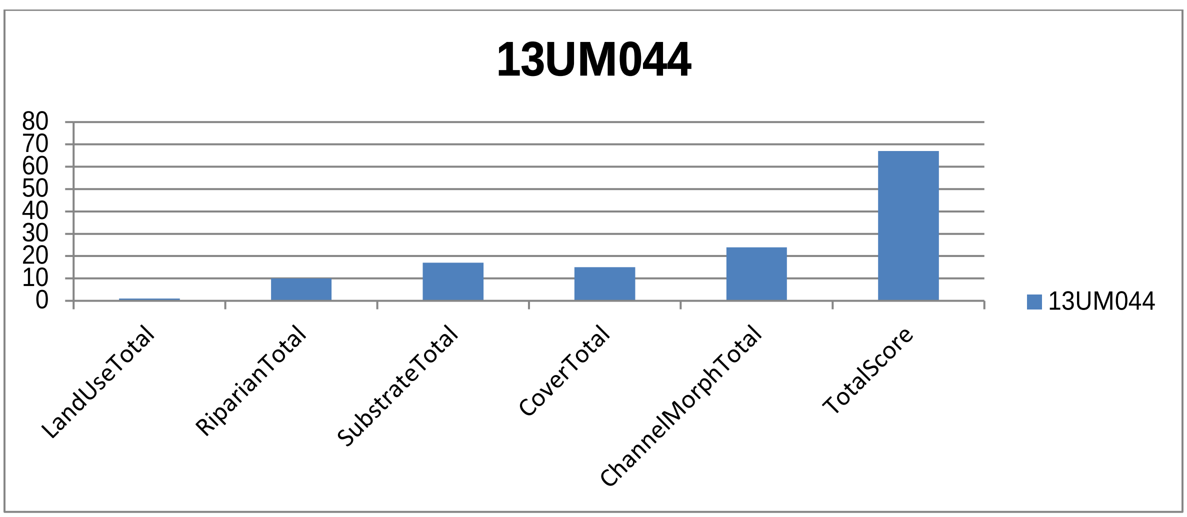



**Figure 4.2-5: MSHA score for Trott Brook during the 2013 fish sampling event at 13UM042. The land use category scores poorly because of the encroachment of residential development along the sampling location.**

### Altered hydrology

Trott Brook does not have an active stream gage. There is no stream flow record to analyze for altered hydrology. The majority of the channel is altered (either ditched or straightened in some form). The only portion of the channel that is still natural is downstream of the sampling location 13UM044. Most of the land use along the channel has recently been converted to residential development. This development (within the city of Ramsey) may have impacted how the stormwater is delivered to the stream. Increased impervious surfaces usually means an accelerated rate of water movement into the stream channel. Figure 4.2-6 shows the condition of the stream network and the high percentage of channelized sections.

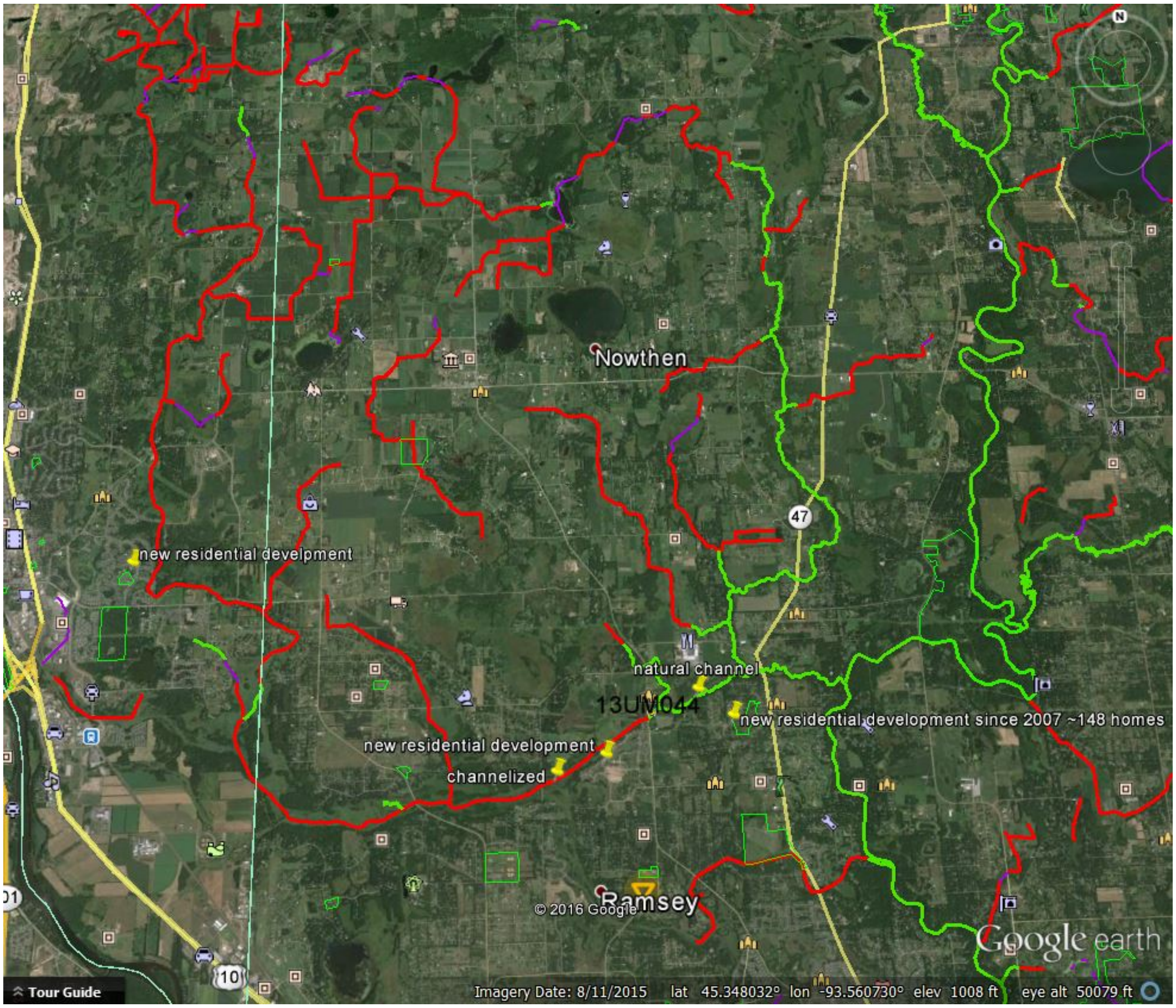



**Figure 4.2-6: Trott Brook channel condition map. The red lines indicate altered channel and the green line shows natural channel, the purple line shows impounded channel. Almost entire AUID is altered channel.**

An HSPF hydrologic model was built for Trott Brook. The model output covers 1996 through 2009 and shows that there are no critically low flow (less than 1cfs) periods for Trott Brook. The model does show that the mean discharge for the period modeled is 47 cfs with a peak discharge of 1281 cfs for reach 439 in Assessment Unit Identification (AUID) 680. To review the peak discharge from the model, a multiplier of five times the mean flow was used to understand when the peak flows were occurring and during which season the peak flows occurred. The flow value of 235 cfs was used to express high discharge values. Discharge was at or above 235 cfs during 1.4% of the model run. Most discharge values occurred during April and May (pre-2001) and the pattern changed to July, August, and October from 2002 through 2005. The model prediction is based on precipitation and land use so the heaviest runoff estimates occur during periods of increased rainfall. If the data is sorted to look at discharge values of

141 cfs the frequency increases to 4% of the flow record and the distribution follows a similar pattern. Spring month's pre 2001 and summer months (post-2002) experience the greatest frequency of flows above 141 cfs.

A stream gage installed at this location would help us understand the water delivery through the system. It also would be beneficial for computing flow weighted average concentrations for nutrients to determine the extent of nutrient availability. It is recommended that a stream gage be installed and operated on Trott Brook in the future to better understand the watershed hydrology.

### 4.2.3 AUID summary

#### Stressor pathway discussion

The nature of the altered stream channel upstream of site 13UM044 is affecting the fate and transport of nutrients in the watershed. The drainage network appears to have changed the delivery of water and its associated pollutants.

#### Stressor conclusions

Low DO and daily fluctuations in DO concentrations are a main stressor to the biological communities in Trott Brook. Eutrophication evidenced by DO flux and TP eutrophication is a stressor. Based on qualitative data at 13UM044, this is due to extensive growth of periphyton and aquatic macrophytes in response to elevated TP concentrations. Habitat at the monitoring location scores very well and does not appear to impacting the biology. Altered hydrology does appear to be indirectly affecting the biology at the stream site through its effect on the fate and transport of nutrients in Trott Brook; however, there is only modeled data available to analyze for seasonal discharge patterns.

## 4.3. Tibbetts Brook (AUID 07010207-676; 677)

### 4.3.1. Biological communities

Tibbetts Brook has one biological sampling station (13UM088) located on AUID 07010207-676. The fish were sampled on 8/14/2013 and scored 31 points below the threshold (9 F-IBI with a threshold of 40). The macroinvertebrate sample was collected on 8/12/2013 at this station and scored 1 point above the threshold (passing). AUID 676 is impaired for fish only. Tibbetts Brook has one biological sampling station (13UM043) located on AUID 07010207-677. The fish were sampled on 6/18/2013 and scored 18 points above the threshold (60 F-IBI with a threshold of 42). The macroinvertebrate sample was collected on 8/13/2013 and scored a 22.8. This score is well below the threshold of 52 for a Northern Forest Streams Glide Pool Class 4 stream type. Twenty samples were collected using the QMH sampling protocol. Theses samples were evenly distributed between Aquatic macrophytes and snag woody debris samples. There was no rock or riffle habitat available to sample in the sampling reach. There is an active beaver dam located downstream of the sampling location. In 2015 station 13UM043 was resampled for macroinvertebrates and scored a 55. Both macroinvertebrate samples were collected under similar flow conditions (flow not perceptible). The difference in the two years M-IBI scores at station 13UM043 does not appear to be flow related or even habitat related as the downstream beaver dam was intact during both sampling events. There was a second site located on Tibbetts Brook that was sampled in 2007 only for fish. This site is 07UM081 and was located in the channelized section of Tibbetts Brook and scored a 22.8 for fish.

## 4.3.2. Data analysis/evaluation for each candidate cause

### Low dissolved oxygen

Continuous DO data was collected in August of 2015 to determine if low DO and DO flux were potentially causing problems in the stream. Figure 4.3-1 below shows the deployment data for DO. At times the DO does drop below the standard of 5 mg/L. The macroinvertebrate community has a Community DO index of 6.681 and falls within the 72 percentile for the community DO index within the class. All Class 4 macroinvertebrate sites were ranked by the DO Index score computed by MPCA (Chirhart). The scores were then ranked and placed in their respective quartiles based on the DO index score. This ranking can help explain how the macroinvertebrate community at the site is related to low DO conditions. If the ranking is below 25%, it would suggest that the stream has low DO as a stressor. If the ranking is above 75% low DO does not affect the macroinvertebrate community. The 72 percentile suggests that the macroinvertebrate community at 13UM043 is not affected by low DO conditions. The macroinvertebrate sample was dominated by physa and Ferrissia, along with several wetland taxa present. The fish scored very high and the MSHA score was good. The water levels were also low during the August 2013 sampling and the low macroinvertebrate score is believed to be caused by the beaver dam, low water conditions, and the wetland characteristics of this particular reach.

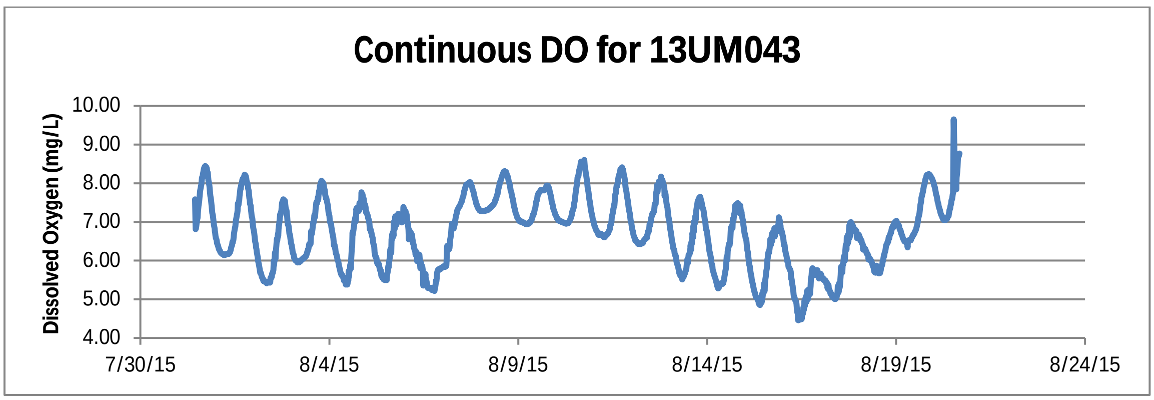



**Figure 4.3-1: YSIä continuous sonde data collected for DO from 8/1/2015 through 8/20/2015. Data shows concentrations and daily flux in DO.**

A number of macroinvertebrate metrics were analyzed to help us understand potential stressors to the macroinvertebrate community. Theses metrics are viewed against the stream class metric scores for streams that meet the M-IBI within that class. Since Tibbetts Brook is a Class 4 stream for macroinvertebrates the Class 4 metrics are used for comparison.

**Table 4.3-1: Tibbetts Brook macroinvertebrate metrics compared to the Class 4 metric averages of sites with passing MIBI scores. Yellow highlight shows metrics that indicate stress.**

| Site | Parameter | Index Score | % Tolerant Individuals | Taxa CountAllChir (DO related, expected lower if DO problem) | Statewide Class 4 Index Score | Expected Response | Statewide Class 4 % Tolerant Individuals | Expected Response |
|---|---|---|---|---|---|---|---|---|
| 13UM043 | DO | 6.68 | 7.33 | 29 (47.3) | 6.62 | Down | 22.9 | Up |
| 13UM043 | TSS | 2.4 | 10.33 | | 16.31 | Down | 25.4 | Up |
| 13UM043 | N | 0.05 | 44.67 | | 0.16 | Down | 34.17 | Up |

Table 4.3-1displays the macroinvertebrate metric data as compared to the class average of metrics that pass the M-IBI score. The DO data and the DO associated macroinvertebrate metrics suggest that low DO is not a stressor to the Tibbetts Brook macroinvertebrate community in AUID 677. If available DO was an issue the percentage of macroinvertebrates tolerant of low DO concentrations would be expected to be above the class average and at Tibbetts the low DO tolerant taxa were well below the class average. The percent tolerant of low DO at 13UM043 is 7.33 and the average percent tolerant is 22.9 for Class 4 streams.

The fish sample from 13UM088 in the upstream AUID 676 is 31 points below the threshold. The fish community indicates that low DO may be stressing the fish in this upstream reach. There is limited DO data from this AUID. On August 14, 2013, the DO was 7.05 at 1610 and 7.54 on August 12, 2013, at 1707. Both samples were collected late afternoon when DO would be expected to be at the daily peak. MPCA has computed community tolerance probability scores for each fish sample along with the paired DO reading. The individual fish are assigned a tolerance value and those tolerance values are then ranked and accumulated to assign a community score for the sampling site. The probability of 13UM088 meeting the DO standard is 26% based on the fish community sampled. There is not enough DO data to verify if this AUID has low DO; it is recommended that additional DO data be collected at site 13UM088.

### Elevated nutrients

Water chemistry samples were collected at Tibbetts Brook in 2013 and 2015. The majority of samples were collected for Total Phosphorus and appear to be below the river eutrophication standard most of the time (Figure 4.3-2).

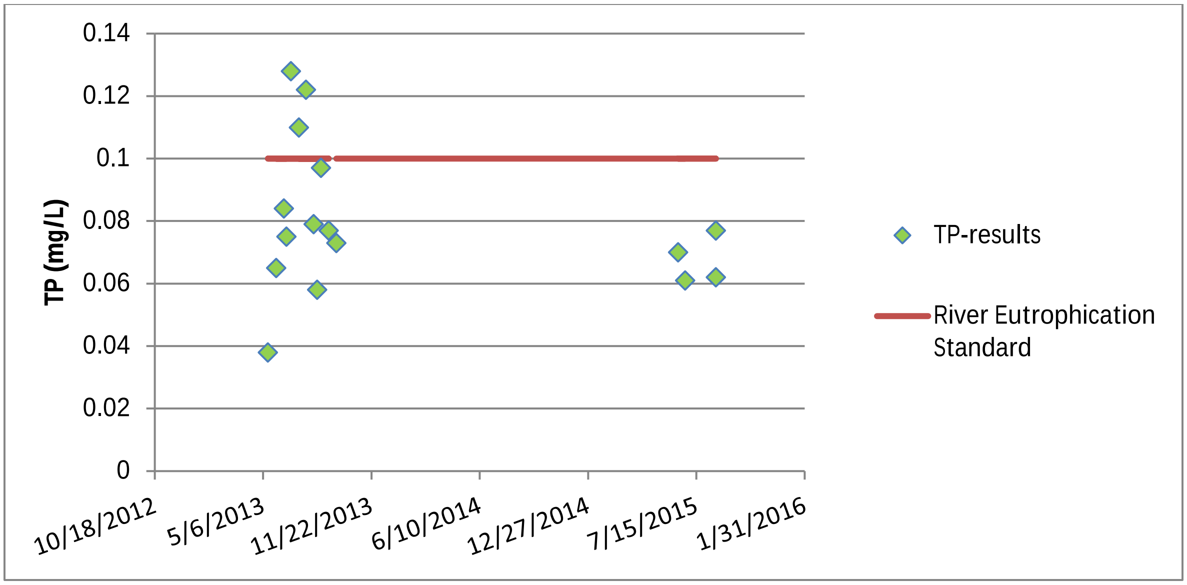



**Figure 4.3-2: Total Phosphorus data for Tibbetts Brook near biological station 13UM043.**

The three samples above the eutrophication standard were collected in late June through July of 2013. In 2015, samples were also collected in June and July and were below the standard. There does not appear to be a eutrophication issue but additional samples should be collected to further understand the transport of nutrients through the system. Daily DO flux would also be above 3.5 mg/L/day if eutrophication was evident. The daily DO flux seen in 2015 during the continuous sonde deployment was near 2.5 mg/L/day (Figure 4.3-1).

Nitrogen would likely be elevated if agricultural practices or septic systems were the cause of issues in the stream. The low number of nitrogen (nitrate + nitrite) samples cannot conclusively eliminate nitrogen as a stressor. The macroinvertebrate information from Table 4.3-1 suggests that nitrogen may be a stressor to the macroinvertebrate community. There is an elevated percentage of nitrogen tolerant individuals in the biological sample and the biological index score is much lower than the class average for stream passing the M-IBI. Additional nitrogen samples should be collected as the information is inconclusive at this time as to whether nitrogen is a stressor to the macroinvertebrate community.

### Lack of physical habitat

Tibbetts Brook at sampling location 13UM043 is impounded by beavers at the downstream portion of the reach. This impoundment may be having an effect on the quality and variability in habitat type available to the macroinvertebrates. The MSHA score is computed for all biological sampling locations and can be used as a reference point on what the available habitat is at the sampling location. Figure 4.3-3 displays the MSHA score for Tibbetts Brook along with the five categories that make up the score. The overall score is 27 which is poor at site 13UM088 and 64.8 at site 13UM043 which is good. All five categories score poorly at 13UM088 and the sum of these categories is used to generate an overall habitat assessment.

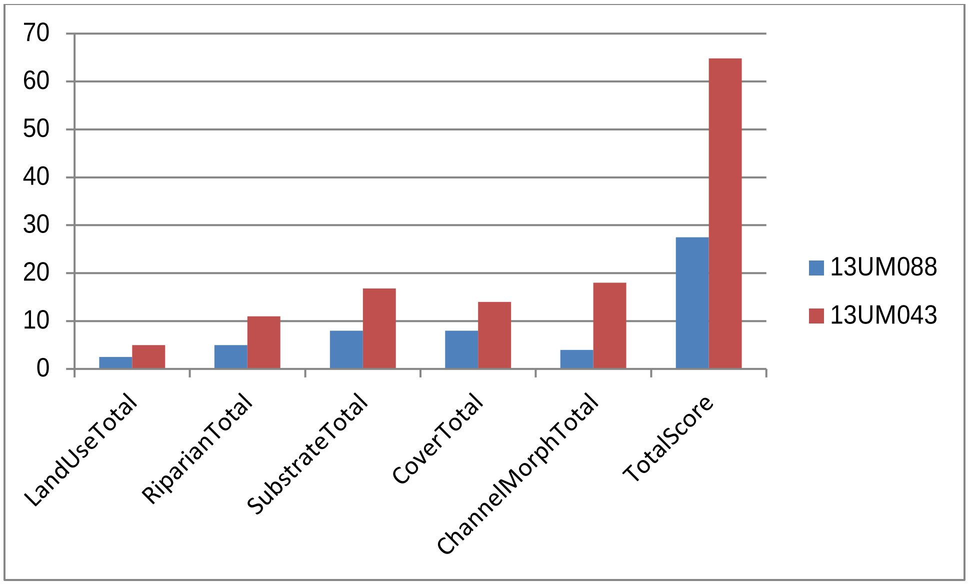



**Figure 4.3-3: The individual scores and the sum of the MSHA assessment conducted at 13UM043 in 2013. The overall score is poor for this class of stream and the lack of available habitat is a stressor to the macroinvertebrate community.**

Site 13UM043 appears to be impounded based on the comments during the sampling visit. These two photos in Figure 4.3-4 show low velocity water conditions during the sampling and arrowhead growing along the stream edge. This can be indicative of slow moving water and may explain why the macroinvertebrate sample was dominated by Physa sp.and Ferrissia sp. Both of these taxa are wetland taxa and the available habitat appears to be favorable for wetland taxa. The beaver dam is located just downstream of the biological station and can be seen in Figure 4.3-5 below. The nature of the impoundment and lack of habitat are main stressors to Tibbetts Brook. Site 13UM088 also had comments of below normal water levels during the fish visit on August 14, 2013. Habitat assessed at site 13UM088 indicates that 95% of the reach was run and only 5% was pool. The substrate was sand/silt and stream sinuosity was poor at this site. There are no riffles or coarse substrate material located at 13UM088 and the pool depths are shallow less than 2 times the run depth. The general lack of habitat is affecting the fish population at 13UM088.

Figure 4.3-4: Tibbetts Brook photos taken during the SID investigation at site 13UM043. Photos indicate not much flow velocity and stagnant water conditions. The site is impounded by a downstream beaver dam.

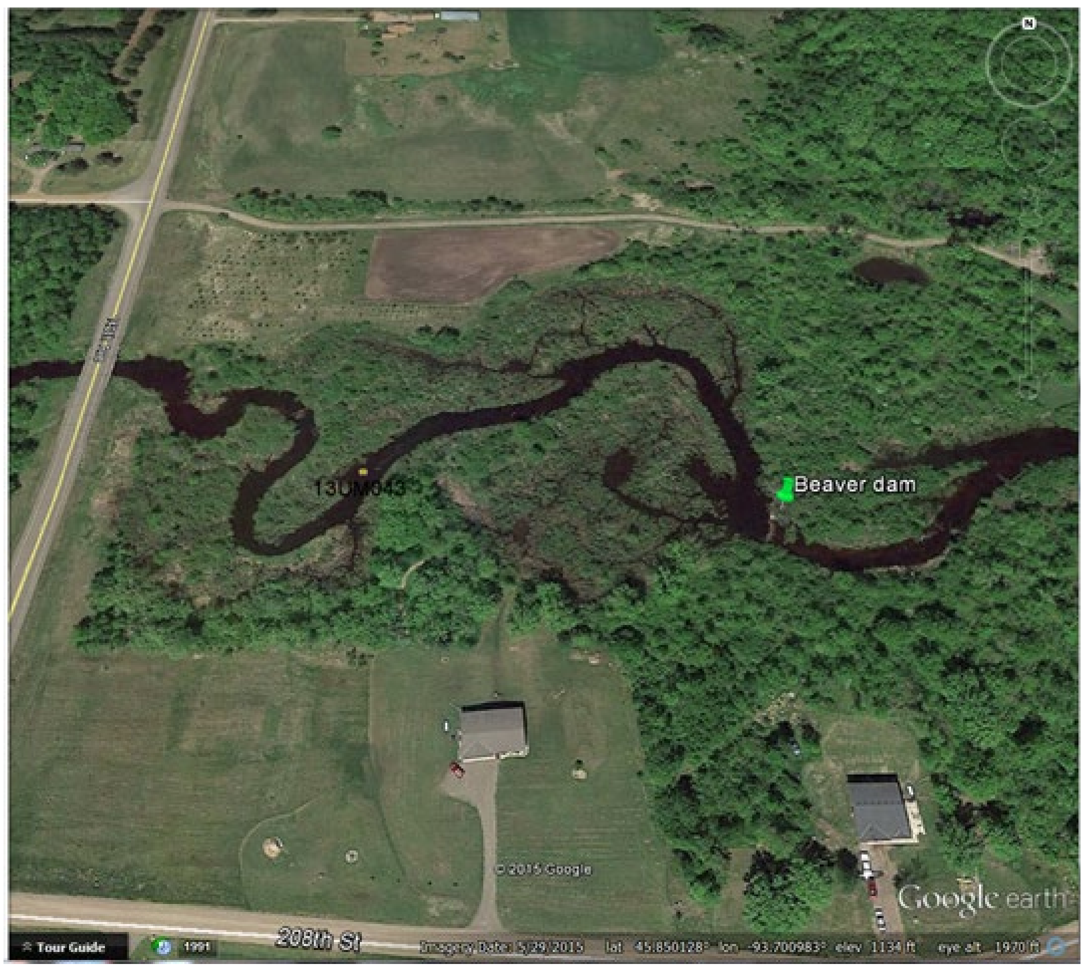



**Figure 4.3-5: Location of existing beaver dam on Tibbetts Brook which is affecting the available habitat for macroinvertebrates.**

### Altered hydrology

A stream gage was operated in Tibbetts Brook from 2013 through 2015. Stream stage was collected on a continuous 30-minute interval and discharge was calculated using a site specific rating curve. Figure 4.3-6 shows the continuous discharge record for Tibbetts Brook.

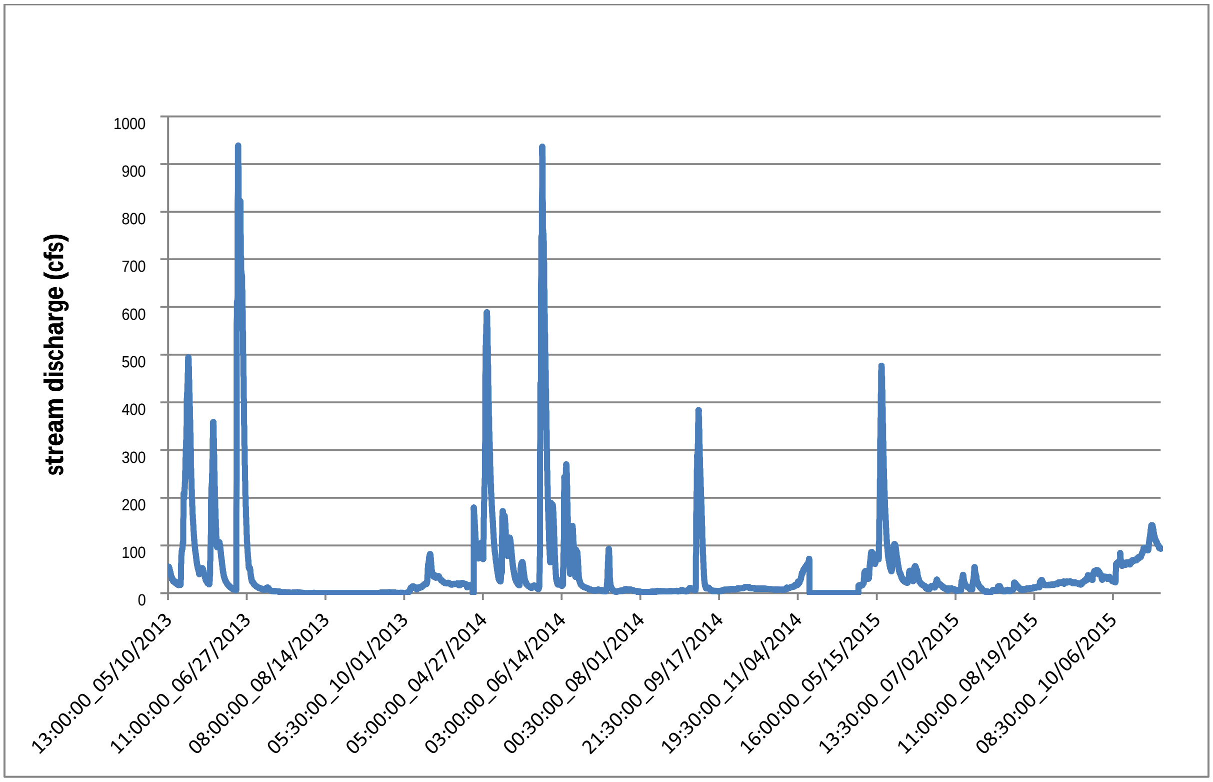



**Figure 4.3-6: Continuous discharge for Tibbets Brook from 2013-1015.**

During the 3-year period stream discharge was greatly reduced during the late summer months. In the late summer months discharge is reduced; however, in 2013 discharge was very low (below 0.5cfs) and in 2014 and 2015 there was increased late summer discharge. A lack of baseflow is causing stress on the macroinvertebrate community in 2013. In 2015 the discharge during the macroinvertebrate sample had improved and the corresponding MIBI was also improved (55.4) which is above the threshold for Class 4 streams. The low flow conditions sampled in 2013 affected the M-IBI score at 13UM043.

A review of the Hydrological Simulation Program – FORTRAN (HSPF) modeling results for hydrology in Tibbetts Brook (Reach 173) shows that discharge is below 1 cfs for 17% of the modeled daily flow record and less than 0.5 cfs for 8.7% of the record. The HSPF model was built for years 1996 through 2009, and can be used as a means of analyzing hydrologic patterns during this time frame. The results from the model show that the months of August and September routinely have flow periods that are very low and can occur for extended periods of time. Based on the 3-year gage record and the HSPF model results, flows are routinely very low during the late summer months and would affect the available habitat and the biology associated with that habitat.

### 4.3.3. AUID summary

#### Stressor pathway discussion

Almost the entire Tibbetts Brook AUID is natural channel. There are tributaries that are channelized that drain into Tibbetts Brook. There are multiple active beaver dams located on the stream that were identified using Google earth and by analysis of the May 29, 2015, aerial image. The upstream portion of the stream has multiple cattle pasture operations which are showing signs of limited riparian cover, potential for high nutrient export and a source of bacteria. This delivery system needs additional sampling to determine if the upstream sources are potentially impacting the macroinvertebrate community via nitrogen export.

#### Stressor conclusions

The lack of habitat variability and the impoundment caused by the beaver dam downstream of the sampling location is stressing the macroinvertebrate community. Low DO is not a stressor and while there are elevated TP values, eutrophication as a stressor is considered inconclusive. Additional water quality samples should be collected to determine in nitrogen is a stressor to the macroinvertebrate community. Altered hydrology is a stressor in Tibbetts Brook. The low flow conditions documented in 2013 help to explain the poor M-IBI score at site 13UM043 and also the poor fish score at 13UM088. In 2015, when flow conditions were near normal the MIBI at 13UM043 was above the threshold. Fish were not resampled at 13UM088 in 2015. The low IBI score at 13UM088 is also being affected by a lack of habitat as seen by the shallow pools and the general lack of pools in the reach. The substrate at this site is sand/silt and lacks and rock substrate. The MSHA score is poor and all categories for the MSHA score poorly at 13UM088.

## 4.4. West Branch Rum River (AUID 07010207-525)

### 4.4.1. Biological communities

The West Branch of the Rum River has one biological station (13UM048) located on AUID 525. This site passes the fish IBI, scoring 27 points above the Fish Index of Biological Integrity (F-IBI) threshold (74). The macroinvertebrate sample was 34.9 which is 2 points below the MIBI threshold of 37.

### 4.4.2. Data analysis/evaluation for each candidate cause

#### Low dissolved oxygen

Low DO can be a source of stress to aquatic communities. In 2015 a YSIä sonde was deployed from August 5 through August 22. Neither DO flux nor low DO was an issue during this deployment. The DO metrics for the macroinvertebrate community were also reviewed. The macroinvertebrate community taxa information is listed below and shows that the macroinvertebrate community is not stressed by low DO. The tolerance indicator values were reviewed and compared against statewide average for class 5 streams meeting the M-IBI.

**Table 4.4-1: Site 13UM048 macroinvertebrate metrics in relation to Class 5 metrics of sites that pass the MIBI. Yellow highlight shows metrics that indicate stress.**

| Site ID | Parameter | Index Score | Class 5 statewide average Index Score meeting MIBI | Expected Response | # Intolerant Taxa | # Tolerant Individuals | % Tolerant Individuals | Class 5 statewide average meeting MIBI (% Tolerant Individuals) | Expected Response |
|---|---|---|---|---|---|---|---|---|---|
| 13UM048 | DO | 7.43 | 7.23 | Down | 9 | 4 | 2.5 | 9.52 | Up |
| 13UM048 | TSS | 5.6 | 16.38 | Down | 1 | 11 | 30.2 | 25.92 | Up |
| 13UM048 | N | 0.73 | 5.29 | Down | 3 | 19 | 70.5 | 64.13 | Up |

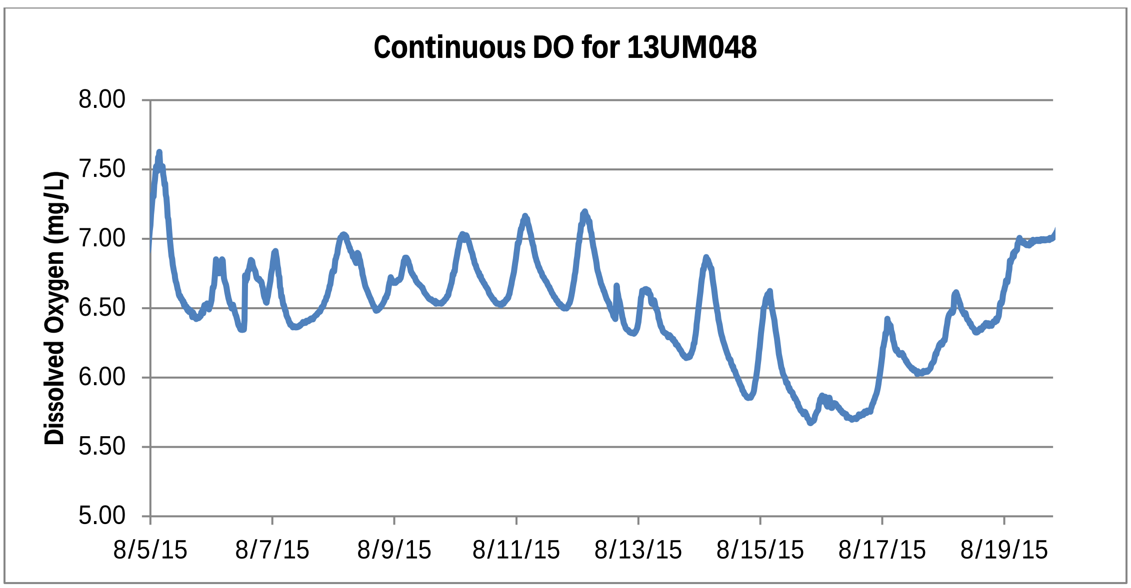



**Figure 4.4-1: Continuous DO data collected on the West Branch Rum River from August 4, 2015 through August 22, 2015. Sonde was deployed to record the daily minimum DO concentrations and compute daily DO flux.**

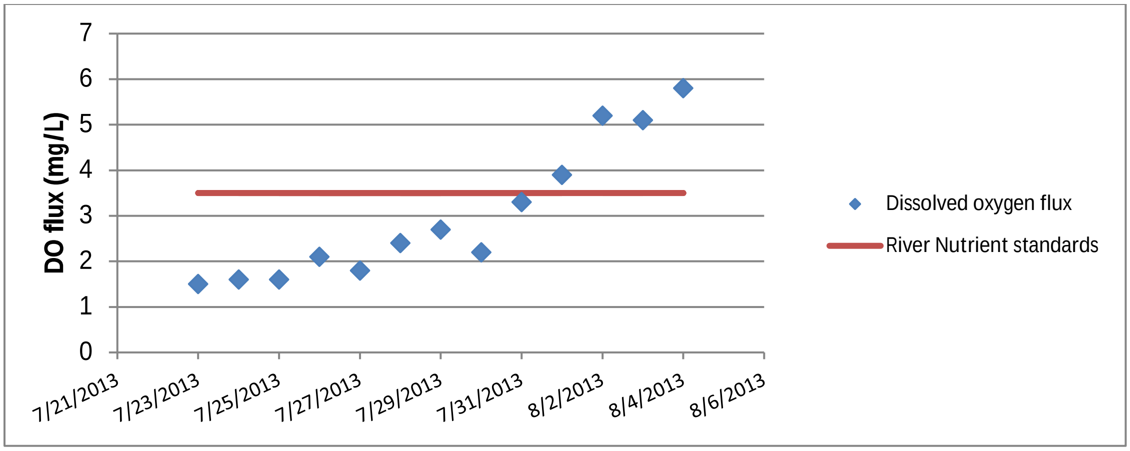



**Figure 4.4-2: Daily DO flux calculated from YSIä continuous sonde readings. The DO flux is the difference between the daily maximum and minimum DO readings. Flow was very low during the August 2013 period. It is believed that the increase in DO flux in August is due to a lack of aeration from riffles and the DO flux increases due to night time low DO readings.**

### Elevated nutrients

TP levels are high at times but there does not appear to be elevated Chlorophyll-*a* (Chl-*a*) concentrations. There is a response with abnormally high DO flux late in the 2013 season. This also corresponds to very low flow conditions. On August 1 the flow dropped below 18 cfs. At the beginning of the continuous DO record from July 23, 2016, the stream discharge was at 28 cfs and on July 15, 2013, discharge was 98 cfs. This rapid decline in discharge could allow for some algal growth that is not seen during sampling events for water chemistry. During normal flow conditions the stream has adequate riffles that should reaerate the stream and stabilize the DO concentrations. On July 23, 2013, the TP concentration was 101µg/L which is at the 100 µg/L standard. On June 22, 2013, and July 11, 2013, the TP concentrations were 171 µg/L, which is above the standard of 100 µg/L. The Eutrophication standard needs a secondary response variable of DO flux, which during the July 2013 period is well below 3.5 mg/L/day (the daily flux standard). The elevated TP concentrations are directly tied to stream flow and when stream flow is normal or above the DO flux appears to be low. Eutrophication could be causing stress on the macroinvertebrate community.

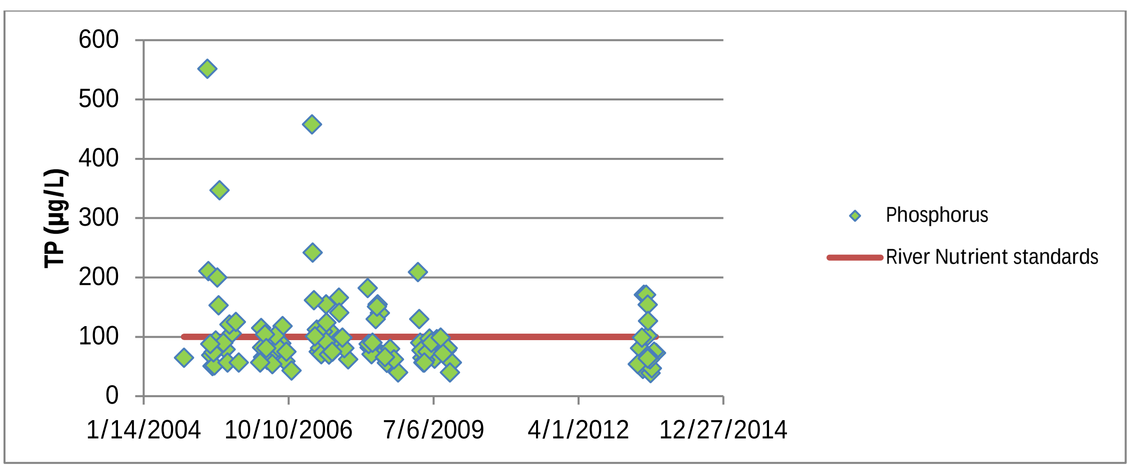



**Figure 4.4-3: Total phosphorus sample concentrations collected from the west Branch Rum River. Samples were collected between October 2004 and September 2013.**

Stream flow was evaluated against TP concentrations to see if TP is related to stream discharge. There is a weak relationship as seen in Figure 4.4-4. This relationship shows an increase in TP concentrations based on discharge but the one caveat is that TP is elevated following prolonged higher flows such as after heavy rain events. This also indicates that the elevated TP concentrations are coming from watershed runoff via overland flow. Figure 4.4-5 displays the May 1 through August 31, 2013, TP samples and the associated stream hydrograph location of the samples. The highest TP concentrations are associated at or near the peak discharge points.

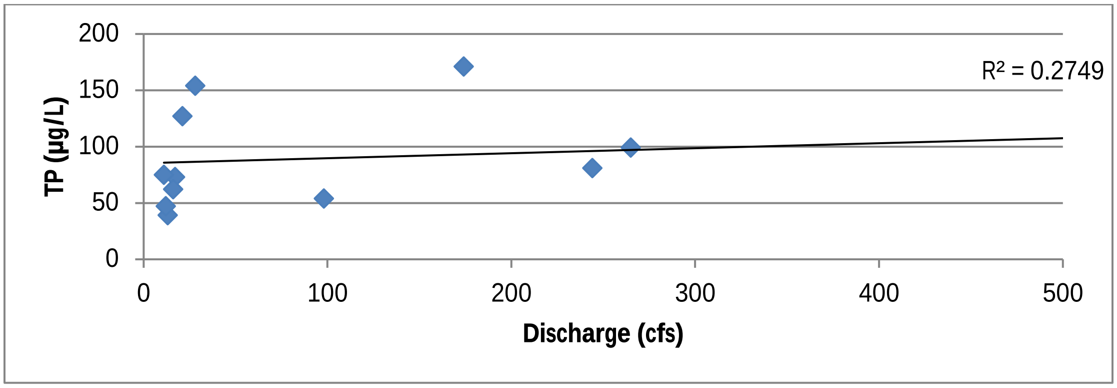



**Figure 4.4-4: TP concentrations plotted against paired discharge measurements. Stream TP concentrations are related to discharge.**

A small number of nitrogen samples were collected in 2015 to better understand the role that nitrogen is having on the stream ecosystem. The three nitrate/nitrite samples that were collected were elevated (minimum of 0.21, maximum of 0.51 and mean of 0.4 mg/L). These values are elevated but not high when compared to other areas of the state. However, the macroinvertebrate community is showing signs of nitrogen stress. The nitrogen based metrics when compared to Class 5 metrics for M-IBI passing stream sites all indicate stress (Table 4.4-1 above). Additional water quality samples for nitrogen parameters should be collected. This will help determine if nitrogen is inhibiting the macroinvertebrate community.

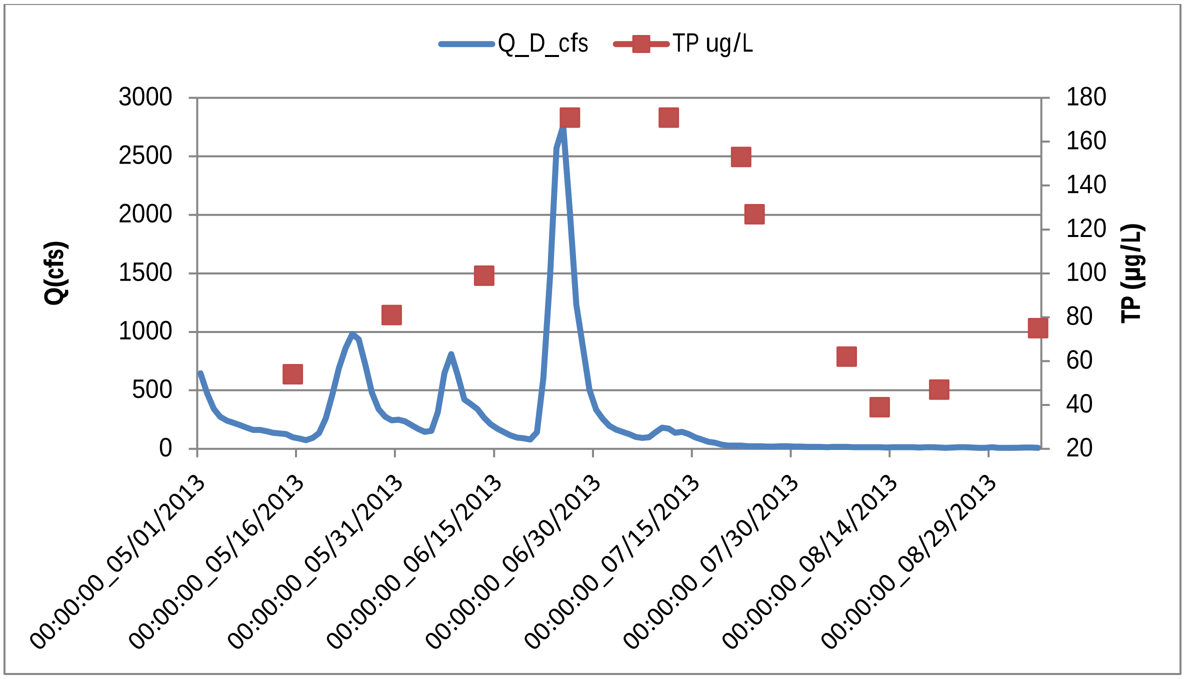



**Figure 4.4-5: Daily discharge data from West Branch Rum River from May 1, through August 31, 2013. The stream is very flashy and does not retain base flow very long. TP concentrations are plotted against stream discharge.**

### Lack of physical habitat

Site 13UM048 had two visits for biological sampling where MSHA scores were calculated. The MSHA scores are a standardized measure of five main habitat features that are summed to calculate a total score. This score is then viewed as poor, fair or good. Both MSHA scores at 13UM048 were good. The two subcategories of substrate and channel morphology both scored excellent (Figure 4.4-6).

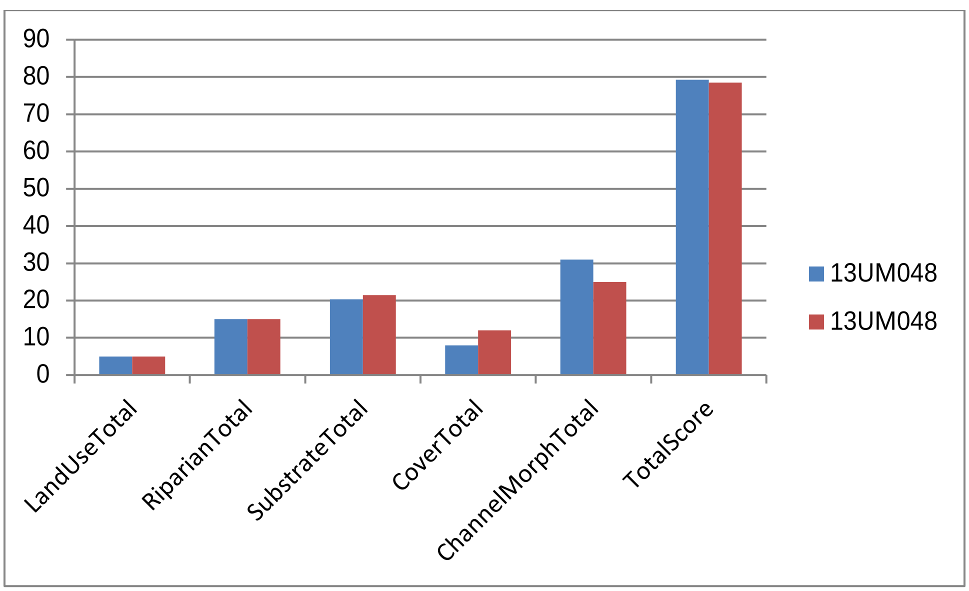



**Figure 4.4-6: MSHA scores for site 13UM048 on the West Branch Rum River.**

Habitat does not appear to be limiting the biology at 13UM048. The fish community scored very well. The macroinvertebrates were below the threshold by 2 points (34.9 score and a 37 threshold). The EPT taxa had 15 species and represented 39% of the sample. The invert sample had several sensitive Ephemeroptera taxa present. The qualitative multi-habitat (QMH) sample method was used for macroinvertebrate sampling. The sampling method consists of collecting 20 samples that are aggregated into one composite sample. Of the 20 samples, 10 were collected in rock/riffle and 10 were collected from woody debris. Pictures from the site show some undercut banks that were possibly dry during the macroinvertebrate sampling event on August 19, 2013. The stream flow was low during macroinvertebrate sampling which may have limited some of the available habitat in the stream channel.

**Picture 1: West Branch Rum River during the macroinvertebrate sampling visit on August 19, 2013. Stream flow was very low and some of the habitat features appear dry.**

### Altered hydrology

Flow gaging was conducted on the West Branch Rum River from 2004 through 2014.

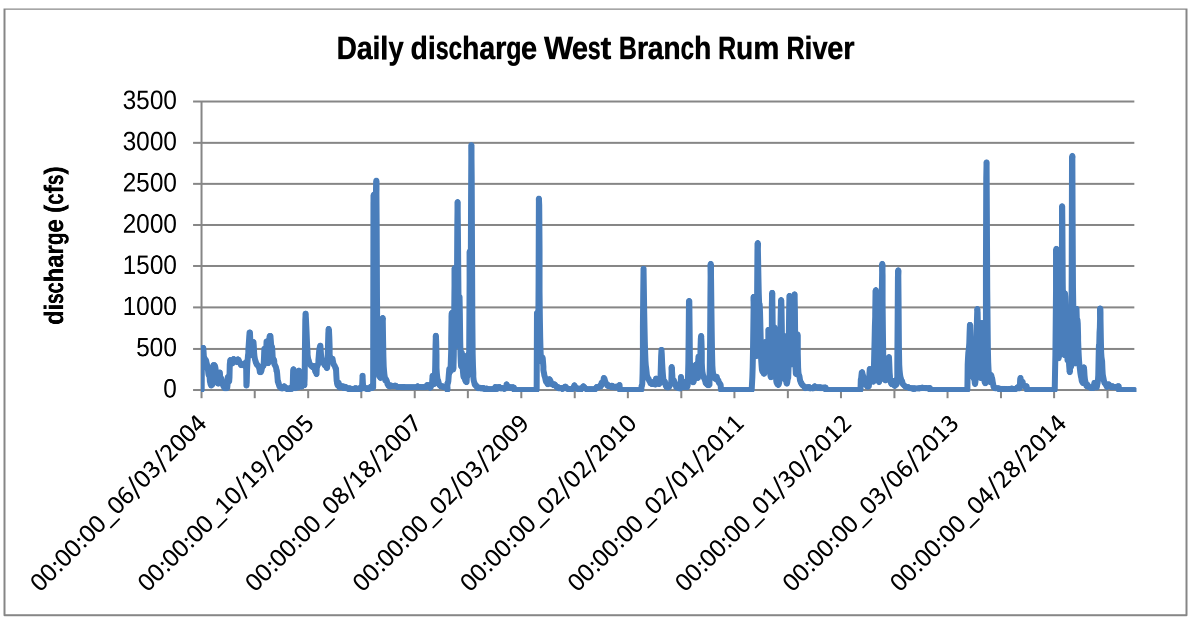



**Figure 4.4-7: Daily discharge record for west Branch Rum River. Data starts in 2004 and continues through 2014. Discharge during August of 2013 was very low when compared to early summer periods.**

Discharge appears to be variable during the seasons. Early summer when June rains are plentiful the stream discharge is high and as summer progresses stream discharge drops off suddenly when precipitation is absent. This suggests that the water storage capacity in the watershed is reduced and that possibly the amount of wetland storage has been minimized as a result of wetland loss. On August 19, 2013, the stream discharge was 13 cfs. On June 25, 2013, discharge was 2760 cfs (Figure 4.4-5).

Review of the altered water course Arc GIS layer shows that the tributaries leading into the West Branch Rum River have been heavily channelized. This channelization may be impacting the timing of surface runoff and the delivery of that runoff. The channelized stream reaches are probably causing the runoff to move into the West Branch Rum River at a faster rate which is causing the increased peak discharges and the lack of baseflow after precipitation events pass. The high density of cultivated fields in this HUC 12 is also playing a role in loss of stream baseflow through plant transpiration. As the row crops become more mature the plants are up taking high percentages of the precipitation and not allowing any water to recharge the stream baseflow. Figure 4.4-8below shows the channelized streams in red along with the 2011 land use upstream of Princeton.

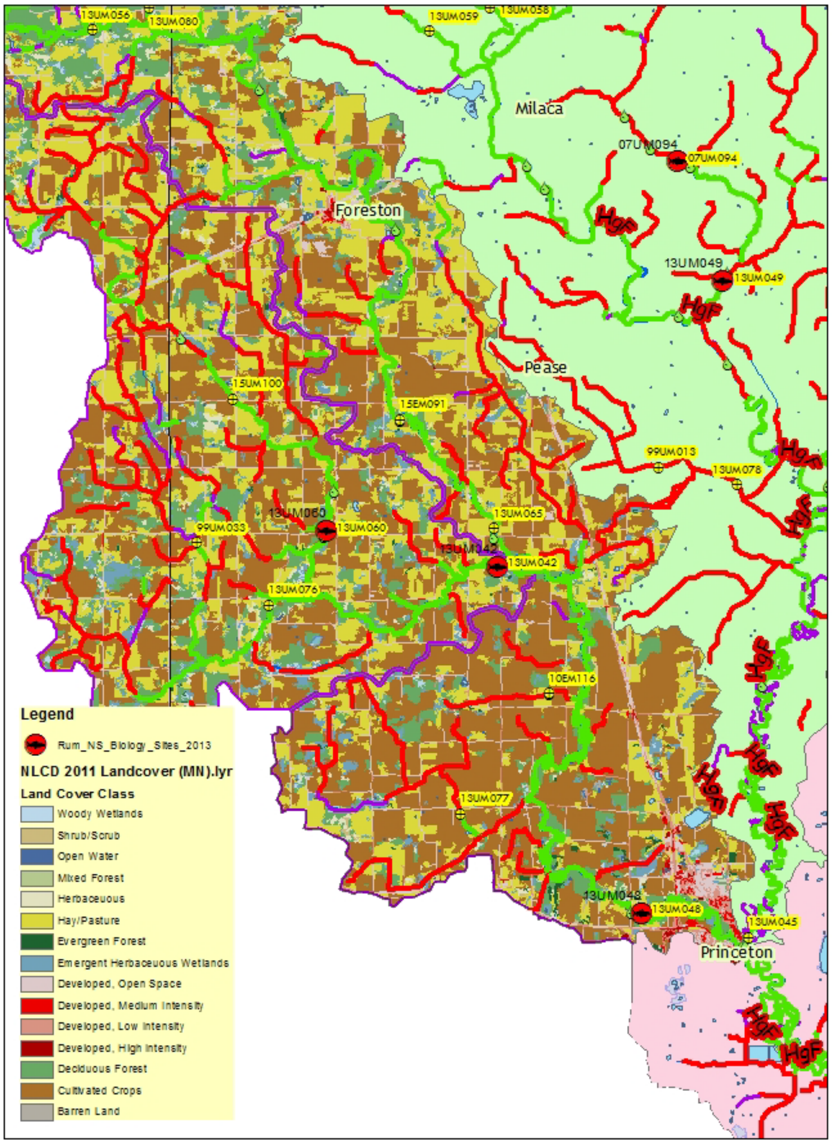



**Figure 4.4-8: West branch Rum River showing stream channel conditions and 2011 land use. Red lines indicate channelized streams and green lines are natural stream channels. Brown polygons are for cultivated row crops.**

## 4.4.3. AUID summary

### Stressor pathway discussion

The riparian corridor is mostly wooded; however, there are agricultural fields (43% of watershed) and 23% of the stream is channelized in the watershed. The channelization can move water and chemicals through the stream system at an accelerated rate. As the agricultural plants mature water is consumed at rates different than native vegetation. This can also impact the amount of precipitation that is available for stream flow. During periods of active growth, a percentage of the rainfall is up taken by row crops and the stream baseflow is diminished.

**Stressor conclusions**

Eutrophication caused by elevated total phosphorus may be causing stress to the macroinvertebrate communities. Altered hydrology is also causing stress to the macroinvertebrate community. At low flow conditions some of the available macroinvertebrate habitat is left dry and a loss of that habitat may be in part why the M-IBI scores below the threshold.

## 4.5. Tributary to West Branch of Rum (AUID 07010207-667)

### 4.5.1. Biological communities

Unnamed Creek is a tributary to the West Branch of the Rum River and has one biological sampling site (13UM075) located within the Assessment Unit Identification (AUID). Two fish visits were conducted at the site and both passed the F-IBI with a score of 49 and 61 but failed the M-IBI with a score of 34.4 with a threshold of 53. The entire AUID is channelized but the reach that was sampled along 380 Avenue has some stream features with quality habitat present. The invertebrate sample was collected August 13, 2013. The notes indicate that flow was very low during the macroinvertebrate sampling event and the banks were difficult to sample as most of the overhanging vegetation was out of the water. There were sparse submerged macrophytes in the channel and along the bank and sparse filamentous algae in the stream channel. The drainage area for this AUID is very small at 6.78 square miles. The ditch may experience extended periods of low or no flow late in the summer as precipitation lessens and plant transpiration increases. The fish community was dominated by pearl dace which is a species that is sensitive to human disturbance. Nine fish taxa were present during the August 12, 2013, fish visit and six taxa were present during the June 18, 2013, fish visit. The August 12, 2013, fish visit shows there is still ample flow in the stream.

**Picture 2: Station 13UM075; August 12, 2013 fish visit showing stream conditions during sampling**

### 4.5.2. Data analysis/evaluation for each candidate cause

**Low dissolved oxygen (DO)**

Low DO can have a negative impact on the biological communities in aquatic systems. The standard for DO is 5 mg/L and when DO drops below this level aquatic biology can be stressed. There is limited DO data collected at 13UM075. Two instantaneous DO data points were collected during the fish visits (7.99

and 11.46 mg/L). A YSIä sonde was deployed on July 30, 2015, and recorded at 15 minute intervals until August 19, 2015. Figure 4.5-1 displays the continuous DO and stream temperature during the sonde deployment in 2015.

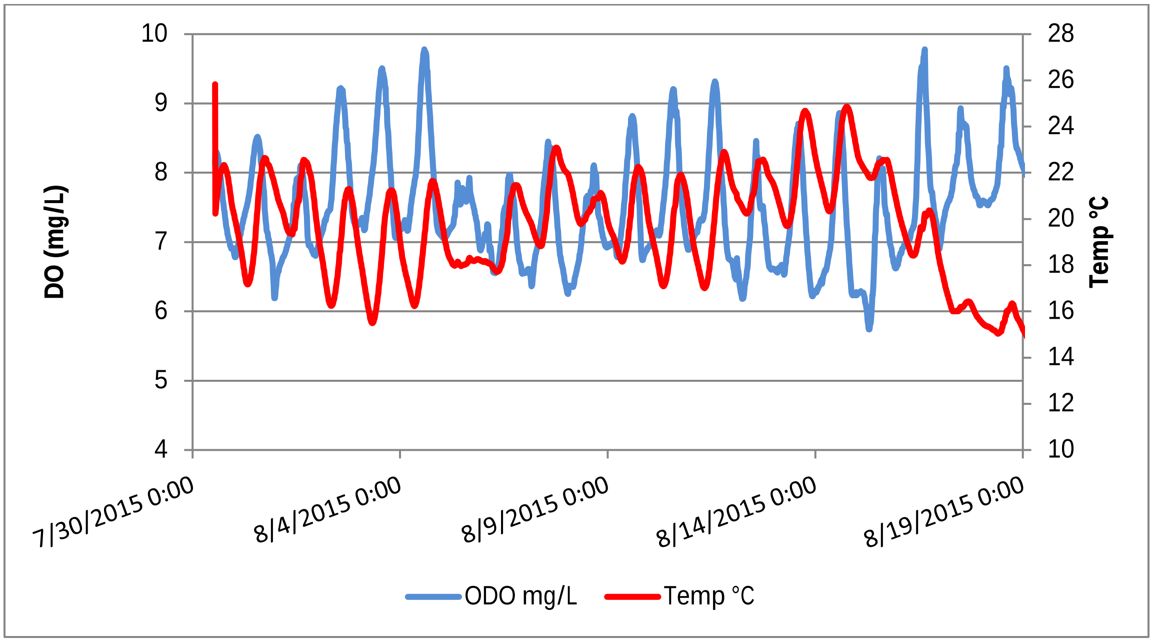



**Figure 4.5-1: A YSIä sonde was deployed at 13UM075 for 20 days. Data was collected at 15 minute intervals.**

The deployed sonde shows that the daily minimum DO concentrations never drop below the 5 mg/L standard. During this deployment there were no periods of low DO. Biological metrics that look at low DO as a possible stressor were also analyzed for this site. The macroinvertebrate data suggests that low DO is not a problem at 13UM075. The macroinvertebrates were compared against the Class 3 macroinvertebrate metric scores for sites passing the M-IBI. The DO index score and the percent low DO tolerant taxa were within the range of Class 3 sites that pass the M-IBI (Table 4.5-2). This suggests that low DO is not affecting the macroinvertebrates. The fish community TVI shows a slightly different story. Based on the fish community sampled, there is an 80% chance of the stream not meeting the DO standard. This can be explained by the wetland tolerant taxa that dominate the fish community. These fish species can do well with low DO or good DO concentrations.

Low DO does not appear to be a stressor in this AUID.

### Elevated nutrients

Eutrophication can cause a change in the stream food web by elevating the growth of algae, periphyton or submerged aquatic macrophytes. Nutrients such as phosphorus and nitrogen are the cause of eutrophication. The data shows that the TP concentrations are below the 0.10 mg/L standard. Phosphorus is considered problematic when it exceeds 0.100 mg/L in Central Minnesota streams. There is a very limited dataset at 13UM075 for phosphorus concentrations. Currently there is not a state standard for nitrate except the 10 mg/L drinking water standard. Table 4.5-1 below displays the nutrient and total suspended solids data collected during 2013 and 2015. Nitrogen concentrations are elevated but below 1 mg/L.

**Table 4.5-1: Water quality sample concentrations collected at 13UM075.**

| STATION_ID | START_DATE | TP-Results | NOx-results | Chl-a | VSS | TSS |
|---|---|---|---|---|---|---|
| 13UM075 | 6/18/2013 | 0.062 | 0.40 | | | 5.6 |
| 13UM075 | 8/12/2013 | 0.065 | 0.9 | | | 14 |
| 13UM075 | 8/20/2015 | 0.048 | 0.39 | 4.32 | 1.6 | 3.2 |
| 13UM075 | 6/11/2015 | 0.082 | 0.25 | | | |

The small dataset does not include elevated TP concentrations. The average DO flux during deployment was 2.17 mg/L per day. This is below the response variable concentration for eutrophication. If phosphorus was elevated above the 0.100 mg/L standard there would be an expected response of increased Chl-*a* concentrations in the stream or a daily flux in DO greater than 3.5 mg/L/day. The data that is available for this stream suggests that phosphorus driven eutrophication is not a stressor to the biology.

Nitrate and nitrite forms of nitrogen can adversely affect macroinvertebrate communities directly through toxicity. The four data points that were observed at 13UM075 are all slightly elevated and may be impacting the macroinvertebrate community. Review of a select group of macroinvertebrate metrics compared to the Class 3 average for passing M-IBI sites reveals that nitrogen may be inhibiting the macroinvertebrate community.

**Table 4.5-2: Macroinvertebrate metrics at site 13UM075 compared to metrics at Class 3 macroinvertebrate sites that pass the MIBI.**

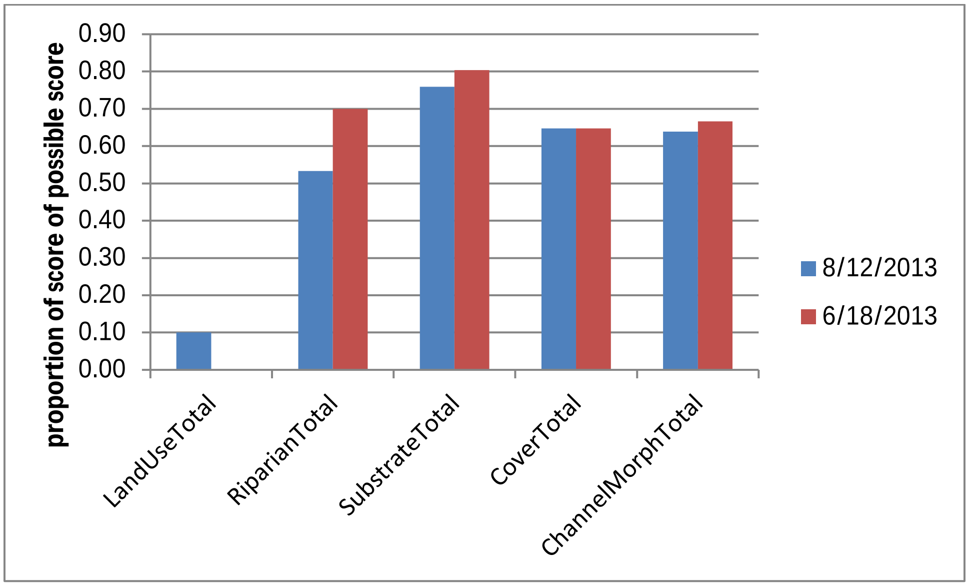
| | Parameter | Index score | % Tolerant taxa | HBI_MN | Class 3 HBI_MN | Class 3 Index Score | Class 3 % Tolerant Taxa |
|---|---|---|---|---|---|---|---|
| 13UM075 | DO | 7.11 | 5.88 | 7.60 | 5.8 up | 7.05 down | 9.8 up |
| 13UM075 | TSS | 9.8 | 32.50 | | | 16.3 down | 25.63 up |
| 13UM075 | N | 0.65 | 65.63 | | | 0.23 down | 36.13 up |

The yellow highlighted metric scores are scores that are identified as having failed to meet the passing M-IBI score range. The high percentage of nitrogen tolerant macroinvertebrate taxa may indicate that the macroinvertebrate community is shifting to a nitrogen tolerant community. Some of the nitrogen sensitive species may be missing due to the elevated concentrations of nitrogen. At this time there is not enough information to conclude that nitrogen is a stressor and additional water quality samples should be collected and analyzed for nutrient concentrations.

### Lack of physical habitat

The MSHA is the main method used to assess habitat condition at the biological monitoring sites. An MSHA score below 45 is considered poor and a score above 66 is considered good. During the two fish visits at site 13UM075, the MSHA scored a 61 and a 67. Considering that this stream reach is located in a public ditch the habitat is excellent and the biological communities reflect that. The fish during both visits scored very well. Figure 4.5-3 below shows the proportion of the site score as against the total possible score for each of the five categories that are summed to calculate the MSHA.

**Table 4.5-3: Site 13UM075 MSHA proportion of site score against the total possible score for each category. The higher the proportion the better the category scored. Note substrate scores very well.**




The only MSHA category that did not score well during the 2013 visits was land use. This category scored poorly due to the nature of agricultural fields in the upstream watershed. Habitat does appear to be affecting the macroinvertebrate community at this time. Biological metrics can be used as a means of explaining the biological response to a stressor. There is a relationship with clinging taxa of macroinvertebrates and habitat. If macroinvertebrate taxa that represent the clinger group are lower than expected there may be a habitat feature that is missing. The clinger taxa richness at site 13UM075 is 12 which are slightly lower than the Class 3 clinger average in the Rum River Watershed which is 14.5. Also an increase in the dominant two species of macroinvertebrates in the sample can reflect a decrease in habitat that is available. When reviewing the dominant two taxa relative percentages as (DomTwoChAs1Pct); site 13UM075 has a relative percent of 79.6 while the Class 3 average for this metric is 45.08%. This increase in relative percent can be indicative of habitat as a stressor. Since this is a county ditch there is a chance that a cleanout may be proposed. Currently the fish community is strong and a cleanout would negatively affect this community.

### Altered hydrology

Since this is a county ditch system the upstream watershed has been designed not to store a lot of water. This lack of storage is probably affecting stream base flow during periods of low precipitation. The notes from the August 13, 2013, macroinvertebrate sample state that the water is low and portions of the macroinvertebrate habitat were dry. This is probably an ongoing issue late in the summer months and will continue as long as the drainage network is maintained. There is no gage data at this site so the annual stream flow pattern cannot be reviewed. Figure 4.5-2 below shows the condition of the channel and the drainage network.

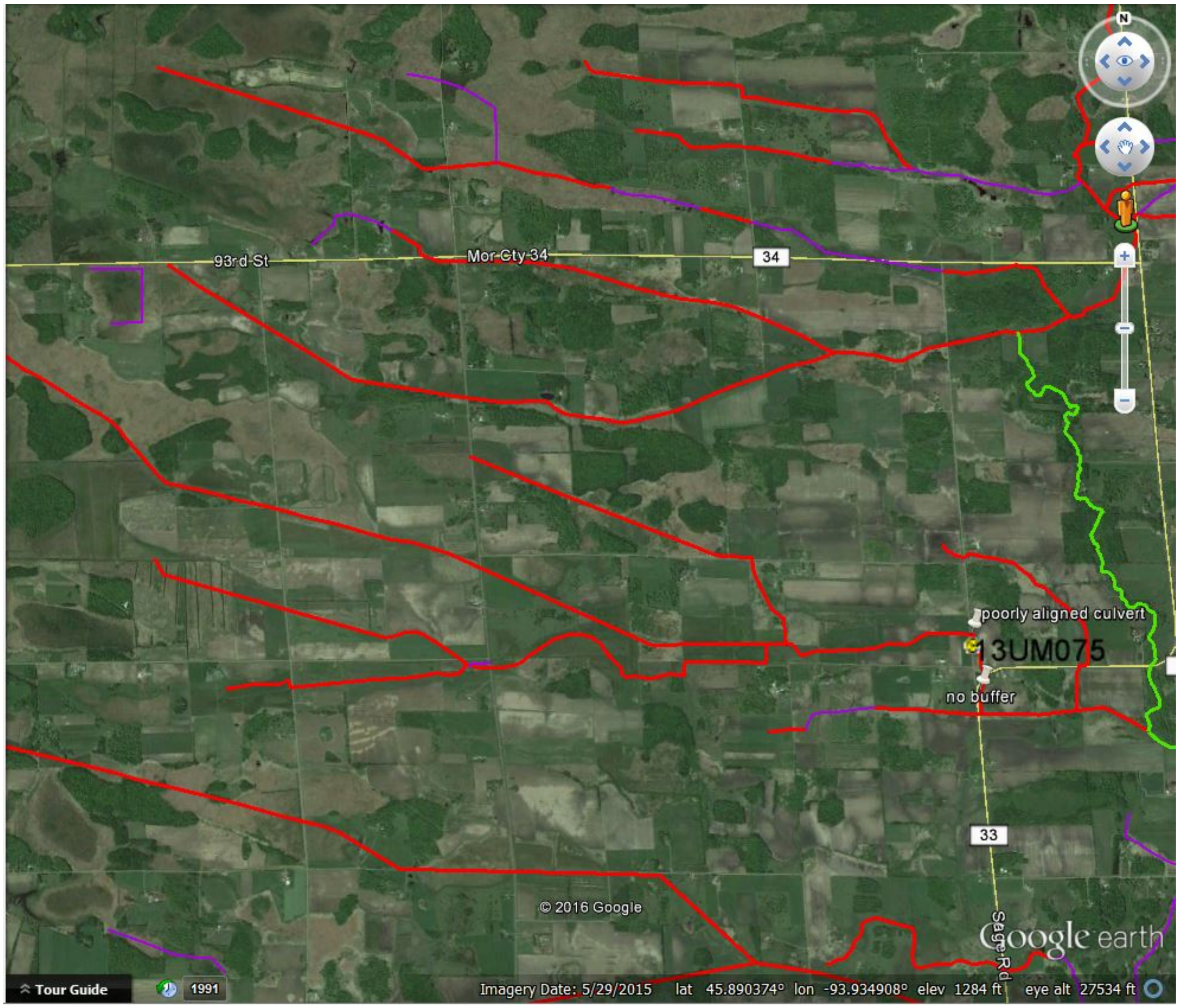



**Figure 4.5-2: Tributary to West Branch Rum River drainage network. Red lines show altered watercourse and green lines show natural channel.**

A Hydrological Simulation Program – FORTRAN (HSPF) model was built for the Rum River Watershed (RRW) using data from 1996 through 2009. The model showed that at reach 231, which coincide with AUID 667, flows are very low during the summer months. Flows of less than 1 cfs were analyzed and determined to be low enough to affect the biological communities at this reach. Flows of less than 1 cfs occurred 42% of the model run and flows less than 0.5 cfs occurred 30% of the modeled timeframe. Also the most common months that flows were below 1 cfs were in August and September in the modeled prediction. With the model showing that August and September are generally very low in stream discharge there would be a direct correlation to the macroinvertebrate community. With very limited or in some cases no flow the macroinvertebrate community would have lost and clinger species and species associated with flow velocity and coarse substrates. Habitat availability would also be affected by low stream discharge or near dry conditions.

The HSPF model showed that the mean daily discharge for reach 231 is 5.39 cfs during the 13-year modeled period. Looking at discharge that is 10 times higher than the mean annual discharge may reveal some patterns and frequency of high flow events in this AUID, using 54 cfs as a high flow benchmark the model showed that flows were above this level for 1.5% of the modeled period. Nearly all of these higher flows occurred in the spring months of the record. The modeled hygrograph shows a typical drainage network pattern where high flows occur in the spring and early summer followed by a slow dry out period in late summer which leads to increased flow in late fall as precipitation increases in October and November. The drainage network has changed the rate and delivery timing of stream flow. Water is moving through the system at an accelerated rate. The frequent peak flows and periods of prolonged low flow is having an effect on the macroinvertebrate community. Site 13UM075 was dry during the 2012 fall reconnaissance visit. The documented lack of flow at various times of the year and the potential for reduced surface water storage on the landscape would suggest that altered hydrology is a stressor to the macroinvertebrate community.

### 4.5.3. AUID summary

**Stressor pathway discussion**

The nutrients along with other unknown pollutants are being delivered through this system at an accelerated rate due to the tile network and channelization that has occurred.

**Stressor conclusions**

The main stressor to the macroinvertebrate community is altered hydrology and a lack of habitat. The entire drainage system is a county ditch and is designed to transport water off the landscape. Currently the fish community is doing well; however, the macroinvertebrates are experiencing a loss of habitat due to periodic low flow conditions within the channel. Low DO does not appear to be affecting the biology and eutrophication in the form of TP and its associated response variables are not affecting the biology; however, the dataset is limited and the 2015 flows were higher than the 2013 flows during sampling in the late summer. Nitrogen is elevated and may be affecting the macroinvertebrate community; however, there is not enough information at this time to make a conclusion. Additional water quality samples should be collected to determine the seasonal concentrations of nutrients and the relationship of nutrient transport at various flow regimes.

## 4.6. Vondell Brook (AUID 07010207-567 and 687)

### 4.6.1. Biological communities

Vondell Brook has two biological stations located on two Assessment Unit Identifications AUIDs. Biological site 13UM049 is located in the lower portion of the watershed and biological site 07UM094 is located in the middle of the stream just east of the city of Milaca. Both sites were assessed as general use streams based on natural stream characteristics at 13UM049 and habitat of sufficient quality at 07UM094. The fish scored were sampled twice at 13UM049 and scored a 36 and 40 with a threshold of 42, and one fish sample from 07UM094 which scored a 36 with a threshold of 42. The macroinvertebrates were sampled once at 13UM049 and scored a 63.5 with a threshold of 51.

MPCA has created a Tolerance Value Index based of fish community traits from each site sampled. These fish community TVIs can be used as a means of assessing two main stressors to the fish community. The community TVIs for Vondell Brook show that TSS does not appear to a stressor and low DO may be impacting the fish at site 07UM094. At site 07UM094 there is a 36% chance of the stream DO concentrations being above the 5 mg/L standard based on the DO probability score. Table 4.6-1 shows the TVI scores from both sampling locations in Vondell Brook. The scores are presented as the probability of passing the associated water quality standard.

**Table 4.6-1: Probability of passing the water quality standard based on the fish community that was sampled at each site. Yellow and green colors are likely not a stressor to the fish community.**

| FieldNum | WBName | FishBCG | Probability_TSSRA | probability_DO_earlyAM_RA |
|---|---|---|---|---|
| 13UM049 | Vondell Brook | 3 | 0.752428197 | 0.425698171 |
| 07UM094 | Vondell Brook | 5 | 0.775734207 | 0.3626669 |
| 13UM049 | Vondell Brook | 4 | 0.810540731 | 0.522464002 |

The macroinvertebrate community passed the M-IBI. One site was sampled and this site was used to look at community metrics that can lead to stress to see if the macroinvertebrate data and the fish data supported the possible stressor explanation. Table 4.6-2 below shows the macroinvertebrate community metrics that have been used to assess potential stressors. The yellow highlighted boxes indicate that the macroinvertebrate communities are outside of the normal range for those metrics assessed.

**Table 4.6-2: Macroinvertebrate metrics scores for site 13UM049 assessed against Class 4 streams that have passing M-IBI scores. Even though the M-IBI passes at this site we can use this information to support potential stressors in the fish community.**

| | Parameter | Index Score | Class 4 statewide average for Index Score passing streams (response) | % Tolerant Individuals | Class4 statewide average for % Tolerant Individuals in passing streams (response) | # Intolerant Taxa | Class 4 statewide average for # Intolerant Taxa in passing streams (response) |
|---|---|---|---|---|---|---|---|
| 13UM049 | DO | 6.71 | 6.62 (down) | 10.69 | 22.9 (up) | 7 | 3.9 (down) |
| 13UM049 | TSS | 11.6 | 16.31 (down) | 17.93 | 25.4 (up) | 2 | 2.89 (down) |
| 13UM049 | N | 0.075 | 0.16 (down) | 47.93 | 34.17 (up) | 4 | 5.94 (down) |

## 4.6.2. Data analysis/evaluation for each candidate cause

### Low dissolved oxygen

Low dissolved oxygen (DO) can cause stress to the biology in a stream. In 2015 a continuous YSIä sonde was deployed for 10-day intervals at both 13UM049 and 07UM094. The results of the continuous deployments can be found in Figure 4.6-1 and Figure 4.6-2. Both sites showed that DO is generally above the 5 mg/L standard. This is also evident when looking at the fish and macroinvertebrate community tolerance metrics listed in Table 4.6-1 and 4.6-2 above. Both of these tables show that there is not a strong biological signal with low DO. On July 28, 2015, 1.64-inches of rain fell at a rain gage at the station on the West Branch Rum River. This heavy rainfall can explain the drop in DO at site 07UM094 as seen on July 28, 2015 in Figure 4.6-2. After that significant rainfall, the DO appears to recover within 18 hours. Low DO is not a stressor to the biological communities in Vondell Brook.

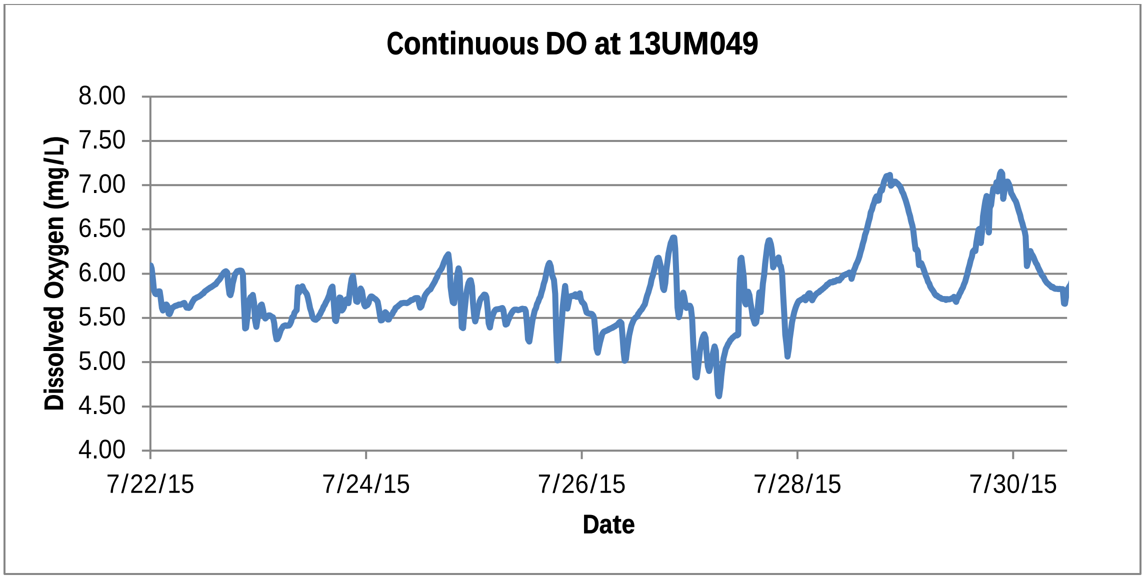



**Figure 4.6-1: Continuous sonde deployment at site 13UM049 on the downstream portion of Vondell Brook. DO data is generally above the 5 mg/L standard threshold.**

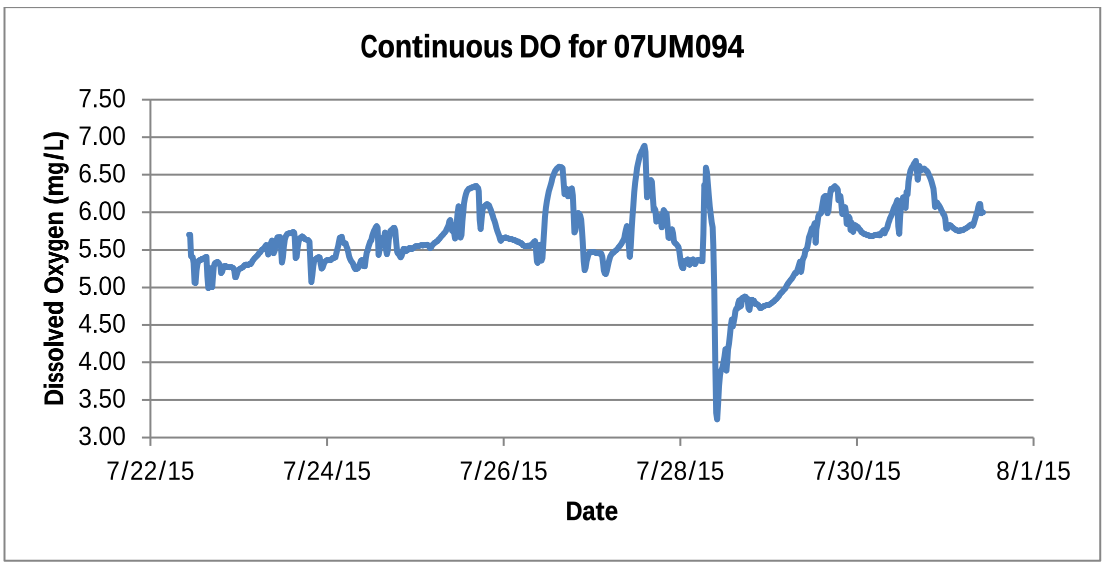



**Figure 4.6-2: Continuous sonde deployment at site 07UM094 on the upstream portion of Vondell Brook. DO data is generally above the 5 mg/L standard threshold.**

### Elevated nutrients

Water quality samples were collected at both sites in Vondell Brook in various years from 2006 through 2015. Samples were collected and analyzed for Total Phosphorus (TP), Nitrate-nitrite (NOx), and Total Suspended Solids (TSS). The TP data collected shows that the TP concentrations are often higher than twice the state standard. Figure 4.6-3 shows the TP data from Vondell Brook. The river eutrophication standard requires additional response variables; elevated DO flux, elevated Chlorophyll-*a* (Chl-*a*) concentrations or increased submerged aquatic plant growth in the stream, for the river eutrophication standard to be assessed. The DO flux does not indicate eutrophication; it is below the 3.5 mg/L per day standard threshold. There is some evidence of elevated nutrients causing an increase in plant growth in the form of elevated duckweed growth in the channel. The growth of duckweed also indicates lentic conditions within the channel.

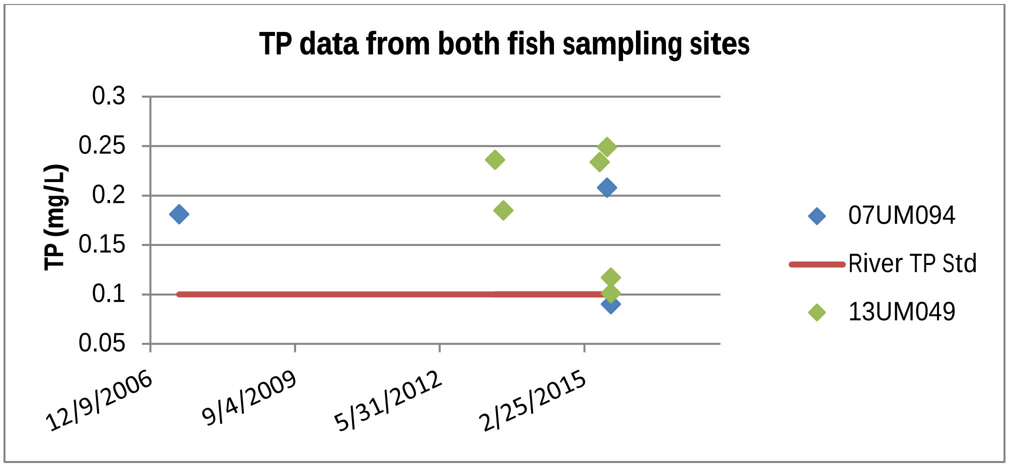



**Figure 4.6-3: Total phosphorus concentrations from water quality samples collected in both AUIDs along Vondell Brook. TP is often twice the state standard for eutrophication.**

Increased duckweed growth can be seen in the photo below. This photo was taken on August 26, 2015, at EQuIS site S008-630; the corresponding TP concentration was 0.117 mg/L. The photo also shows that the stream can get very low flow late in the summer when there is not a lot of precipitation.

This area of Vondell Brook also has some cattle pastures that are located along the stream corridor. The free access to the cattle will allow for nutrient and sediment transport to occur. A large portion of Vondell Brook and its tributaries are also channelized and run adjacent to agricultural row crop fields and various pastures. This land use will contribute to the elevated TP concentrations. Review of macroinvertebrate metrics can help explain if elevated TP is changing the macroinvertebrate community. As TP increases there would be a response of increased periphyton growth which should be seen as an increase in scraper macroinvertebrates. The scraper groups feed on periphyton. The Class 4 average in the Rum River Watershed (RRW) for scraper taxa richness is 5.6 and site 13UM049 was 6. Another macroinvertebrate metric that can be used to determine if eutrophication is affecting the biology is taxa richness of Mollusca (snails/clams). The Class 4 average for Mollusca is 4.8 in the RRW and the Mollusca taxa richness at 13UM049 is 4. A response to elevated nutrients by the fish community can be seen by a decrease in sensitive fish species. Both fish sampling sites scored a 2.5 for the Fish Index of Biological Integrity (F-IBI) in the sensitive fish category. This is below the 4.0 and 4.2 needed to help the sites pass the F-IBI. This does indicate that there is a biological response to the elevated TP concentrations in the stream. Phosphorus reduction in Vondell Brook would benefit the biology in the stream and is a stressor.

A limited number of nitrogen samples were collected in 2015. The three samples collected were all below 0.13 mg/L. The data set is too small to make any real conclusions. Additional nitrogen sampling should be conducted to determine if nitrogen is elevated enough to be affecting the biology in Vondell Brook. Currently the lack of nitrogen data makes this stressor inconclusive.

#### Lack of physical habitat

Both sites were recorded to have moderate embeddedness of fine sediments located on the bottom and evidence of sediment bars being developed along the stream perimeter. This high amount of fine sediment is probably linked to the upstream channelization and the potential for bank failure due to altered hydrology and the presence of cattle having free access to the stream in various locations. The MSHA score is a standardized method of collecting habitat data during the fish sampling visits. MSHA scores below 45 are poor, and above 66 is good. Both MSHA scores on 57 at site 13UM049 are in the fair category. Figure 4.6-4 below shows the five categories that are recorded and summed to come up with the total MSHA score. The MSHA substrate score is affected by the dominance of sand/silt and the lack of substrate types along with moderate embeddedness noted at site 13UM049. The substrate scored a 12 and 14 out of a maximum score of 27. At site 07UM094 substrate scores improve with the addition of cobble and gravel and a reduction of sand/silt. This corresponds to a subcategory score of 19 out of a possible 27. Even though the stream has moderate embeddedness along with a large amount of sand substrate at 13UM049 the fish do not appear to be directly affected. The simple lithophilic (gravel) spawning fish score above the mean score at both biological sites. A reduction in darter and sculpin species would also be expected if the substrate was impacting the fish community. Both sites score above the mean for passing the F-IBI for darter sculpin species. There does appear to be a direct biological link to the degraded substrate due to the channel embeddedness. However, it is believed that the sand/silt substrate observed at 13UM049 is impacting the fish community indirectly. The Department of Natural Resources (DNR) performed a channel stability rating for Vondell Brook in 2015. The Pfankuch rating is a way to summarize the stability of three main channel components: the channel, the lower banks, and the upper banks. The Pfankuch ratings were fair at the two sites assessed. The lower banks at both sites had significant bank cutting of 12-24 inches and deposition of sand and gravel was noted. Also deposition and filling of pools was observed in the reaches. This resulted in moderately unstable ratings at sites 15-02 and 15-03. Site 15-01 was rated as unstable. Extensive deposition of fine sediment within the channel and moderate to heavy amounts of debris resulted in an unstable rating. Figure 4.6-6 shows the locations of the Pfankuch stability ratings. The stability ratings help identify changes in localized habitat due to erosion and deposition as a stressor.

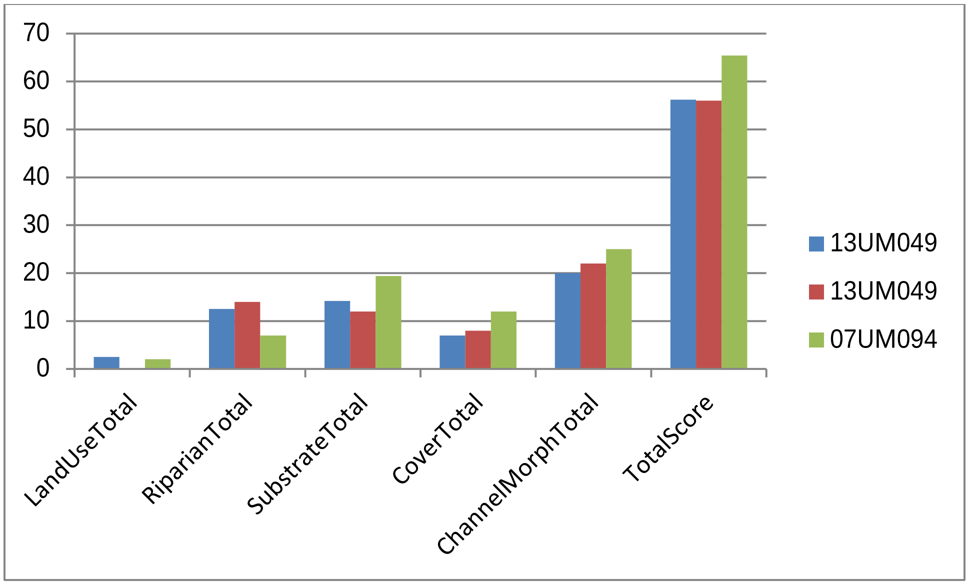



**Figure 4.6-4: MSHA scores collected during fish visits at biological sites 13UM049 and 07UM094. The 07UM094 site was sampled in 2007 as a reference ditch.**

### Altered hydrology

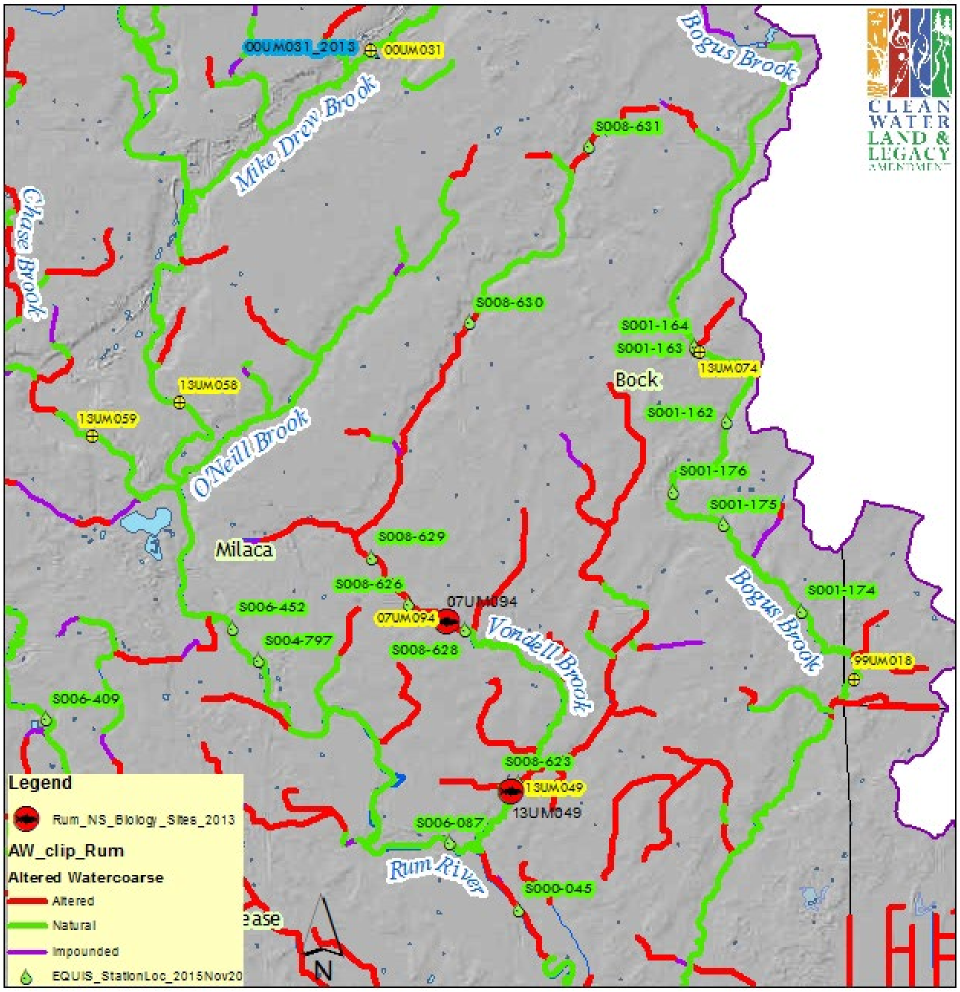
The sampling photos from June and August show a very different looking stream. The August 2013 and 2015 photos show a stream that is nearly dry and there is evidence of very high flows occurring earlier in the year. A review of the Altered Watercourse Layer shows that 62% of Vondell Brook is channelized. The majority of the channelized sections are upstream of the two biologically impaired AUIDs. This channelization is affecting the rate and delivery of water within the stream and causing the channel to overwiden. The channel appears overwidened and there is considerable deposition occurring within the channel at site 13UM049 as seen in Figure 4.6-5.

**Figure 4.6-5: Photos of site 13UM049 downstream of the 85th Avenue road crossing. This site is between two road crossings which may be having a localized impact on the channel hydrology.**

An HSPF model was calibrated and ran for the period of 1996 through 2009 for the RRW. Vondell Brook was modeled as reach 213 and the flowing flow characteristics were taken from the model results. The maximum discharge was 594 cfs, the mean discharge was 12.4 cfs and the minimum discharge was 0.04 cfs. The stream was below 1 cfs for 24.5% of the model period. This low flow occurred generally in August through October during 1996 through 2002, and in July through September in 2003 through

2009. This very low stream discharge would have an impact on the biological community by limiting available habitat and also eliminating biological species that require swift velocities to thrive. The average cross sectional area for the surveyed stream channels was approximately 30sq.ft. If we assume 2.5 ft/sec of stream velocity and multiply by 30 sq.ft of channel area we get a bankfull discharge of 70 cfs. This discharge would be considered the channel shaping discharge and should occur every 1.5 years. Reviewing the modeling results for the reach we see that 70 cfs is exceeded 2.8% of the time from 1996 through 2009. On average the higher flows are occurring twice each modeled year which is allowing the channel to erode and adjust the cross sectional area to accommodate the increased frequency of higher flows.

Figure 4.6-6 displays the altered watercourse layer with the hill shade light detection and ranging (LIDAR) as the background. This map shows the relation between the altered stream reaches compared to the biological sampling locations. Both biological sites are located in sections of natural channel; however, there are large sections of altered channel upstream of both locations. In 2015, the DNR conducted a geomorphic channel assessment of Vondell Brook. Three stations were surveyed to look at channel dimension, pattern and profile and are shown in Figure 4.6-6. Station VB15-02 is near biological site 13UM049 and station VB15-01 and VB15-03 are near the upper biological site 07UM094. The full results can be found in the DNR Vondell Brook Geomorph Summary report. Here is a summary of the findings of that report.




## Catchment summary

The reaches 15-01 and 15-02 appear to be only slightly or moderately unstable and contributing minimal amounts of excess sediment from the streambanks. Reach 15-03 is categorized as unstable based on confinement and width-to-depth ratio assessments. However, investigation of historical photography shows the reach was previously a man-made ditch and has evolved into a stable, two-stage channel with a small floodplain within the originally excavated ditch (Figure 4.6-6). Straightening of the stream, much occurring prior to 1939, is fairly prominent in the upper reaches of this catchment. In many of the channel not "cleaned out" over time, natural channel evolution, as illustrated in reach 15-03, has resulted in stabilization in many of the straightened reaches.

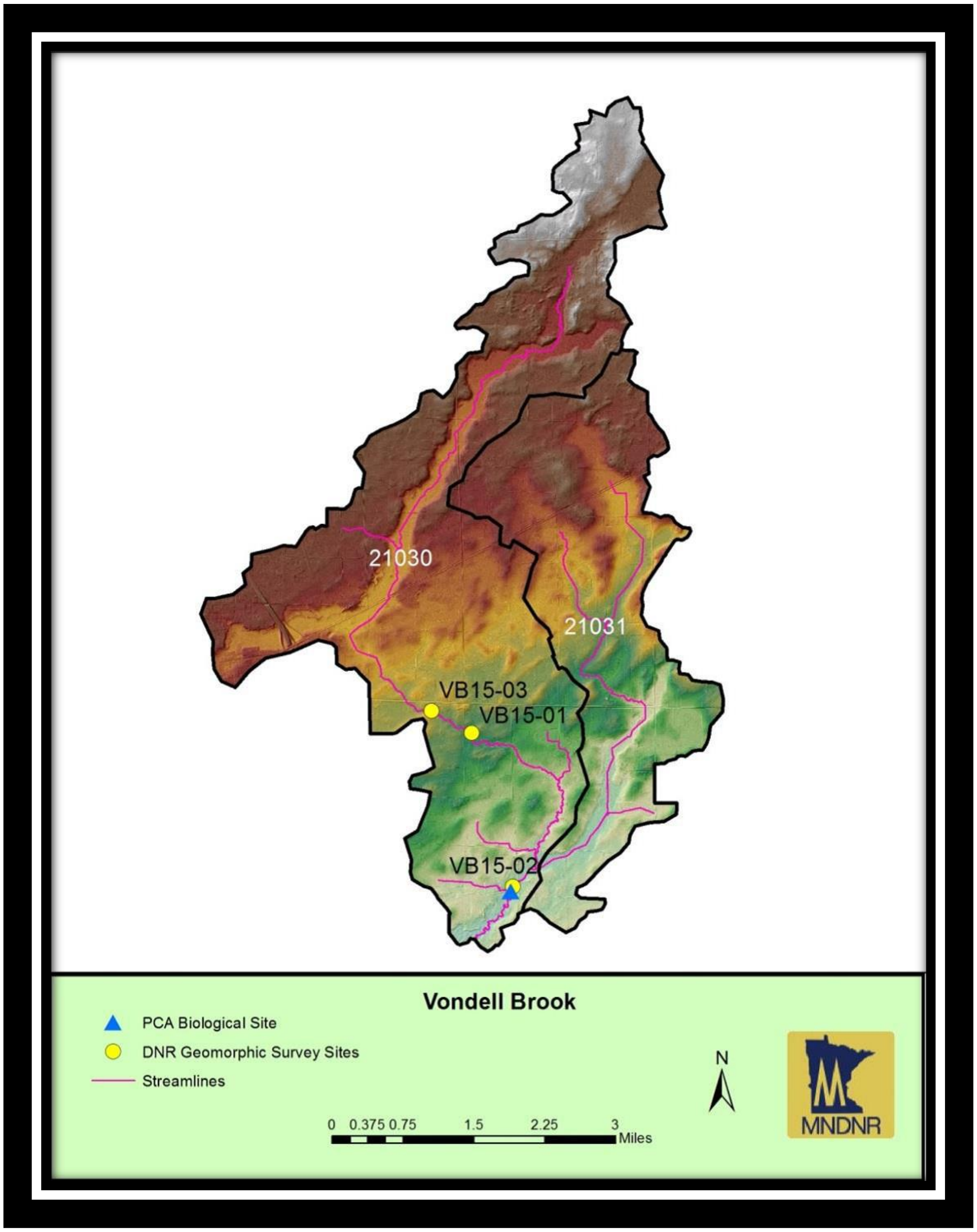



**Figure 4.6-6: Catchments with geomorphic and MPCA sites**

### Crossing assessment

The majority of road crossings on the main branch were assessed utilizing a standardized culvert assessment procedure. Only one crossing was incorrectly sized (within 5-feet) for bankfull flows and none were a barrier to fish passage (Figure 4.6-7). Two crossings located in the lower portion of the watershed were the cause of stream bank erosion.

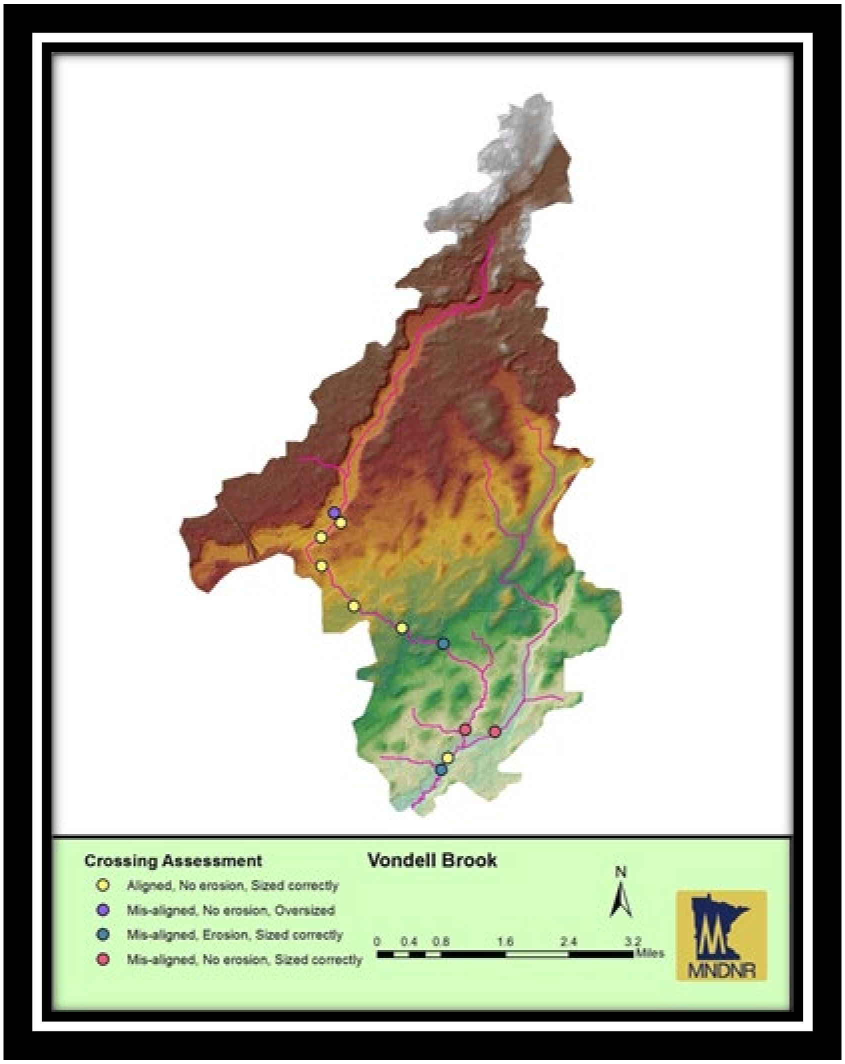



**Figure 4.6-7: Crossing assessment results**

### Summary from the DNR Geomorph Report

Combined effects of factors such as cattle grazing and crossing impacts can cause significant but localized sediment issues. In this case, the Index of Biological Integrity (IBI) site is located in a short section of stream with close proximity to crossings upstream and downstream as well as a small tributary joining a short distance downstream of the IBI site. The lower crossing is noted as being misaligned and causing active erosion. The confluence of the two Vondell Brook catchments is located in a cattle pasture upstream of the 85th Avenue crossing. The IBI impairment in Vondell Brook appears to not be related to systematic sediment problems but to multiple localized issues such as crossing impacts and other biotic and abiotic factors.

From the standpoint of sediment and stability, Vondell Brook appears to be in generally good condition. In the upper portions of the watershed the stream was straightened prior to 1939 for presumably, agricultural purposes. Channelization of streams can result in sediment stability problems. But as observed in survey 15-03, many ditched sections of the stream not "cleaned out" have naturally evolved to a stable state with multi-staged channels. Surveys further downstream in the watershed were categorized as moderately unstable with minimal sediment contributions from streambanks. Channelization of stream reaches in the lower portion of the watershed occurred much later and evidence points to these reaches in the earlier stages of progression to a more stable state. Results indicate a minimal amount of significant sediment issues in the Vondell Brook watershed.

### 4.6.3. AUID summary

#### Stressor pathway discussion

Overall the stream geomorphic results concluded that Vondell Brook is not carrying an excessive amount of sediment. There are localized sediment issues that were identified in the lower portion of the brook near sampling location 13UM049. This area has two crossings that are misaligned and causing localized bank failures that are impacting the available habitat at site 13UM049. Cattle grazing along the stream corridor are also causing some localized impacts to the stream channel which is impacting the habitat.

Elevated phosphorus in the stream channel appears to be affecting the growth of peryphyton in wooded sections of Vondell Brook. The elevated TP is coming from agricultural and residential runoff and BMPs should be investigated to reduce this pollutant.

#### Stressor conclusions

Habitat appears to be a stressor to the biological communities at a localized scale. The problem does not appear to systemic according to the DNR Geomorph report. Elevated TP concentrations are causing an increase in both peryphyton growth and duckweed growth. This may be impacting the food web in the stream which may be indirectly affecting the fish communities. Nitrogen also appears to be affecting the macroinvertebrate communities (which are currently passing the M-IBI) but there is not enough information to assess this pollutant. Additional nitrogen samples should be collected throughout the growing season to determine the impacts of nitrogen. Due to the large percentage of altered stream miles within the Vondell Brook subwatershed and the frequency of both high flows and very low flows from the Hydrological Simulation Program – FORTRAN (HSPF) model, altered hydrology is also stressing the biological community due to a change in flow patterns, over widening of channel cross section, and lack of base flow at various times of the year.

## 4.7. Stanchfield Creek (AUID 07010207-520)

### 4.7.1. Biological communities

Biological sampling was conducted at site 13UM061 in 2013. On June 18, 2013, a fish sample was collected that scored a 36. On August 20, 2013, a second sample was attempted but the stream had insufficient flow to sample. Another sample was attempted September 17, 2015, but the stream was too deep at the time. Six fish taxa were collected on June 18, and the dominant two taxa were common shiner and central mudminnow. The stream is classified as a low gradient (Class 7) stream for F-IBI purposes. The threshold for this stream class is 42. During the second visit on August 20, 2013, the channel had no flow and notes indicate that cattails were growing within the channel. No macroinvertebrate sample was collected on August 20, 2013, for the same reasons. The picture below is from the August 20, 2013 visit.

The fish community has a probability of 21% of passing the DO standard according to Sandburg Tolerance Value Index (TVI) probability. This indicates that the fish community sampled in 2013 was dominated by species that can tolerate low DO. Data analysis/evaluation for each Candidate Cause

## 4.7.2. Data analysis/evaluation for each candidate cause

### Low dissolved oxygen

Based on the wetland characteristics of the immediate riparian area, it was believed that low dissolved oxygen (DO) may be affecting the biological communities at Stanchfield Creek. In 2013, a YSIä sonde was deployed for thirteen days to assess the DO concentrations. The data shows that DO routinely drops below the 5 mg/L standard (Figure 4.7-1), as the stream temperature increases. The daily DO flux remains around 2 to 2.5 mg/L. This data confirms that low DO concentrations are present. The fish community sampled in 2013 also showed a tolerance to low DO conditions.

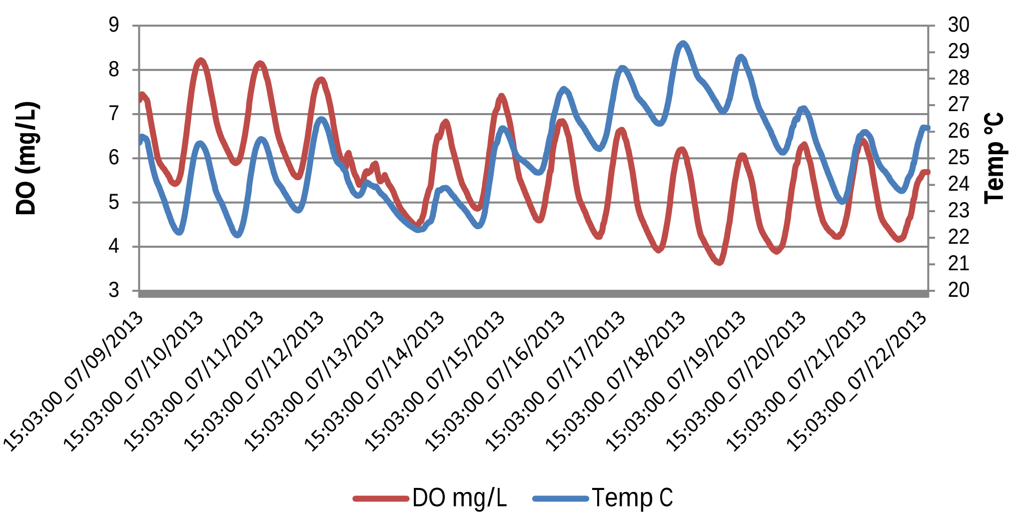



**Figure 4.7-1: Continuous DO and temperature data collected using a YSIä sonde deployed from July 9, 2013, through July 22, 2013.**

Since there is no macroinvertebrate data to analyze at this site we cannot look at the percent of low DO tolerant taxa or the macroinvertebrate DO Index score.

### Elevated nutrients

Elevated nutrients can cause a change in the food web within a stream. This can be associated with increased submerged aquatic plant growth and/or increased algal or peryphyton growth within the stream. Eutrophication caused by TP is the major contributor to this increased plant growth. TP samples were collected from 2006 through 2013 in Stanchfield Creek.

The sampling shows that routinely the TP concentrations are above the 0.100 mg/L standard. Figure 4.7-2 below displays the TP data from Stanchfield Creek.

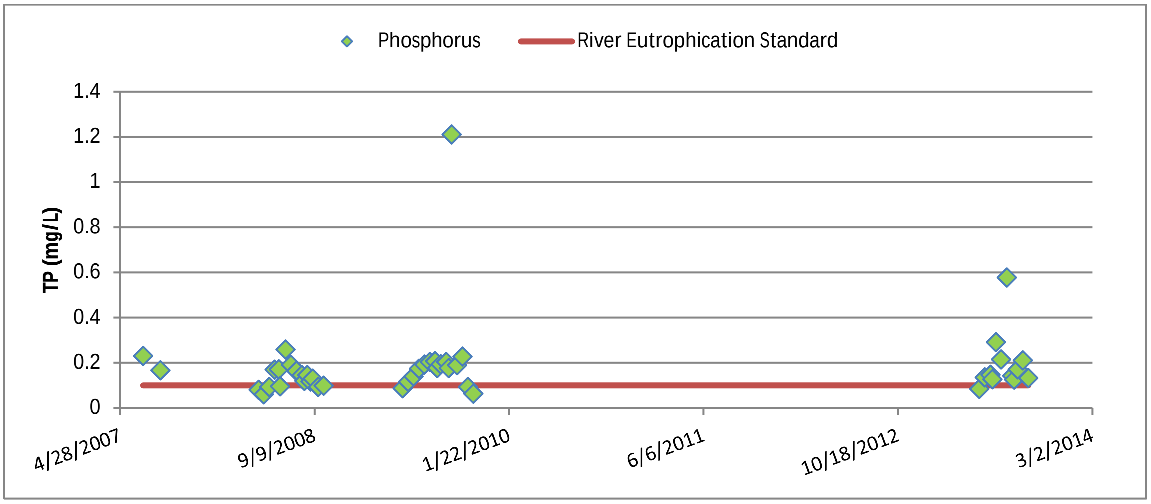



**Figure 4.7-2: TP concentrations collected from 2006 through 2013 on Stanchfield Creek.**

Eutrophication will result in the increased productivity of Chl-*a* and/or rooted macrophyte growth and can cause a disruption of the biological community. Chl-*a* samples were collected between 2007 and 2010. When Chl-*a* sample concentrations are above 18µg/L the eutrophication is applied. Out of the 34 Chl-*a* samples collected, only 2 were above the 18µ/L standard. The majority of the samples were well below 5µg/L. Since the high TP is not showing an increase in Chl-*a* concentrations, the other response that is more difficult to measure is rooted aquatic macrophytes. Stanchfield Creek does have an extensive amount of rooted macrophytes as can be seen in Figure 4.7-3.

**Figure 4.7-3: Elevated submerged macrophyte growth and duckweed growth in Stanchfield Creek. This growth is a direct response from the elevated TP concentrations in the stream.**

Eutrophication from elevated TP concentrations is causing stress to the fish community. Sensitive fish species will show a decrease in abundance when eutrophication is evident. The sensitive fish metric of the F-IBI scored a 0 at 13UM061. The number of fish per meter sampled minus tolerant taxa also would be reduced. This is evident by the F-IBI scoring 0 for this metric. The response variable for eutrophication is increased submerged rooted macrophytes in the stream channel which may change the food web. Approximately 4.5 miles upstream of biological site 13UM061 there is an industrial facility that has wastewater ponds located on the south side of Stanchfield creek near Dalbo, Minnesota. The facility name is DairiConcepts LP-Dalbo Facility (Facility) and it is located in Isanti County. The principal activity at this Facility is the reprocessing and packaging of cheese that has been processed in bulk form at different production facilities and shipped to the Dalbo plant. Primarily, the Facility will receive finished Italian style cheese, then grind, dry and package these products for sale. Because cheese is delivered to the Facility in a finished bulk form, the processing is considered a dry process. Liquid waste is primarily from the periodic cleaning of equipment, involving an initial dry clean-up step prior to wet cleaning. The two step process results in a relatively low volume of wastewater. Other wastewater includes condenser water. The average discharge from the Facility is 37,000 gallons per month.

Wastewater is pumped from the plant to a two cell pond system, consisting of a 9.5 acre, 19.7 million-gallon primary cell and a 3.6 acre, 9.5 million-gallon secondary cell. The primary cell is designed for the use of floating aerators. However, since the wastewater flow rate is well below the design capacity of 170,000 gallons per day, aerators are not used. The Facility has not needed to discharge from the ponds since commencement of business in 1997.

### Altered hydrology

The fish sampling visits and the recon visit in September of 2012 confirm that the stream goes nearly dry during periods of low precipitation. The stream channel has been altered over the years. There is a 1.6-mile section of stream that has been lost due to a diversion channel being built (Figure 4.7-5). There are also many stream miles of altered tributaries that are probably altering the delivery of water to the stream. There appears to be a lack of baseflow some years which may be partially caused by the ditching and loss of wetland storage in the system.

A stream gage was installed in Stanchfield Creek from 2013 through 2015 to document stream discharge. The gage records water level on a continuous basis every 30 minutes. Stage is then converted to discharge based on a site specific rating curve that is created using the Hydstra database program.

The stream gage revealed that during August in all three monitoring seasons that stream discharge becomes very low. The gage is located downstream of where Ties Creek enters Stanchfield Creek, near the city of Springvale, approximately 9 river miles downstream of biological site 13UM061. The gage record shows periods of very low flow below 15 cfs which would probably translate to a near zero discharge at biological site 13UM061 9 miles upstream. The HSPF model results show that the Stanchfield creek reach is below 15 cfs for 59.5% of the record from 1996 through 2009 at the outlet of the stream. This helps us understand the severity of the low flow conditions within the Creek. Figure 4.7-4 displays the continuous discharge record for Stanchfield Creek at CR 6 near Springvale, Minnesota.

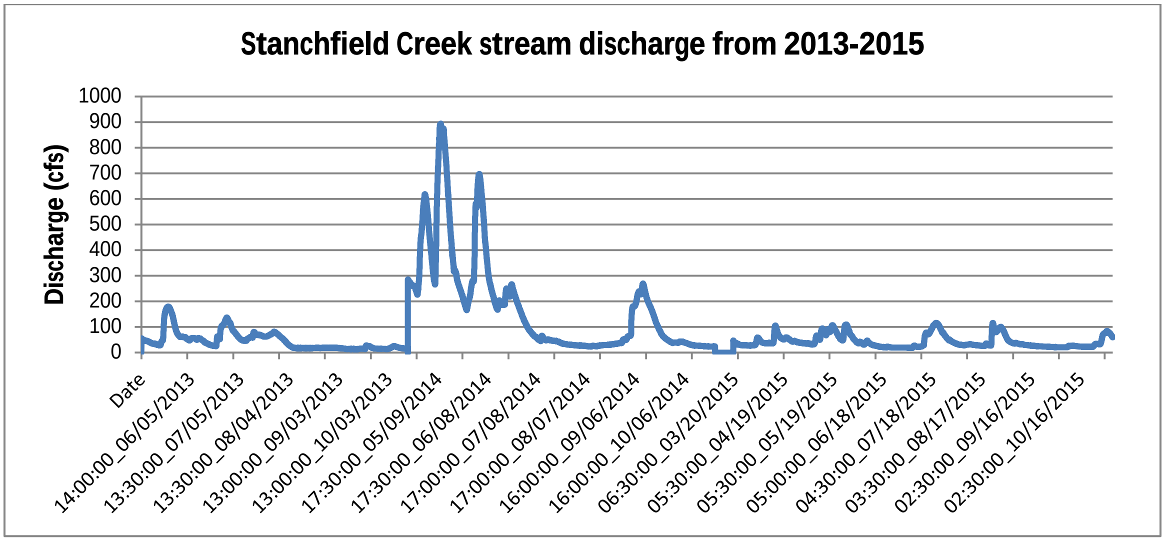
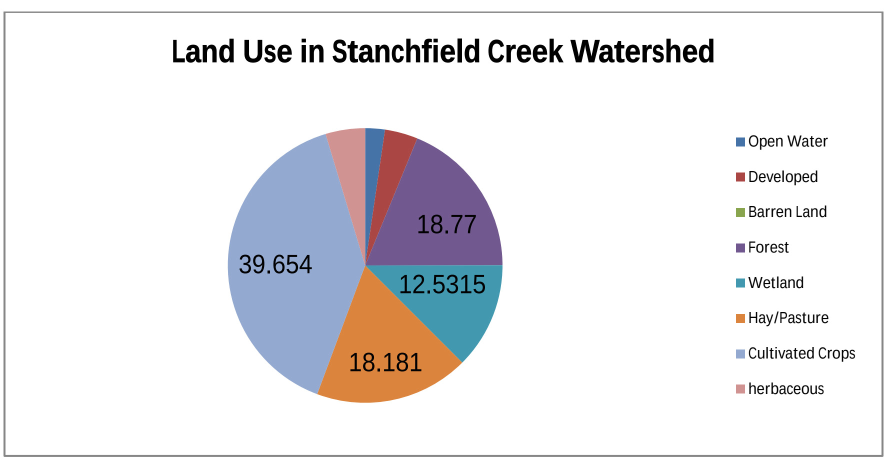



**Figure 4.7-4: Discharge record for Stanchfield Creek near Springvale, Minnesota. A continuous record was collected from 2013 through 2015.**

Land use is this subwatershed is dominated by row crop agriculture. The conversion of wooded acres and potential drainage of wetland acres is altering how the water is delivered through the stream system. As summer progresses and row crops mature the amount of precipitation delivered to the stream is minimized through transpiration. This reduction in runoff will also reduce the amount of water that the stream receives. Spring rainfall can enter the stream system at a higher rate because the row crops are not utilizing as much water. In the Stanchfield Creek Subwatershed land use is dominated by cultivated row crop and hay/pasture (57.8%) followed by forest (18.8 %) and wetland (12.5 %). All other land use categories are below 5 % per category.



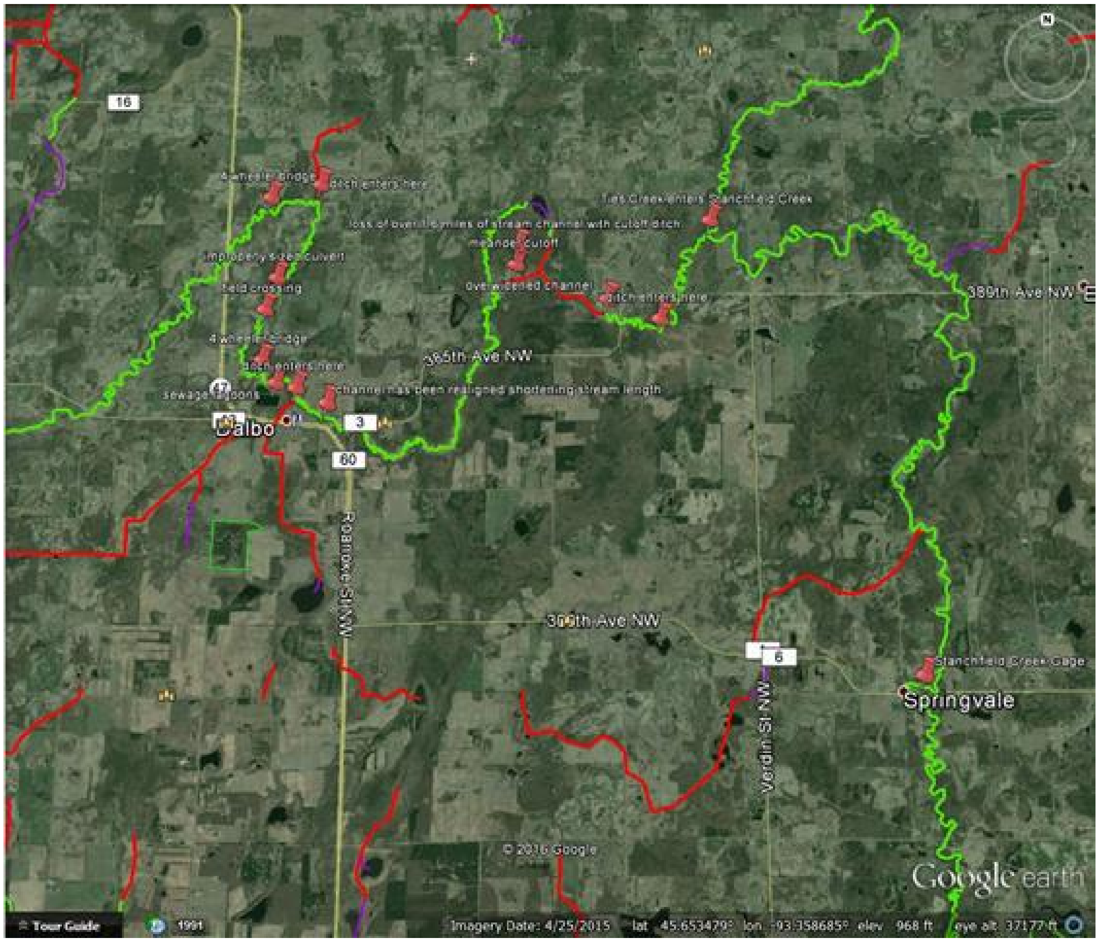



**Figure 4.7-5: Points of interest that were identified for Stanchfield Creek during aerial photo interpretation. The stream lost 1.6 miles of length when the ditch was created just upstream of the biological sampling site 13UM061.**

Based on the field observations made both during the sampling visits and looking at the stream discharge record a lack of baseflow is a stressor to the biological communities at 13UM061.

## 4.7.2 AUID summary

### Stressor pathway discussion

There are multiple channelized wetlands upstream of biological site 13Um061 along with a series of sewage treatment ponds located in Dalbo, Minnesota. The combination of channelized wetlands and elevated nutrients that are associated with these land use practices may be lowering the DO concentrations of the stream, elevating the TP concentrations and delivering water at a different rate through the stream system.

### Stressor conclusions

Altered hydrology and eutrophication are leading stressors to Stanchfield Creek. The significant land use change from forest to agriculture is impacting the stream flow and how water is delivered to the stream. The lack of base flow in the late summer months is partially caused by transpiration of row crops and also the change in precipitation patterns. The low flow conditions from the HSPF model show that during July through September the stream is annually below 15 cfs at the outlet. This is confirmed by reviewing the gage data from 2013 through 2015. Eutrophication is causing an elevated growth of submerged aquatic macrophytes and possibly leading to the low DO concentrations observed in 2013. Low DO is also a stressor to the biological communities in this Assessment Unit Identification (AUID) as the DO is dropping below the 5 mg/L standard on a daily basis. The stream is also experiencing very low flow periods during periods of little rainfall. This is evidenced by reviewing site visit pictures along with review of the downstream hydrograph.

# 4.8. Isanti Brook (AUID 07010207-592)

## 4.8.1. Biological communities

This AUID on Isanti Brook has one biological monitoring station located on it (13UM052). This site fails both the fish and macroinvertebrate IBIs and is listed as impaired for both. The fish community is dominated by low DO tolerant species such as central mudminnow, bluegill and northern pike. The fish community Tolerance Value Index (TVI) score that was created by Sandberg (MPCA) suggests that the sampled fish community has a 90% chance of failing the DO standard. The macroinvertebrate sample was also dominated by low DO tolerant taxa and this data also suggests that low DO is a main stressor to the biology.

## 4.8.2. Data analysis/evaluation for each candidate cause

**Low dissolved oxygen (DO)**

Table 4.8-1below displays the macroinvertebrate metric scores for three main stressors that have been identified statewide. These stressors are low DO, TSS, and Nitrate/nitrite as N.

Low DO can have a significant impact on the biology that lives in a stream. Both the fish and macroinvertebrate communities sampled suggest that low DO is stressing the biology in Isanti Brook. An YSIä sonde was deployed on July 23, 2015, and collected data through August 1, 2015. The data collected is displayed in Figure 4.8-1 below and shows that the DO dropped below the 5 mg/L standard on a daily basis. Low DO is a source of stress to the biology at 13UM052 and may be the leading stressor. The DO index score for the macroinvertebrate community is below the expected DO index score for Class 6 stream. The expected response is a decrease in score. The percent macroinvertebrates that are tolerant to low DO concentrations is also higher than the Class 6 average. The fish community suggests a 90% chance of DO concentrations below the 5 mg/L standard.

**Table 4.8-1: Select macroinvertebrate data that was used to identify potential stressors to the macroinvertebrate community. Yellow highlighted data suggest that the macroinvertebrate community is affected by the pollutants listed.**

| FieldNum | Parameter | %Tolerant Taxa | Index Score | Class 6 watershed average (Index Score) | Expected Response | Class 6 watershed average (% Tolerant) | Expected Response |
|---|---|---|---|---|---|---|---|
| 13UM052 | TSS | 12.41 | 2.8 | 16.36 | Decrease | 25.82 | Increase |
| | DO | 53.35 | 6.28 | 7.03 | Decrease | 14.53 | Increase |
| | N | 28.18 | 0.5 | 0.41 | Decrease | 46.88 | Increase |

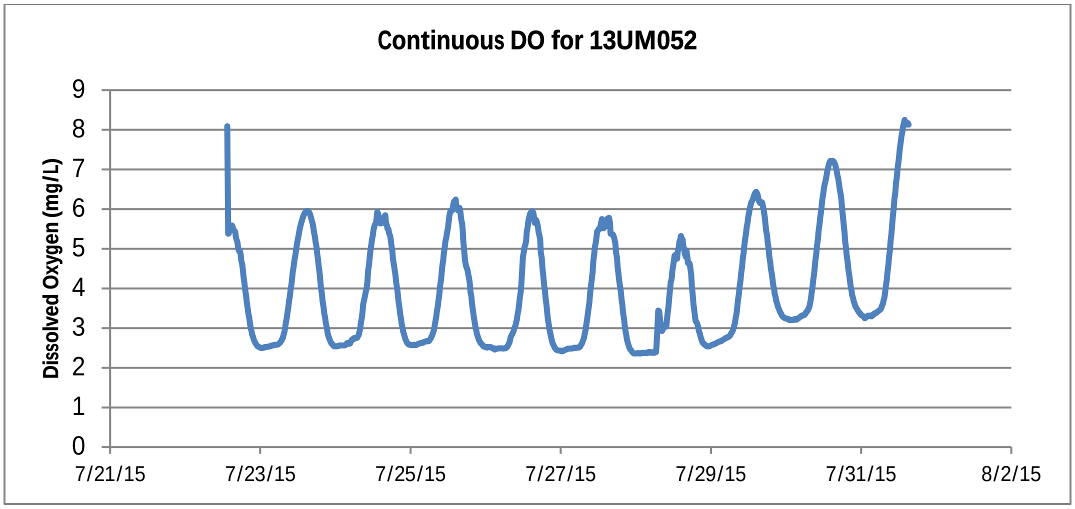



**Figure 4.8-1: Continuous DO data collected using a YSIä sonde at site 13UM052 in Isanti Brook. Daily readings below 5 mg/L were recorded during the deployment.**

### Elevated nutrients

Water chemistry data is limited to three samples collected in Isanti Brook. Two of the samples were collected in 2013 and one in 2015, all three samples had total phosphorus concentrations between 48 and 83 µg/L. This is below the eutrophication standard of 100 µg/L set for this Central part of Minnesota; however, there is extensive instream macrophyte growth which could be using any available phosphorus. The uptake of TP by macrophyte growth could be reducing the amount of TP in the water chemistry samples. The daily DO flux and low DO concentrations at night could be related to elevated macrophyte growth in the channel.

Nitrogen samples were collected during the fish visit on June 19, 2013. The results from this visit show an elevated nitrogen concentration of 0.5 mg/L. Further nitrogen samples were collected in 2015 at the fish sampling location. This sample had a nitrogen concentration of 0.07 mg/L. The limited nitrogen dataset makes it difficult to assess nitrogen as a stressor to the biology. The macroinvertebrate metrics shown in Table 4.8-1 above suggest that nitrogen is not inhibiting the macroinvertebrate community. With the data being inconclusive as a stressor it is recommended that additional water chemistry samples be collected for both nitrogen and phosphorus parameters.

### Lack of physical habitat

Physical habitat is not believed to be a source of stress in Isanti Brook. The MSHA score during the June 19, 2013, fish sampling event was 65.7. The main reason that the score was slightly lower was the substrate score was only 10 out of a possible 27. This was due to the amount of sand and silt located in the sampling reach. The stream channel appears to have good riparian cover and connectivity to its floodplain during high water events. There was no coarse substrate located in the sampling reach. The pools are identified as having sand and clay; there are no riffles at the site and the runs are dominated by sand and silt along the perimeter. The instream macroinvertebrate habitat was diverse. There were undercut banks, overhanging vegetation, deep pools and woody debris along with submerged aquatic macrophytes present. The channel has a nice diversity of water depths, excellent sinuosity, moderate to high channel stability and various velocity types within the sampled reach. Habitat does not appear to be a stressor.

**Figure 4.8-2: Isanti Brook pictures showing the riparian cover along with channel development. Habitat features appear to be diverse and habitat does not appear to a stressor.**

### Altered hydrology

There is no stream gage data available for Isanti Brook. Altered hydrology cannot be fully assessed without the help of gage data. However, review of the aerial image on Google Earth suggests that beaver dams and upstream channelization may have impacted the hydrology within this drainage. The aerial shows improperly aligned and sized culverts that need further investigation. There is one field road crossing just downstream of Highway 65 and one improperly sized culvert at the Jackson Street NE crossing. These two culverts are causing localized issues rather than systemic issues. Near biological site 13UM052 there is also evidence of channel migration and loss of stream length due to loss of stream meanders (Picture 2). A Hydrological Simulation Program – FORTRAN (HSPF) model was built for the Rum River watershed (RRW) predicting stream discharge from 1996 through 2009. Isanti Brook showed flows of less than 1 cfs for 14% of the record. The mean stream flow was predicted at 8.5 cfs and the maximum stream discharge was 254 cfs. The model may be over predicting stream discharge at the low flow (<1 cfs) estimates. The frequency of low flows occurred in late summer in 2000, 2003, and 2007, covering the months of August and September. Often these predicted flows were closer to 0.6 cfs than 1 cfs. In contrast, looking at higher flow predictions can show the frequency of possible flow that could cause bank failure. The mean annual discharge was 8.5 cfs and multiplying by 5 gives a discharge of 42.5 cfs. Analyzing the HSPF model results showed that Isanti Brook had flows greater than 42.5 cfs for 1% of the record. This high of flow was predicted about every other year in the model. The frequency of low flows may be stressing the biological community.


**Picture 3: Stream has lost some stream length due to loss of stream meanders. Taken from Google Earth using April 25, 2015 aerial image.**


**Figure 4.8-3: Isanti Brook drainage. This aerial shows the large wetland areas upstream of the sampling site along with some improperly sized culvert locations and beaver dams. From Google Earth April 25, 2015 image.**

## 4.8.3. AUID summary

### Stressor pathway discussion

Low DO is potentially coming partially from the vast wetland areas upstream of site 13UM052. There are multiple wetland areas that drain into Isanti Brook between the sampling location and the headwaters at Florence Lake. There are also multiple agricultural fields upstream that drain directly to the stream along with a nursery and some residential development.

### Stressor conclusions

Low DO appears to be the main source of stress affecting the biological communities at Isanti Brook. Both the fish and macroinvertebrate data have a high degree of confidence that support this theory. Nutrient concentrations appear to not be affecting the biology; however, there is not enough information to assess and additional data should be collected. Altered hydrology is having a localized effect on the stream channel which may be affecting isolated areas of the stream. Habitat features appear diverse for macroinvertebrates and habitat does not appear to be affecting the biology.

## 4.9. Washburn Brook (AUID 07010207-641)

### 4.9.1. Biological communities

Washburn Brook is a modified use ditch with one biological monitoring station located on it (13UM089). Being a modified use stream, the biological community is required to meet a much lower Fish Index of Biological Integrity (F-IBI) standard. The F-IBI at 13UM089 is 13 with a threshold of 23. Fish were sampled on June 18, 2013, and on August 20, 2013, macroinvertebrates were scheduled to be sampled. During this site visit there was insufficient flow to sample. During the June 18 sample, four species of fish were collected. All four species are low DO tolerant. Central mudminnow, young of year northern pike, and fathead minnow were the most frequently sampled taxa with one creek chub also sampled.

### 4.9.2. Data analysis/evaluation for each candidate cause

#### Low dissolved oxygen

There were only two samples for DO in this AUID when flow was present and it was collected on June 18, 2013, and June 11, 2015. The concentration was 10.61 mg/L and 12.79 mg/L and had a saturation of 132%. This indicates that there may be very large daily DO flux occurring at this site. The fish community sampled when analyzed through Sandburg TVI for DO shows that the fish community has a 7% chance of passing the low DO standard. Additional data for DO needs to be collected to further analyze this stressor. A third DO reading was collected on August 20, 2013, and read 13.58 mg/L with a saturation of 179%. This sample was collected under near stagnant conditions.

#### Elevated nutrients

Eutrophication is a measure of the nutrient concentrations in the water. Elevated nutrients can lead to increased primary productivity in the form of excessive algal or submerged macrophyte growth. A very limited number of water quality samples were collected in Washburn Brook. There were two samples collected in 2013 and 2015 for TP and both were below the Central Minnesota eutrophication standard of 0.100 mg/L (0.056 and 0.048 mg/L). Additionally, two samples were collected and analyzed for nitrogen. Both samples had elevated nitrogen concentrations (2.3 and 3.2 mg/L). The land use surrounding this AUID is row crop and the elevated nitrogen is coming from excess fertilizer runoff after planting occurs. There is not enough data to support nitrogen as a stressor at this time so it is inconclusive. Additional water quality samples should be collected to determine the variability in nutrient concentrations along with the variability in stream temperature and DO concentrations.

#### Lack of physical habitat

Washburn Brook is a maintained judicial ditch. The habitat features are lacking as the ditch flows adjacent to many agricultural row crop fields. During the fish sampling event on June 18, 2013, some habitat characteristics were documented. The substrate in the channel was 100% silt. There is no solid substrate in the sampling reach. The stream substrate is all non-cohesive mobile material. The MSHA shows there is no water depth variability, no stream sinuosity, unstable channel banks and very low stream velocities. Ditches are general built to carry the 100 year flood flows and are generally very wide which causes a very high width/depth ratio and no capacity for sediment transport. There is also no shade and a very narrow riparian corridor.

The MSHA score is a standardized method that compares five stream categories and is used at all biological sampling sites across MN. The score for MSHA is poor if less than 45 and good if greater than 62. Washburn Brook scores a 14 which is way below even the poor category. The only category of the five score able categories that receives a decent score is riparian; and that is only because there is some riparian grass along the banks. Figure 4.9-1 below shows the channel along with the limited grass buffer along its edge. The entire AUID and all of its tributaries are ditched or altered.

**Figure 4.9-1: Washburn Brook condition photos. Photo on left you can see the boot tracks left in the silt after the fish crew walked upstream. There is no stream features in this reach so there are no pools or riffles or even a difference in water depth.**

### Altered hydrology

There is no hydrologic data for this Assessment Unit Identification (AUID). However, we can say that the channelization and drainage of upstream wetland areas has contributed to altered hydrology which is affecting the biology of the stream. The channel is overwide allowing for fine particles to settle out and thus requiring frequent cleanouts to maintain the flow capacity. Design and construction of a two stage ditch in this system would allow for the movement of sediment, and less frequent clean outs and also possibly allow for biological recolonization.

An HSPF model was built for the RRW and Washburn Brook was modeled at its outlet downstream of AUID 641 in AUID 595. A tributary enters the stream before the outlet so the amount of discharge will be higher than at AUID 641. The model shows that the stream at the outlet has a mean discharge of 5.46 cfs, maximum discharge of 382 and a minimum discharge of 0.18 cfs. The frequency of discharge less than 1 cfs is 38% and 25.6% of the time the stream has less than 0.5 cfs. This is the downstream outlet site so estimating the low flow at AUID 641 would show around 38% of the time the stream is nearly dry based on the modeling results. Hydrologic modification is a stressor to the biology in Washburn Brook.

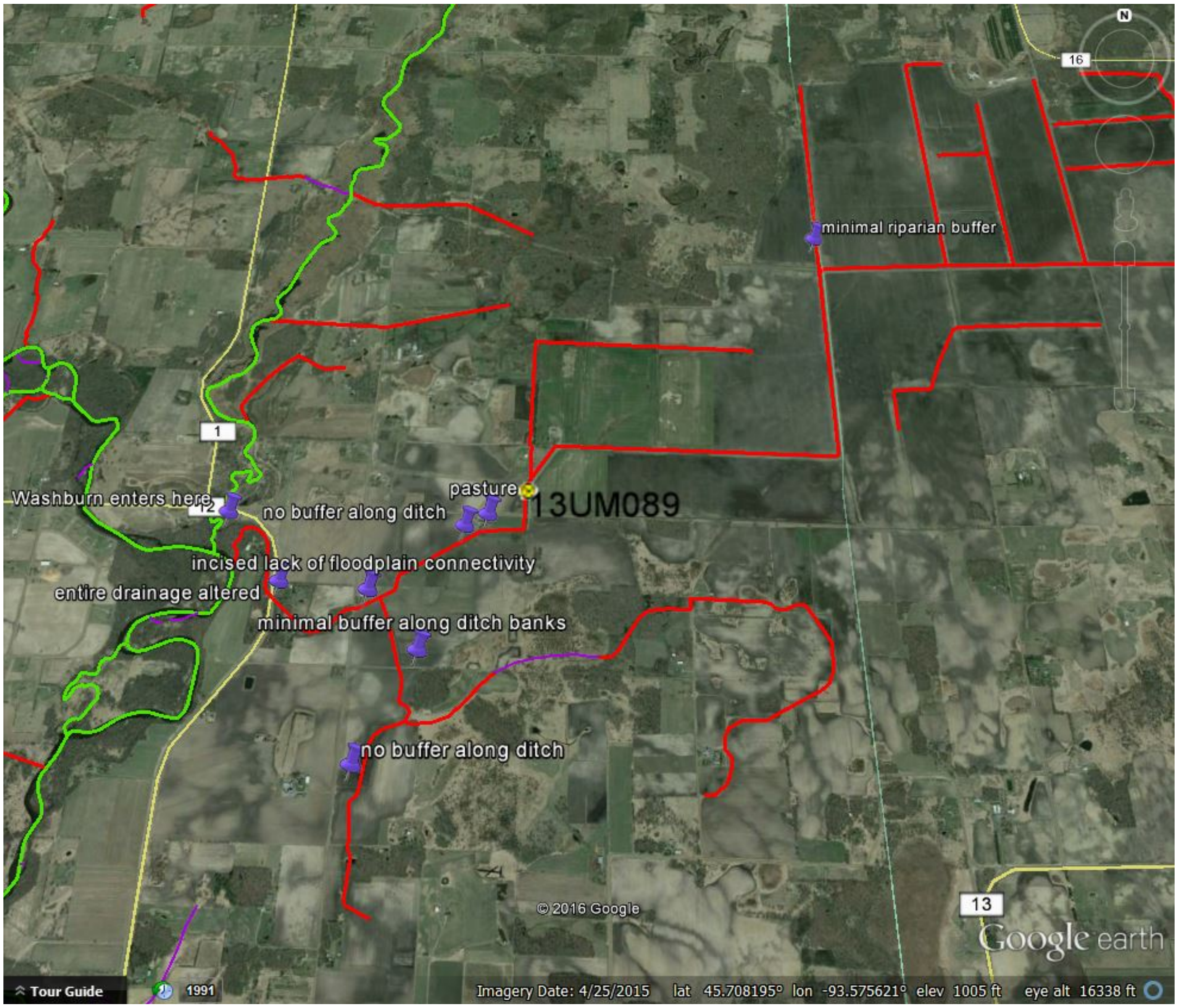



**Figure 4.9-2: Google earth aerial image of Washburn Brook and its tributaries. Notice all red lines are altered watercourse. The entire watershed is channelized.**

## 4.9.3. AUID summary

### Stressor pathway discussion

### Stressor conclusions

The primary stressors that can be identified at this point are lack of suitable habitat along with altered hydrology. The stream has been completely channelized and there is no suitable substrate or variability of habitat types in the system. It is also quite possible that low DO and eutrophication are stressors but at this time there is not enough information to make a strong case. Additional data should be collected in the future to assess the potential of these other stressors.

# 4.10. Mahoney Brook (AUID 07010207-682)

## 4.10.1. Biological communities

Mahoney Brook has one biological sampling site (00UM102). This site was sampled on June 24, 2000, and scored a 62 for F-IBI; the second fish sample was collected on June 20, 2013, and scored a 25 for F-IBI. The stream classification for fish is a Class 6 Northern Headwaters stream. Macroinvertebrates were sampled once on August 5, 2013, and scored a 52.7 with a threshold for M-IBI of 43, and passed the M-IBI.

The main difference between the two F-IBI scores is that in 2000, there were northern redbelly dace and Iowa darter sampled that were absent in 2013, which decreased the sensitive score and a lack of intolerant minnows in 2013. One northern redbelly dace was caught during a 2015 sample, but the score was still below the threshold. Figure 4.10-1 shows the metrics used to calculate the F-IBI for the two sampling events at 00UM102.

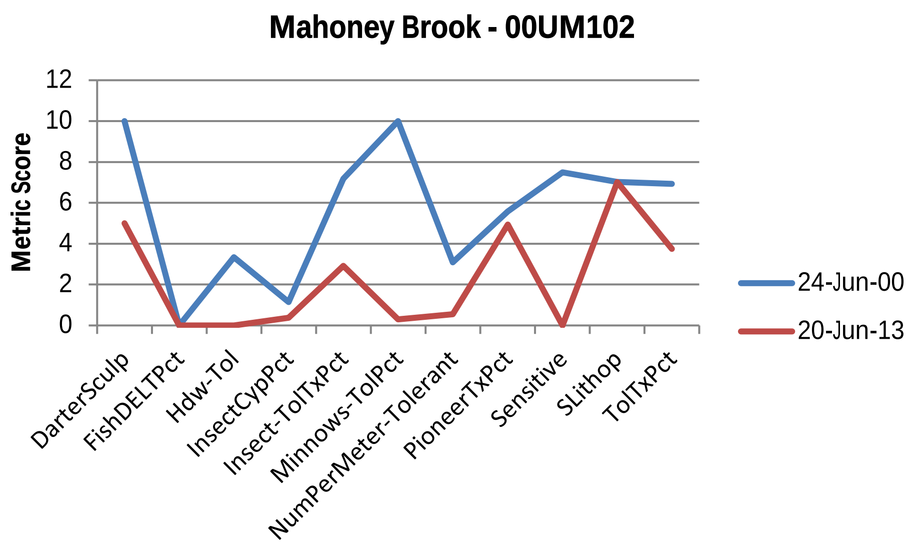



**Figure 4.10-1: Metrics used to calculate the F-IBI scores for Northern headwaters streams (Class 6). The red line represents the 2013 sampling date.**

Initially it was believed the drop in DarterSculp could be a result of the increased plant growth in the stream affecting the availability of coarse substrate habitat. After review of Fishes of Canada, it appears that the Iowa Darter, Blacknose shiner and the northern redbelly dace are all dependent on either submerged plants or filamentous algae for spawning habitat. The loss of sensitive species could be attributed to a number of variables. The addition of Bigmouth Shiner in 2013 (which is considered a "trash habitat" species) indicates something impacted the stream biology between 2000 and 2013.

## 4.10.2. Data analysis/evaluation for each candidate cause

### Low dissolved oxygen (DO)

Dissolved oxygen (DO) concentrations that are below 5 mg/L can be detrimental to the biological communities living in those streams. A YSIä sonde was deployed in Mahoney Brook from August 4 through August 20, 2015. The data was collected to determine the daily minimums for DO along with the daily flux in DO concentrations.

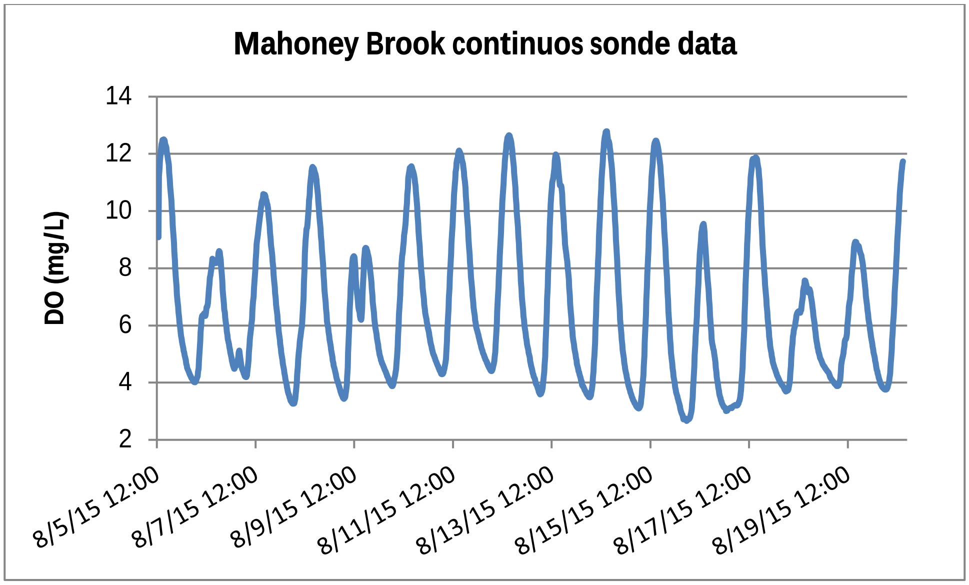



**Figure 4.10-2: Continuous DO data collected at biological site 00UM102. Data shows daily exceedances in the DO standard of 5 mg/L.**

Review of the fish community index scores suggest that something happened between the 2000 and 2013 sampling events. The fish community Tolerance Value Index (TVI) score for the 2000 sampling event shows that the DO standard would be met 35% of the time and this increases to the DO standard being met 45% of the time based on the 2013 fish community. This information indicates that low DO is a stressor in this reach. The daily DO minimum exceeded the 5 mg/L standard. The macroinvertebrates also showed that the community is dominated by low DO tolerant taxa. Table 4.10-2 below shows the metrics most commonly used to identify stressors along with the Class average for passing M-IBI score.

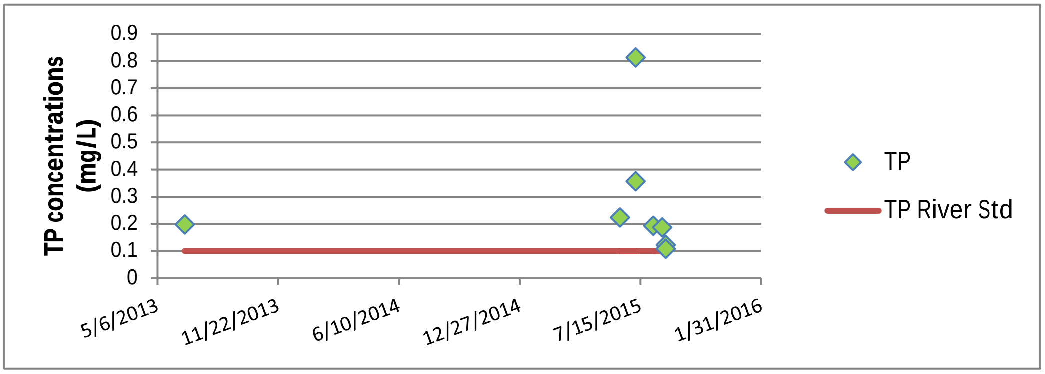
**Table 4.10-1: Comparison of a select group of metrics for macroinvertebrate comparison to the Class 6 average for sites meeting the MIBI. The yellow highlighted data shows a response that indicates a potential for stress to the macroinvertebrates.**

| | HBI_MN | Index score | Class 6 Index Score | Tolerant Taxa | Class 6 Tolerant taxa | Response | Intolerant Taxa | Class 6 Intolerant Taxa | Response |
|---|---|---|---|---|---|---|---|---|---|
| DO | 7.19 | 7.09 | 7.03 | 7 | 5.57 | Up | 2 | 6.51 | Down |
| TSS | 7.19 | 7.2 | 16.36 | 9 | 8.68 | Up | 0 | 2.804 | Down |
| N | 7.19 | 0.26 | 0.41 | 18 | 15 | Up | 1 | 2.89 | Down |

This data suggests that low DO is playing a role in the biological communities but may not be the overall driving stressor to reduced biotic productivity. Low DO is a stressor but not the main driver to the fish IBI.

### Elevated nutrients

Eutrophication can change the food web within a stream by accelerating the growth of algae and submerged aquatic macrophytes. Elevated concentrations of total phosphorus (TP) and nitrogen are the




most common nutrients associated with eutrophication. Water chemistry data was collected in 2013 and 2015. Figure 4.10-3 displays the results for TP concentrations collected at site 00UM102. The TP was always above the state standard of 0.100 mg/L for TP. This indicates that TP is elevated.

**Figure 4.10-3: Total phosphorus concentrations from biological site 00UM102. All sample concentrations were above the Central Minnesota TP standard of 0.100 mg/L.**

The continuous DO sampling that occurred in 2015 can be used to identify if DO flux is a problem in Mahoney Brook. The eutrophication standard states that a response variable must be in exceedance along with elevated TP for a stream to be considered impaired by eutrophication. If the DO flux exceeds 3.5 mg/L per day then the response variable criteria is met. As seen in Figure 4.10-4, the DO flux varies from 7.5 to 12.8 mg/L per day.

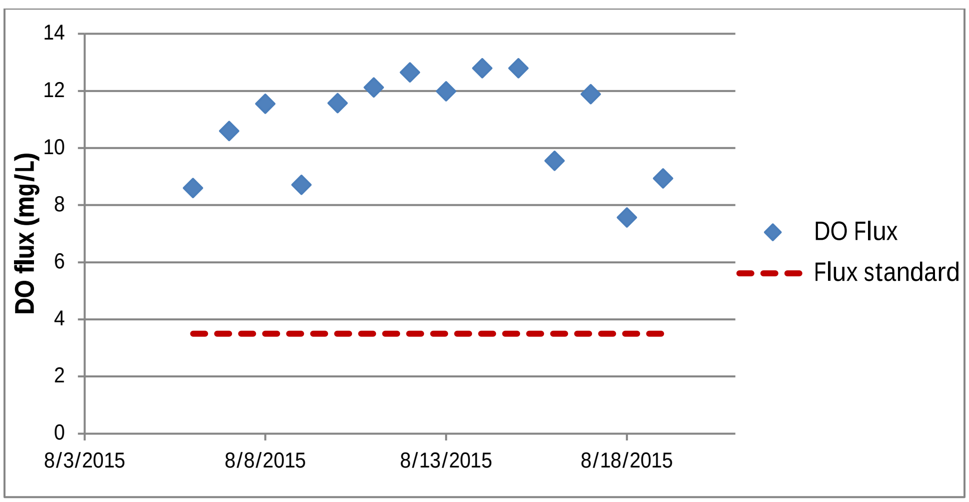



**Figure 4.10-4: Daily DO flux calculated from the continuous DO record collected in 2015 from biological site 00UM102 on Mahoney Brook.**

Elevated Chlorophyll-*a* (Chl-*a*) concentrations are a response variable for eutrophication in streams. This is a measurement of free floating algae in the water column and often is not collected in smaller streams. There were two Chl-*a* samples collected in Mahoney Brook. The August 5, 2015, concentration was 2.62 and the August 20, 2015, concentration was 3.4. Increased submerged aquatic macrophyte growth can be used as a surrogate for Chl-*a* concentrations and can be helpful in determining if eutrophication is altering the stream environment. There is evidence of elevated plant growth in Mahoney Brook as can be seen in Figure 4.10-5.

**Figure 4.10-5: Mahoney Brook showing an example of submerged aquatic macrophyte growth in stream. As the plant material dies back there is oxygen consumption due to decomposition.**

Nitrogen is also a nutrient that is responsible for eutrophication in surface water. There is a limited dataset for nitrogen that was collected in 2015. Five nitrogen samples were collected at biological site 00UM102 in July and August of 2015. The nitrogen concentrations ranged from 0.17 mg/L to 0.44 mg/L. The average was 0.28 mg/L in 2015 at site 00UM102. The macroinvertebrates suggest that elevated nitrogen may be playing a role in the community structure. There are 18 nitrogen tolerant taxa and only 1 nitrogen intolerant taxa collected in the 2013 sample. This suggests that any increase in nitrogen concentrations may have an adverse impact on the macroinvertebrate community. Looking at the fish community TVIs supplied by Sandberg there appears to be a relationship with nitrogen and the response by the fish community between the two sampling events. Sandburg used the Rankin tolerance values and the Sandburg tolerance values and calculated the nitrogen TVI for each sample date at 00UM102. Table 4.10-2 shows the TVIs scores for the parameters that showed a greater than 20% change between the 2000 and 2013 fish sampling event. Based on the fish community TVI information, it does appear that the fish community is shifting toward a nitrogen tolerant community.

There is currently not enough information to fully assess nitrogen and further sampling should occur throughout the growing season to better understand the nitrogen concentrations and variability within the stream.

The lines of evidence show that TP eutrophication is a stressor to the biological communities in Mahoney Brook.

**Table 4.10-2: Fish community TVIs based on the two sampled fish communities from site 00UM102. The difference calculated is the difference between the two scores from 2000 and 2013. Comment section addresses how to interpret the TVI differences.**

| VisitNum | 20130305 | 20000138 | Diff | PctChange | AbsPctChange | Comment |
|---|---|---|---|---|---|---|
| HDSTVR_PctImperv | 2.73100775 | 1.7031746 | 1.02783315 | 0.60348079 | 0.603480786 | indicates shift towards species associated with impervious surface in the watershed |
| ChemTVR_Nitrate | 3.30310078 | 2.13333333 | 1.16976744 | 0.54832849 | 0.548328488 | indicates shift towards species with greater nitrate tolerance (Ed Rankin tolerance values) |
| ChemT | 3.135788 | 2.060638 | 1.075 | 0.5217556 | 0.5217556 | indicates shift towards species with |

| VisitNum | 20130305 | 20000138 | Diff | PctChange | AbsPctChange | Comment |
|---|---|---|---|---|---|---|
| V_Nitrogen | 93 | 98 | 14996 | 1 | 15 | greater nitrate tolerance (Sandberg tolerance values) |
| ChemTV_NitrogenRA | 3.46831033 | 2.36802298 | 1.10028735 | 0.46464386 | 0.464643862 | indicates shift towards species with greater nitrate tolerance (Sandberg tolerance values) |
| ChemTVR_TSS | 49.2217054 | 36.3603175 | 12.861388 | 0.35372045 | 0.353720453 | indicates shift towards species with greater TSS tolerance |
| HabitatTV_PctEmerMac | 2.96347665 | 4.22153247 | 1.25805582 | 0.29800927 | 0.298009273 | indicates shift away from species associated with emergent macrophytes |
| ChemTVR_Ecoli | 606.855039 | 467.698413 | 139.156626 | 0.29753495 | 0.297534955 | indicates shift towards species associated with high E.coli levels |
| HabitatTV_MBankEros | 0.22953305 | 0.18505951 | 0.04447354 | 0.24032022 | 0.240320216 | indicates shift towards species associated with bank erosion |
| HabitatTV_PctEmerMacRA | 3.55730001 | 4.63096328 | -1.07366327 | -0.23184448 | 0.23184448 | indicates shift away from species associated with emergent macrophytes |
| HDSTVR_Audensity | 37.0635659 | 30.3484127 | 6.71515319 | 0.22126868 | 0.221268679 | indicates shift towards species associated with "animal units" (i.e., feedlots) in the watershed |
| HabitatTV_PctDistLURA | 29.8377958 | 24.8071851 | 5.0306107 | 0.20278845 | 0.202788454 | indicates shift towards species associated with watershed disturbance (in general) |

### Lack of physical habitat

Habitat is measured using the MSHA method during the time of fish sampling. The MSHA score is a standardized scoring system used across the state to assess the current condition of habitat at the sampled stream reach. If a site scores a 45 or below the habitat is considered poor; if a site scores above a 66 the habitat is considered good. Mahoney Brook scored a 63 on the MSHA during the 2013 fish visit. The site visit in 2015 scored a 47. The MSHA was not collected during the 2000 fish visit. Mahoney Brook is a small tributary to Cedar Creek and the sampling site is located on a natural channel section. This stream reach is bordered on both sides by altered sections of channel. The entire upstream portion of the AUID is channelized and is draining some extensive wetland areas. The MSHA has five main categories that are summed to create the overall score. When looking at the five main categories there are subcategories that can be evaluated to help explain why a score is achieved. Two of the five categories have subcategories that are directly linked to habitat features in the stream. The two categories explored in depth here are substrate and channel morphology. The substrate score was low because the substrate is made up of 100% sand and there is no coarse substrate available. The channel morphology score is low because there is fair sinuosity, pool width = riffle width (although the substrate category lists the riffle as 100% sand, this would not be a riffle at this point), channel stability is moderate (meaning erosion of banks is present) and channel development is fair (riffles are absent or poorly developed). The substrate category scores 14 out of 27 possible and the channel development scores a 20 out of a maximum of 36.

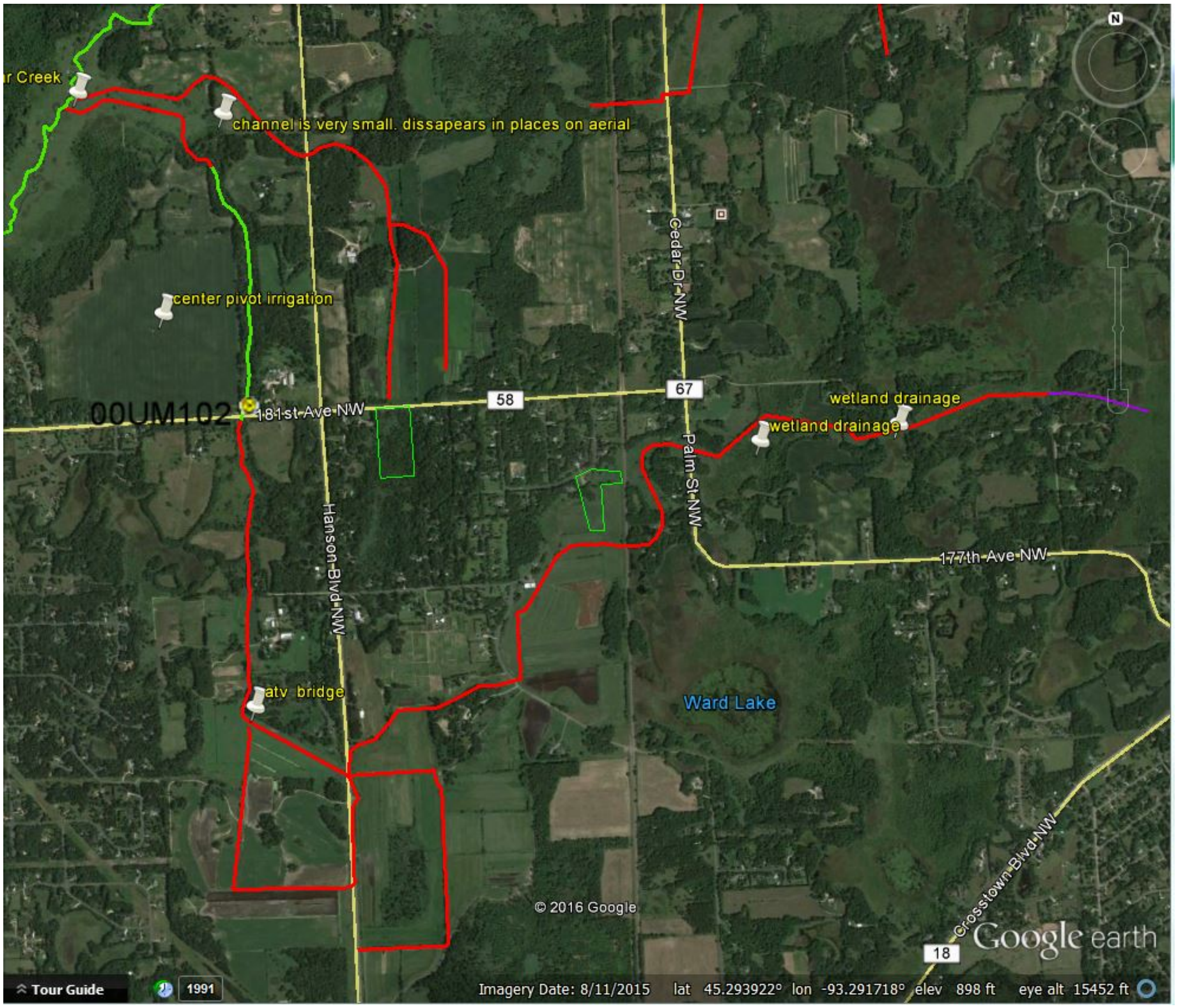



**Figure 4.10-6: Google Earth aerial photo from August 11, 2015, showing the sampling site and the watershed of Mahoney Brook. The red lines indicate altered channel while the green line indicates natural channel. Majority of the stream has been altered.**

Habitat substrate appears to be limiting the fish community in Mahoney Brook. Based on the habitat TVI scores that are presented in Table 4.10-2 above there appears to be a direct link to changing habitat conditions between the 2000 and the2013 fish sampling event. One TVI shows that the fish community is moving away from community requiring submerged vegetation; another TVI shows a community that is more tolerant of bank erosion; and another TVI shows the fish community moving toward a community affected by general watershed disturbance. The link with habitat is fairly strong taking into account the sand substrate and the associated amount of stream alteration and residential development causing watershed disturbance that has occurred in the last 2 decades.

### Altered hydrology

No gaging station was located on Mahoney Brook to use for hydrograph analysis. It is believed that due to the nature of the upstream channelization, altered hydrology is affecting the biological community. The delivery of water during storm events and the lack of storage in the upstream areas tends to make the system flashy with erratic fluctuations in stream flow. The accumulated sand that is documented at the site is likely being transported down the ditch system as flows are flashy and the upstream banks are experiencing erosion. Altered hydrology is inconclusive for this AUID and a gage site should be installed to further understand the connection of ditching and water delivery at this site. An Hydrological Simulation Program – FORTRAN (HSPF) model was built for the RRW predicting stream discharge from 1996 through 2009. Mahoney Brook has a record for the outlet at AUID 682, the mean stream discharge was 5.27 cfs and the highest predicted discharge was 86 cfs. The stream was below 1 cfs for 1.5% of the modeled period. Reviewing the frequency of low flows as 1.5 cfs shows that 11% of the time Mahoney Brook is below this discharge. Looking at higher flow frequency the model predicts that the stream is above 21 cfs for 2.5% of the record. The peak flows occurred in spring through 2001 and then shifted to fall from 2002 through 2007.

## 4.10.3. AUID summary

### Stressor pathway discussion

The amount of channelization in this AUID is causing systemic problems for the biology. The channelization has altered the rate and timing of runoff and is also causing a change in the delivery of nutrients through the stream system.

### Stressor Conclusions

The main stressors affecting the fish community in Mahoney Brook are eutrophication caused by elevated TP concentrations and change in habitat due to general watershed disturbance. Altered hydrology is also playing a role in the change in the fish community but at this time not enough information is available to make a conclusion. Elevated nitrogen is present but additional monitoring for nitrogen should be conducted to determine the impact it is having on the biology. Low DO is also present in Mahoney Brook as the daily minimums are below the 5 mg/L state standard. The biological communities are being impacted by the low DO concentrations in Mahoney Brook.

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