Buffalo River Watershed Biotic Stressor Identification

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

Minnesota Pollution Control Agency

July 2014

Cover photo. The impact of excessive drainage in this watershed has left its mark on the stream channel and the biological communities inhabiting the Buffalo River and its tributaries. Photo credit Dave Friedl, MDNR.

Legislative Charge

Minn. Statutes § 116.011 Annual Pollution Report

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HIST: 1995 c 247 art 1 s 36; 2001 c 187 s 3

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Acronym List

AUID	Assessment Unit Identification
BANCS	Bank Assessment for non-point sources consequences of sediment
BEHI	Bank Erosion Hazard Index
BMP	Best Management Practices
CADDUS	Causal Analysis/Diagnosis Decision Information System
CR	County Road
CCRP	Continuous Sign-up Conservation Reserve Program
CD	County Ditch
cps	cubic feet per second
CRP	Conservation Reserve Program
DHC	Deerhorn Creek
DO	dissolved oxygen
DEM	digital elevation model
EPA's	U.S. Environmental Protection Agency
EPT	Ephemeroptera Plecoptera Trichoptera
FDR	Flood Damage Reduction
F-IBI	Fish – Index of Biological Integrity
FWMC	Flow weighted mean concentration
GIS	Global Information System
GPS	Global Positioning System
IBI	Index of Biological Integrity
LiDAR	Light Detection and Ranging
LiDAR LAS	LiDAR file format
MDA	Minnesota Department of Agriculture
M-IBI	Macroinvertebrate – Index of Biological Integrity
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MRL's	Method Reporting Limits
MSHA	Minnesota Stream Habitat Assessment
NBS	Near Bank Stress
NCHF	North Central Hardwood Forest
Nitrate N	Nitrate Nitrogen
No_3 NO_2	Nitrate plus Nitrite
NRE	Natural Resource Enhancement
NTU's	Nephelometric Turbidity Units
RIM	Re-invest in Minnesota
RR	Railroad
SID	Stressor Identification
SOE	Strength of evidence
SPI	Stream Power Index
TIV	Tolerance indicator values
TMDL	Total Maximum Daily Load
TP	Total phosphorus
TSS	Total suspended solids
VSS	Volatile suspended solids
WMA	Wildlife Management Area

WRAPs	Watershed Restoration and Protection Strategy
WRP	Wetland Reserve Program
Wbkf	Bankfull width

Executive Summary

A Stressor Identification (SID) analysis is a step-by-step approach for identifying the probable cause(s) of biological impairment in a stream system. There are four stream reaches within the Buffalo River Watershed that were identified as impaired for aquatic life based upon poor Index of Biological Integrity (IBI) scores that indicate an unhealthy biological community. Further evaluation was completed to connect the biological community to the stressor(s) causing the impairment. This report describes the evaluation of the environmental data and the diagnoses of the probable causes for the biological impairments. Numerous candidate causes for impairment were evaluated using the U.S. Environmental Protection Agency's (EPA's) Causal Analysis/Diagnosis Decision Information System (CADDIS), the Minnesota Pollution Control Agency's (MPCA's) biological Total Maximum Daily Load (TMDL) protocols, and a weight of evidence analysis.

The Buffalo River Watershed is a complex system with great diversity in topography, stream channel type and condition, soils, and drainage intensity. This diversity results in a variety of conditions that support a broad spectrum of fish and aquatic macroinvertebrate life. The SID analysis determined the probable stressors in each of the four impaired reaches. The stressors found to be acting upon the Buffalo River system include high sediment/turbidity, lack of connectivity, lack of habitat availability, altered hydrology, and low dissolved oxygen (DO). In addition to these stressors, high phosphorus, high nitrate, and pesticides were reviewed for their potential influence on the biology of the impaired reaches.

The lack of connectivity was determined to be a primary stressor impacting three of the four bio-impaired stream reaches. The presence of fish migration barriers or obstacles can have a major impact to the biodiversity and health of a stream system. Many stream fish require and utilize different habitat types during their various life stages. Fish often travel great distances to find the right habitat to support specific requirements. Migration obstacles in the Buffalo River system were related to the presence of man-made dams, road crossings where culverts were obstructing passage, and beaver dams. Migration barriers that prevent or limit the movement of fish within the system reduce the health of the fish community, as well as biomass production and can result in an increase in more tolerant generalist-type species.

A major fish barrier on the South Branch Buffalo River is located 1.7 miles west of Glyndon, Minnesota on the south side of U.S. Highway 10. The sheet pile dam is just two river miles upstream from the confluence of the South Branch Buffalo River and the mainstem Buffalo River. This dam acts as a fish barrier during low to moderate flows, preventing the migration of fish from the Buffalo River, as well as the Red River into the South Branch Buffalo River, in essence limiting fishery access to roughly 50% of the stream miles present in the Buffalo River Watershed. Three of the four impaired reaches are found upstream of this barrier.

Altered hydrology is another important stressor in the Buffalo River Watershed. Urban and primarily agricultural drainage within this watershed has changed the runoff hydrograph to one that has higher peak flow rates and lower base flow rates. Wetland (storage) loss, channelization, ditching, tiling, the landuse change from grassland to row crop, and the increase in impervious surfaces contribute to the increase in runoff rates. The "flashy" hydrograph associated with intensive drainage tends to destabilize and erode the stream banks and beds, resulting in deeper and wider stream channels. The banks and beds of streams in this condition can contribute significant sediment loads downstream. In addition, the loss of bank and bed habitat through sloughing, erosion, and sediment deposition results in poor habitat conditions for most species. The increase in the utilization of agricultural tile has contributed to the altered hydrograph in recent years and the trend for increased tiling in the watershed is predicted to worsen the situation.

The loss of groundwater base flow that results from intensive drainage can have significant impacts on the biota during the typical late summer dry period when peak stream temperatures and diminished flow rates can impact the more sensitive members of the fish and macroinvertebrate communities. This summer peak water

temperature period is typically when the lowest DO levels occur in these streams and loss of flow from cold groundwater sources, previously depleted by tiling, exacerbates these conditions. Altered hydrology was found to be a primary stressor in the South Branch Buffalo River, Deerhorn Creek and Spring Creek and is considered a secondary stressor in the Upper Buffalo River reach.

Erosion from agricultural field sources and the resulting increase in sediment and turbidity also play an important role in biological impairments within this watershed. Many examples are documented where spring runoff and summer storm events have resulted in hundreds of tons of sediment washing off fields and into watercourses. The Stream Power Index (SPI) tool helps to identify where slope and area are such that the potential for significant erosion exists. Reconnaissance surveys of streams with high SPI scores found that when sufficient vegetation is in place in the form of intact riparian vegetation, grassed waterways or buffers, the erosion is typically minimal. In contrast, where the vegetative buffers are poor or absent, significant erosion sources in the form of blowouts, gullies, and head cuts were found. Sediment was identified as a primary stressor in the South Branch Buffalo River and Deerhorn Creek and a secondary stressor in the Upper Buffalo River.

One of the primary sources of sediment in the system is the farming-through of headwater streams. These intermittent streams that are cultivated and planted each spring tend to erode annually during storm events and can be a significant source of nutrients and sediment to the receiving stream. Headwater streams, that typically only flow in response to spring snow melt and storm events, act as the capillaries of the stream system by connecting the land/watershed to the stream. In a natural condition these streams provide significant ecological function in water quality enhancement, habitat, infiltration, nutrient uptake, etc. Their importance to the stream system is brought to light by the fact that cumulatively these first and second order streams compose over two-thirds of the total stream length in a typical river network (Leopold et al., 1964 in Freeman et. al., 2007).

Channelization and the resultant loss of habitat is one of the primary biological stressors within the Buffalo River Watershed. Sixty two biological sites were selected for monitoring the fish and macroinvertebrate communities in the Buffalo River Watershed and of these sites, 33 (53.2%) are channelized. A review of the biological data finds that 18 channelized reaches have poor fish IBI results. Those channelized portions that do contain healthy biotic communities are typically reaches that have not been "maintained" or excavated for a relatively long time. Given time, and a watershed that does not contribute heavy sediment loads, these streams can recover biologically and sometimes contain good fish and macroinvertebrate communities with strong IBI scores. Streams that tend to receive heavy sediment loading from either in-stream or external sources are typically cleaned out on a more regular basis and are not often able to recover biologically between clean outs. Degraded habitat is also a result of lost connectivity, sedimentation, and altered hydrology. Loss of habitat was determined to be a primary stressor in the South Branch Buffalo River and secondary stressor in Deerhorn Creek and the Upper Buffalo River.

This report provides background information in the areas of landuse, hydrology, watershed health, precipitation, and stream geomorphology. A discussion of the candidate causes for biological impairment is presented followed by the assessment results of each impaired reach and the conclusions that culminate in the determination of the biological stressors that are impacting each impaired reach. The report concludes with a discussion about protection and restoration strategies that could be considered to restore the biological health of the Buffalo River Watershed.

Introduction

The Buffalo River Watershed was assessed in 2009 for aquatic recreation, aquatic consumption and aquatic life beneficial uses. Based on this investigation, it was determined that four stream reaches were impaired for fish and/or macroinvertebrates, as part of the aquatic life use assessments. One of the impaired reaches is the headwaters of the Buffalo River beginning at the outlet of Buffalo Lake and continuing to the confluence with an Unnamed ditch located about 1.5 miles NE of Callaway. The other three impaired reaches are tributaries to the Buffalo River: Deerhorn Creek, the South Branch Buffalo River and Spring Creek. This report connects the biological communities to the stressor(s) causing the impairments and negative impacts to the biological communities. Stressors can interact with each other and can be additive to the stress on the biota. The Buffalo River Monitoring and Assessment Report is available with background information about the watershed and the results of recent monitoring and assessment.

This report describes the step-by-step analytical approach, based on the EPA's SID process, for identifying probable causes of impairment in a particular system (Figure 1). In the Buffalo River Watershed, stressors that were examined for possible cause of biotic impairment were low DO, high nitrate-nitrite, excess phosphorus, high turbidity/sediment, lack of habitat, lack of connectivity, pesticides, and altered flow regime. Other stressors were considered but did not have sufficient evidence for further analysis.

Organization Framework of Stressor Identification

The SID is prompted by decisions derived from the biological data, indicating that a biological impairment has occurred. Through a review of available data, stressor scenarios are developed that may accurately characterize the impairment, cause, and sources/pathways of the various stressors. Confidence in the results often depends on the quality of data available to the SID process. In some cases, additional data collection may be necessary to accurately identify the stressor(s).

Stressor Identification draws upon a broad variety of disciplines, such as aquatic ecology, biology, geology, geomorphology, hydrology, chemistry, land-use analysis, and toxicology. Strength of evidence (SOE) analysis is used to develop cases in support of, or against various candidate causes. Typically, the majority of the information used in the SOE analysis is from the study watershed, although evidence from other case studies or scientific literature can also be drawn upon in the SID process.

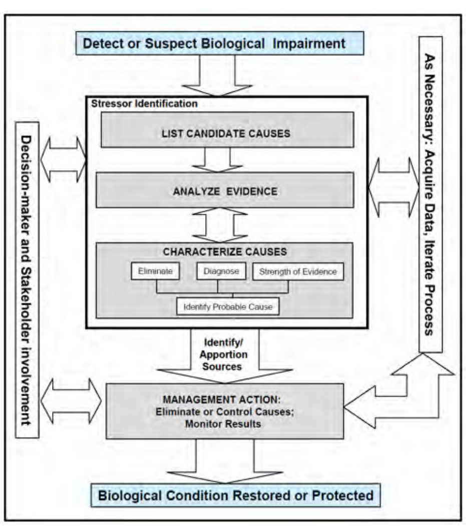


Figure 1. Conceptual model of stressor identification (SID) process (Cormier, et.al. 2000).

Completion of the SID process does not result in a finished TMDL study. The product of the SID process is the identification of the stressor(s) that are having a negative effect on the stream biology. Those stressors, such as turbidity/sediment, that can be allocated as a load can have a TMDL load allocation developed. In other words, the SID process may help confirm excess fine sediment as the cause of biological impairment, however a separate effort is then required to determine the TMDL and implementation goals needed to restore the impaired condition.

Report Format

The SID report begins with background information on monitoring stations, landuse, hydrology, etc. Middle sections provide discussion regarding the candidate stressors. Within these sections there are information about how the stressor(s) relates to the Buffalo River Watershed broadly, standards and ecoregion norms, effects on biology, sources and causal pathways.

The next section is organized to discuss each impaired reach and the particular stressors affecting it, in detail. Each reach on a stream is identified with a number called an AUID and it is with this number that the reaches are most often referred to. In addition it discusses implementation of measures that can be utilized to protect and restore the health of the stream resource. The final section is provided as a transition from the SID findings to implementation of strategies to address the stressors.

Monitoring Stations

Stations identified in Figure 2 were primarily for water chemistry collection while Figure 3 shows the biological monitoring stations. Some of the stations are co-located. Figure 4 shows the biologically impaired reaches that were studied in the report. Please see the Environmental Data Access website at http://cf.pca.state.mn.us/water/watershedweb/wdip/search_more.cfm for the location information regarding the water chemistry sites and see Appendix 2 in the Buffalo River Watershed Monitoring and Assessment Report for biological monitoring station locations within the Buffalo River Watershed.

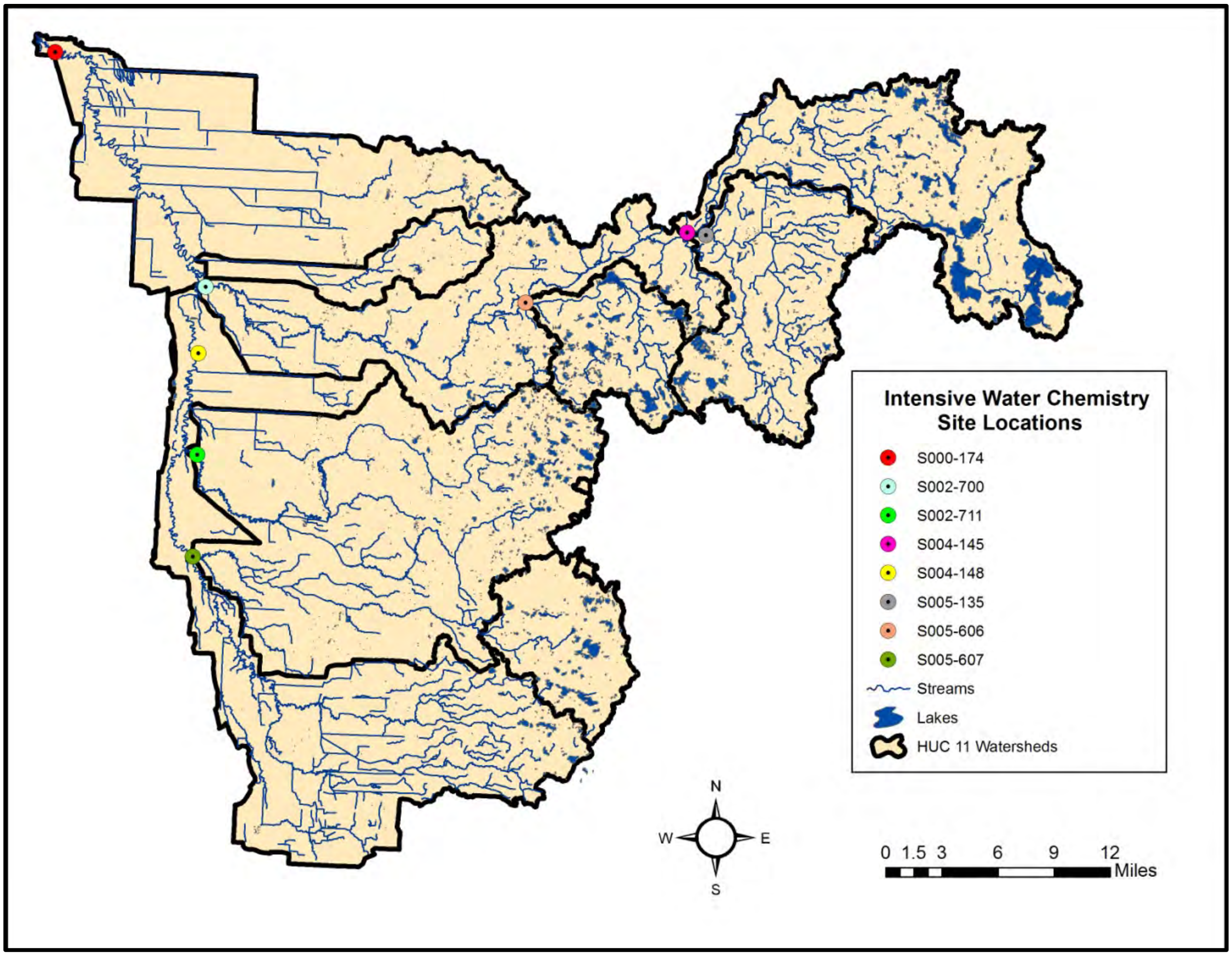


Figure 2. Map of water chemistry stations in the Buffalo River Watershed.

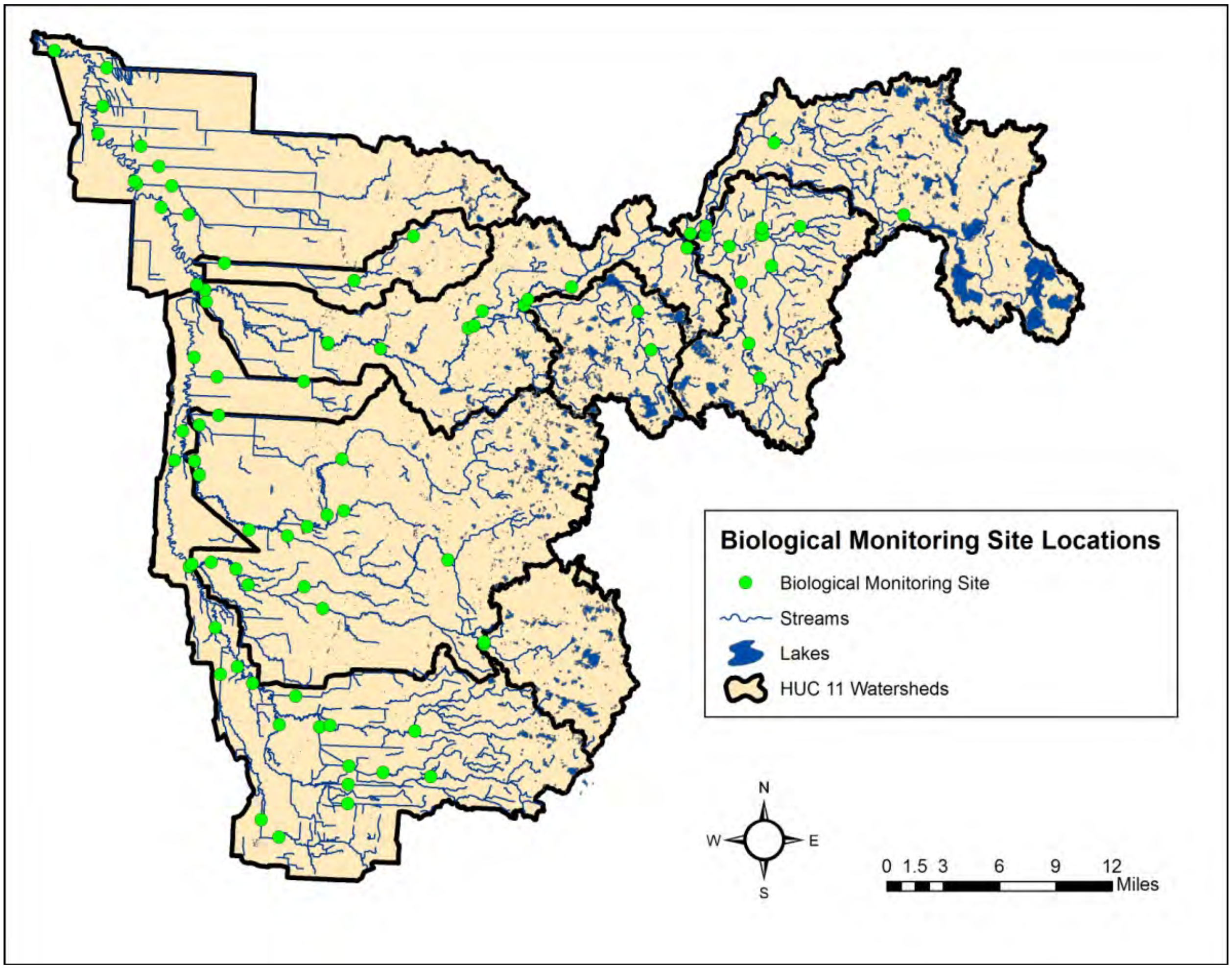
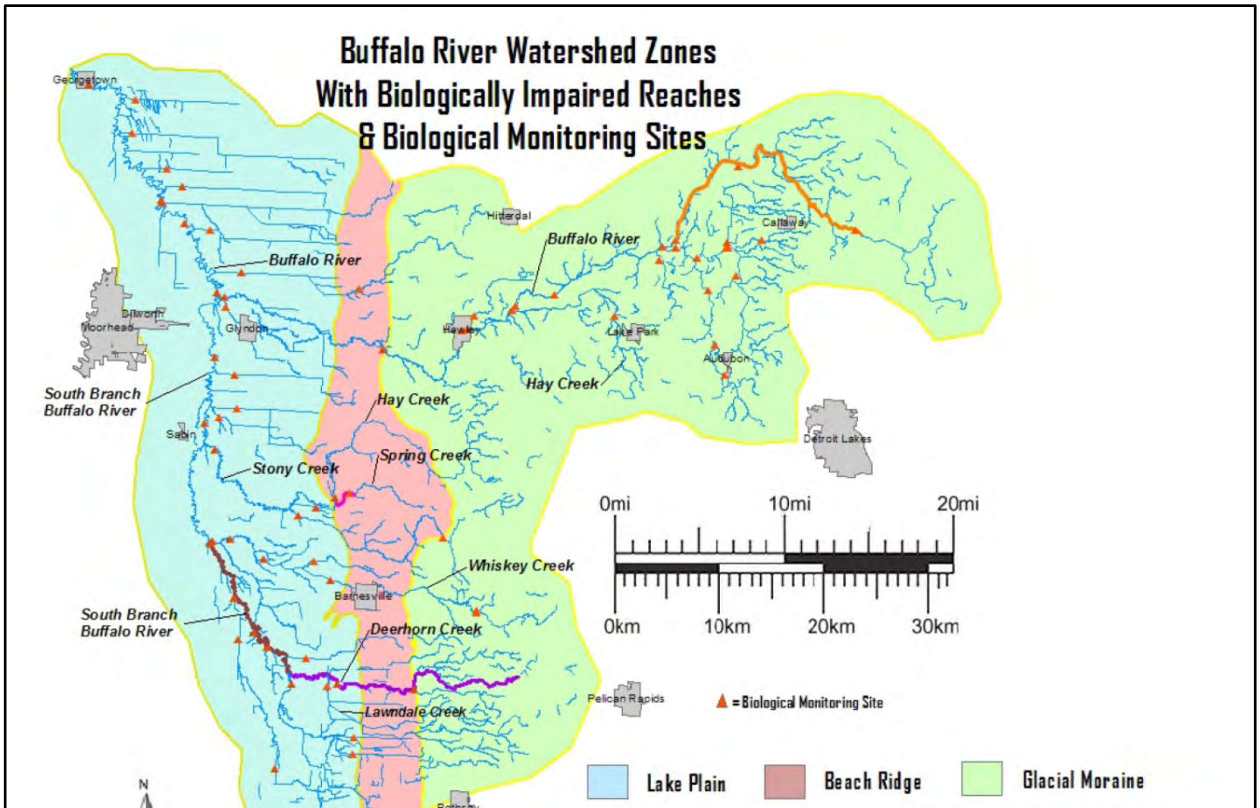


Figure 3. Biological monitoring site locations in the Buffalo River Watershed.

Summary of Biological Impairments

Fish and macroinvertebrate communities were assessed as part of the aquatic life use portion of the watershed assessment. The fish and macroinvertebrates within each stream reach or AUID were compared to a regionally developed threshold, confidence interval and a weight of evidence approach was utilized. Four AUIDs are currently impaired for a lack of biological assemblage of poor fish or macroinvertebrate communities (Figure 6). The biological data that were considered during the assessment process were collected from 2005 to 2010 with the most intensive work conducted in 2009. Of the four listed AUIDs, three are impaired for both fish and macroinvertebrates (Upper Buffalo River, Deerhorn Creek and Spring Creek) and one for only macroinvertebrates (South Branch Buffalo River).



			Impairments	
Stream Name	AUID #	Reach Description	Biological	Water Quality
Buffalo River	09020106-593	Buffalo Lk to Unnamed ditch	Fish IBI / Invertebrate IBI	*E. coli*, Turbidity
Buffalo River, South Branch	09020106-505	Deerhorn Cr to Whiskey Cr	Invertebrate IBI	*E. coli*, Turbidity
Deerhorn Creek	09020106-507	Headwaters to S Br Buffalo R	Fish IBI / Invertebrate IBI	*E. coli*, Turbidity
Spring Creek	09020106-534	Unnamed Cr to Hay Cr	Fish IBI / Invertebrate IBI	*E. coli*

Figure 4. Map of the Buffalo River Watershed showing AUIDs with biological impairments.

The fish and macroinvertebrate thresholds and confidence limits are shown by class in Table 1. Those stations that have an IBI score that fall below the threshold are considered impaired. Appendices 1 and 2 shows the fish and macroinvertebrate IBI scores by station for the AUIDs that are impaired. The IBI scores are color coded by relationship to threshold and confidence interval which is available in Appendix 4.

Table 1. Fish and Macroinvertebrate class, IBI thresholds and confidence limits.

Class	Class Name	IBI Threshold	Upper CL	Lower CL
Fish				
1	Southern Rivers	39	50	28
2	Southern Streams	45	54	36
3	Southern Headwaters	51	58	44
5	Northern Streams	50	59	41
6	Northern Headwaters	40	56	24
7	Low Gradient	40	50	30
Macroinvertebrates				
2	Prairie Forest Rivers	30.7	41.5	19.9
5	Southern Streams RR	35.9	48.5	23.3
6	Southern Forest Streams GP	46.8	60.4	33.2
7	Prairie Streams GP	38.3	51.9	24.7

Table 2. Fish and Macroinvertebrate IBI scores and class by station for impaired reaches.

Reach	AUID	Station	Year	Fish IBI score	Fish class	Invert IBI Score	Invert class
Upper Buffalo River	09020106-593	09RD012	2009	51	5	48.28	7
	09020106-593	09RD012	2009	38	5	NA	NA
	09020106-593	09RD024	2009	27	5	40.68	6
	09020106-593	09RD038	2009	42	5	25.70	7
	09020106-594	09RD005	2009	50	5	54.51	7
	09020106-594	09RD005	2009	47	5	NA	NA
Buffalo River, South Branch Buffalo River	09020106050-503	08RD081	2009	71	7	31.84	7
	09020106050-503	09RD006	2009	58	2	37.02	2
	09020106050-504	09RD019	2009	0	7	0	7
	09020106050-505	05RD037	2009	69	7	21	7
	09020106050-505	05RD118	2009	53	7	31.93	7
	09020106050-505	08RD080	2009	70	7	24.51	7
	09020106050-505	94RD004	2009	65	7	40.5	7
Deerhorn Creek	09020106050-507	09RD052	2009	2	7	24.32	7
	09020106050-507	09RD047	2009	0	7	9.04	7
Spring Creek	09020106-534	09RD022	2009	43	3	30.92	5

Table 3. IBI descriptors by color.

Scores Color Coded by Health of Bio-Community	At or Below Lower Confidence Limit	At or Below Threshold, Above Lower Confidence Limit	At or Below Upper Confidence Limit, Above Threshold	Above Upper Confidence Limit
Biological Condition	Poor	Fair	Good	Very Good
Impairment Status	Impaired	Impaired	Not Impaired	Not Impaired

Each IBI score is made up of fish or macroinvertebrate metrics that are based on community structure and function and that provide a metric score. 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, with a total maximum possible score for each being 100.

Landuse

The Buffalo River Watershed landuse is comprised of 78% agriculture, 7% forest and nearly equal portions of urban (5%), grassland (4%), open water (3%) and wetland (3%) (Figure 5). Row crop agriculture increases from east to west as the forest acres decrease and soil fertility increases (Figure 6). Along with the increase in tillable land comes an increased intensity of drainage.

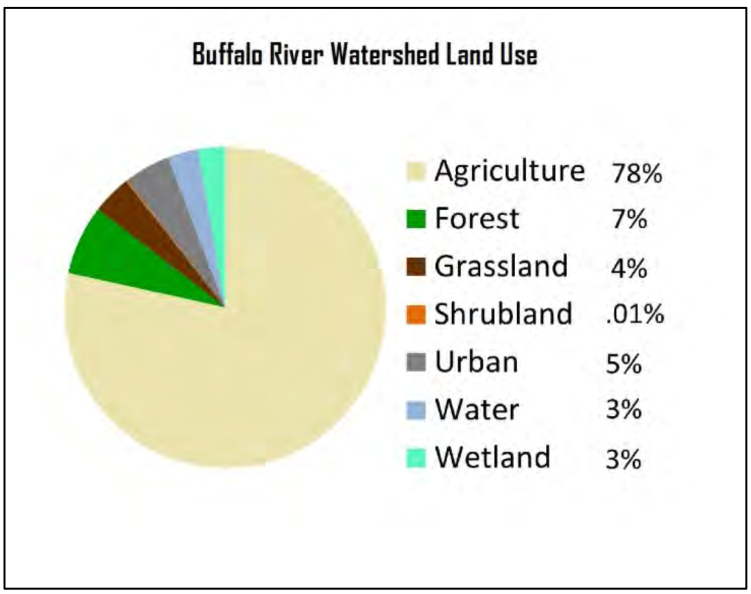


Figure 5. Buffalo River Watershed percent landuse.

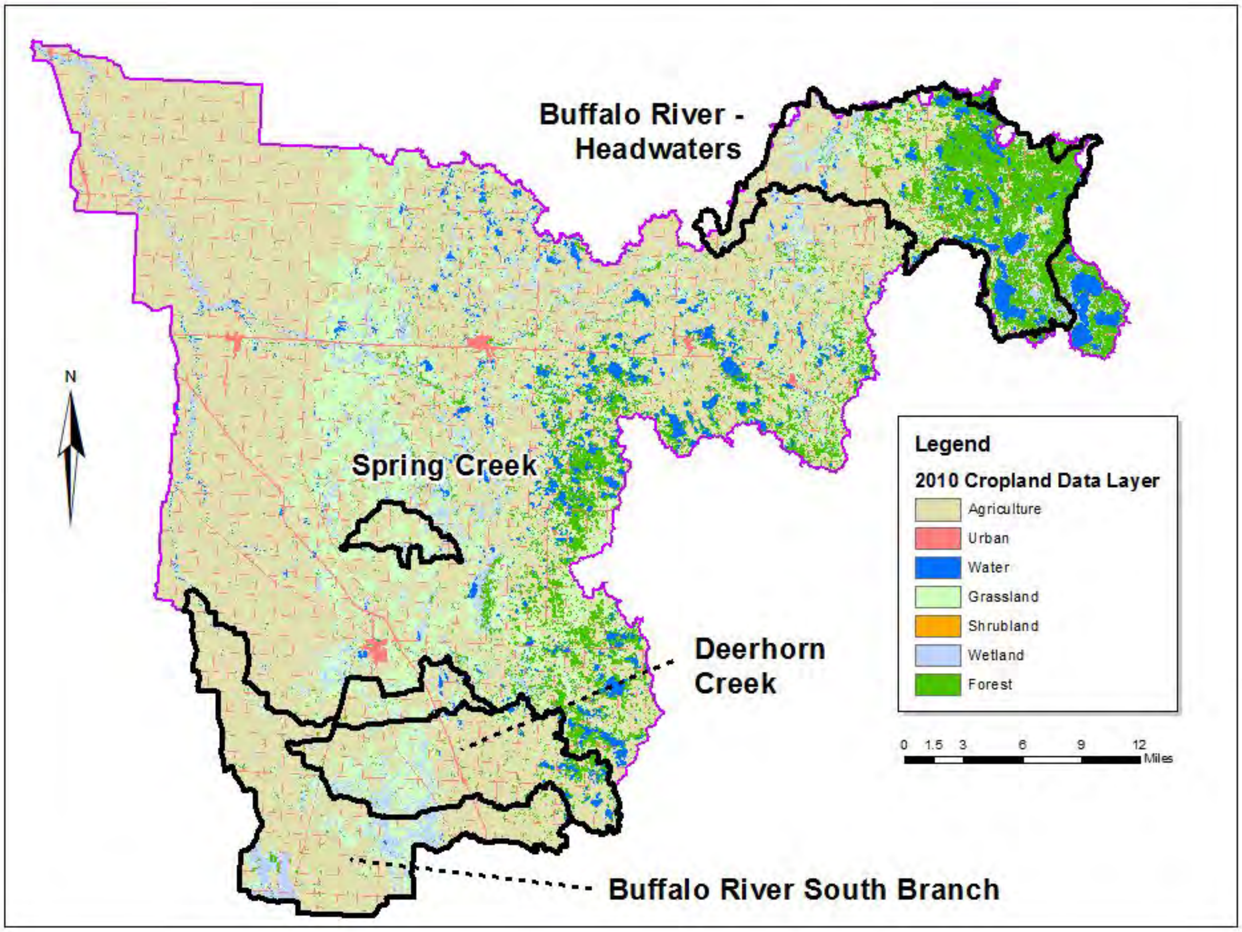


Figure 6. Buffalo River Watershed landuse map with impaired subwatersheds.

The Buffalo River Watershed overlaps three EPA Level 3 Ecoregion boundaries (Figure 7). A small portion (16 square miles) of the northeast part of the watershed is in the Northern Lakes and Forests Ecoregion which is dominated by forested landuse with intermixed lakes. The North Central Hardwoods Ecoregion makes up 319 square miles of the Buffalo River Watershed and is characterized by decreasing amounts of forest and more agriculture. It is often referred to as the transition zone between the heavily forested eastern region to the agriculturally dominated western region. The Lake Agassiz Plain Ecoregion is the lakebed area of Lake Agassiz that was made up of tall grass prairie and wetlands prior to conversion to row crop agriculture. This area is comprised of 797 square miles within the Buffalo River Watershed.

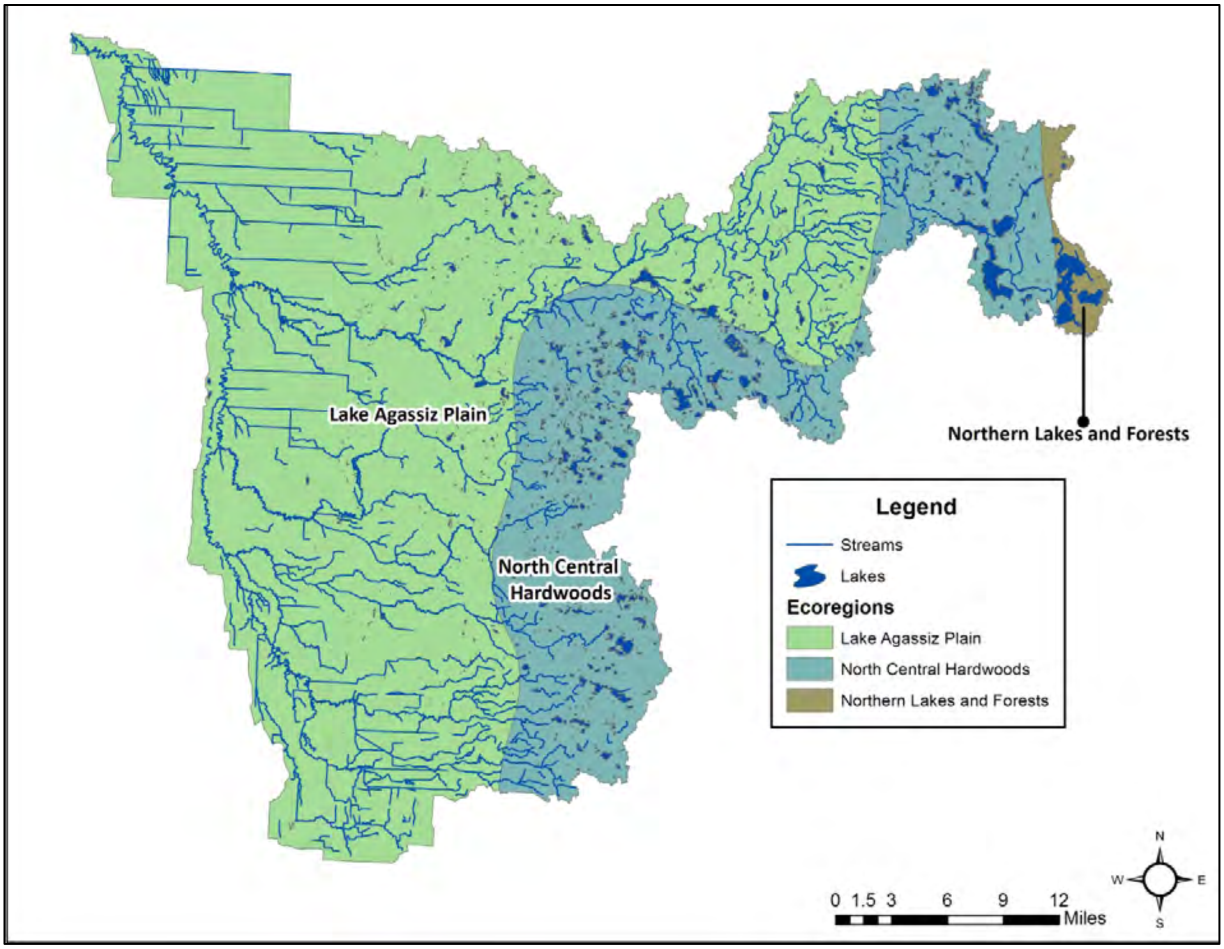


Figure 7. Buffalo River Watershed with ecoregion boundaries.

Hydrologic Features

The Buffalo River Watershed consists of three distinct geographic landforms that impact the quality and quantity of flow to the river. These landforms, oriented from east to west, include the Glacial Moraines, the Agassiz Beach Ridges and the Lake Plain (Figure 8). Changes in land use, soil type, and topography (stream gradient) from each zone have a significant impact on watershed hydrology and water quality. These features or zones are present in the southern six HUC-8 subwatersheds (including the Buffalo River) that drain to the Red River from Minnesota.

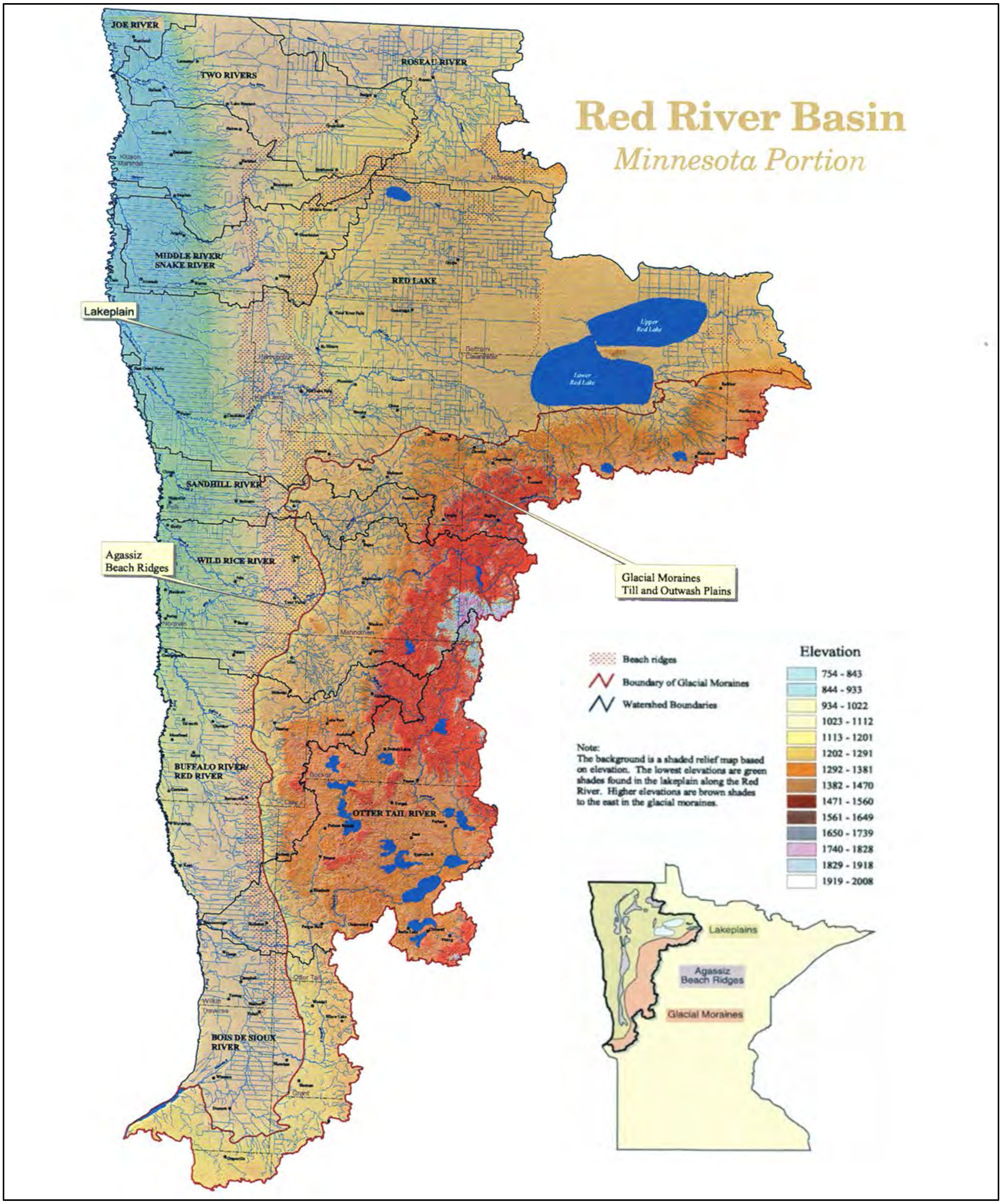


Figure 8. Hydrologic Features in the Minnesota Portion of the Red River Basin (Source: Miller, C., et.al. 2001).

The Glacial Moraines are characterized by forested and mixed forest/ag land use with numerous lakes and wetlands. Landuse within this zone is broken out and described in Figure 9. Elevations range from 1600 feet (above mean sea level) along the eastern fringe of the watershed to 1200 feet bordering the western edge of this landform. This region retains a greater percentage of its pre-settlement hydraulic storage than the beach ridge and lake plain zones. This storage serves to buffer the watershed from storm and snow melt runoff and supply the stream system with base flow from groundwater and surface water storage.

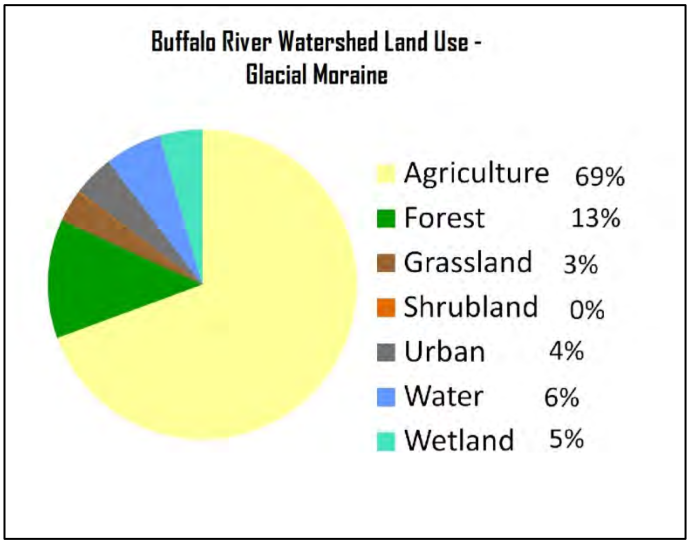


Figure 9. Buffalo River Watershed landuse within the Glacial Moraine Zone.

The Agassiz Beach Ridges are relatively narrow zones that run north to south through the Red River Basin and are characterized by sand and gravel deposits and significant change in elevation. The Agassiz Beach Ridges were formed when Lake Agassiz retreated over 10,000 years ago. These beach ridges within the Buffalo River Watershed begin just west of Detroit Lakes and extend west several miles west of Hawley. The portions of the stream that flow through these beach ridges typically have the greatest gradient within the watershed and are characterized by coarse bottom sediments that are required spawning habitat for some of the basin fishes, known as lithophilic spawners. This area of relatively poor fertility and well drained soils is of less importance to agriculture as demonstrated by the large percentage of land that is enrolled in set-aside programs (Conservation Reserve Program (CRP)), restored to grassland, or is used for haying or grazing (Figure 10). Some of the remaining native prairie in Minnesota is found within the Beach Ridge, and this zone is a priority for native prairie restoration efforts by state and federal agencies.

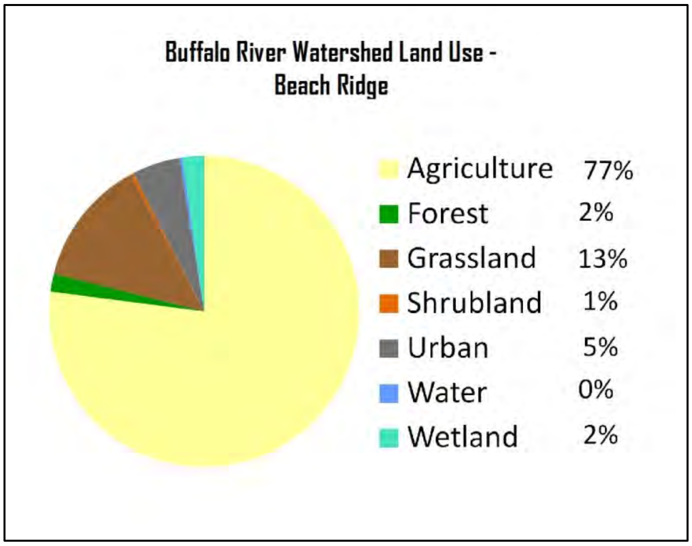


Figure 10. Buffalo River Watershed landuse within the Beach Ridge Zone.

The Lake Plain is the remnant floor of Lake Agassiz and is characterized by deep, rich silt and clay sediments that support intensive, productive agriculture. The landuse within this zone is dominated by 91% agriculture (Figure 11). This low gradient landscape (often less than one foot of elevation change per mile) has an extensive network of drainage to facilitate agricultural production. This zone is vulnerable to flooding as the stream discharge rates and slope from the Beach Ridge are reduced when the streams enter the Lake Plain region. Water quality becomes degraded as the tributaries work through this zone of fine sediment in route to the Red River. The phosphorus-rich clay and silt sediments tend to be easily suspended and transported within the stream system. The fine soils and their propensity to stay in suspension even at relatively low-flow conditions, combined with the extensive drainage network and stream channel instability, results in high turbidity and the degraded condition of these streams.

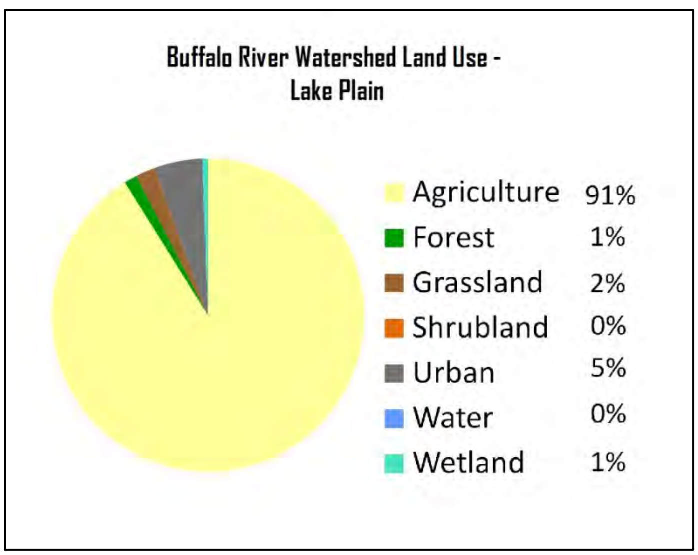


Figure 11. Buffalo River Watershed landuse within the Lake Plain Zone.

Watershed Health Assessment – Watershed Assessment Tool

The Minnesota Department of Natural Resources (MNDNR) has developed a tool to examine watershed health. The tool provides a method for rating the critical components of watershed health. Those components are hydrology, geomorphology, biology, connectivity and water quality. Figure 12 provides the Watershed Assessment Tool results for the Buffalo River Watershed.

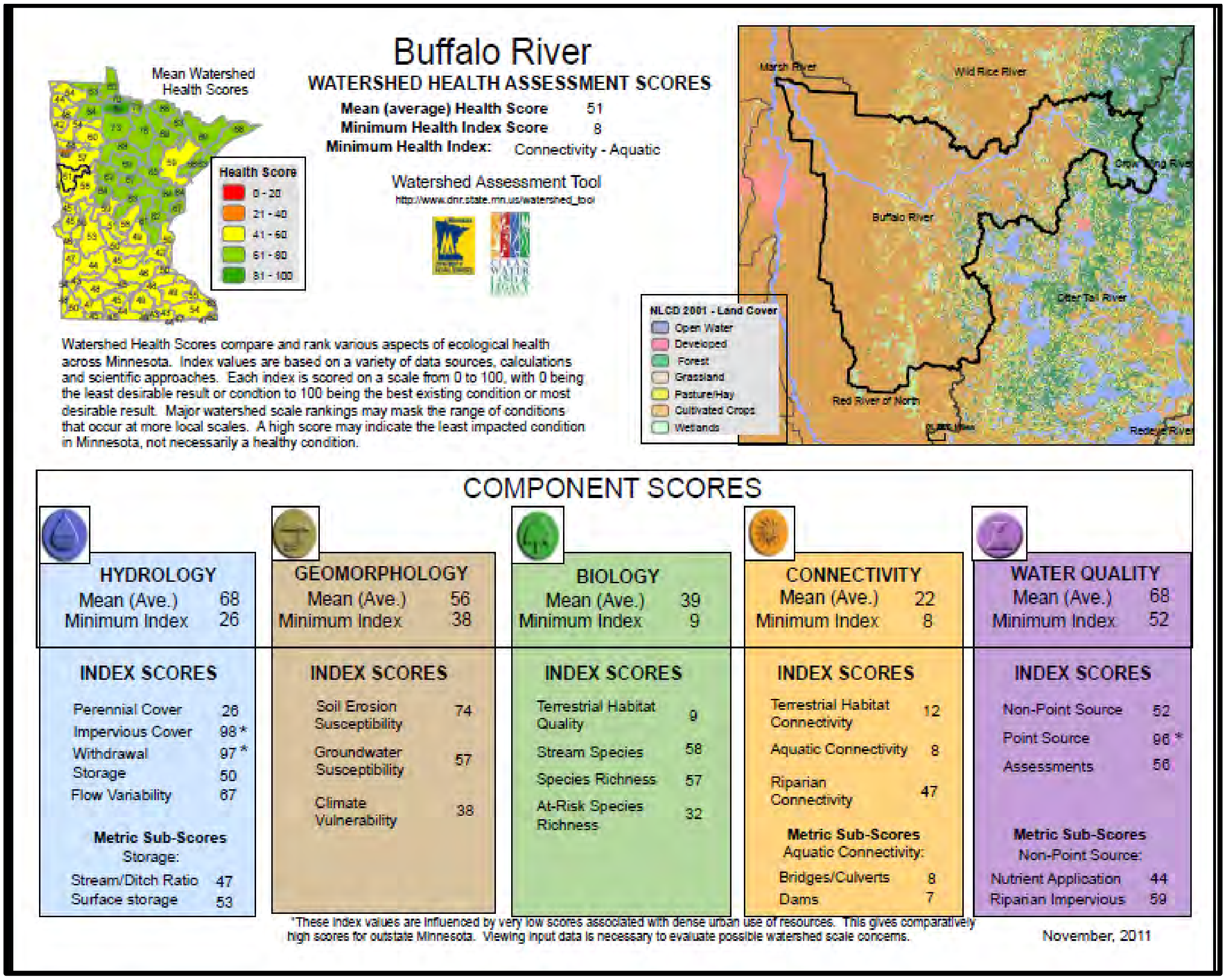


Figure 12. Watershed Health Assessment Scores for Buffalo River Watershed (source MNDNR website).

Precipitation

Statewide annual precipitation totals for the period of study of the Buffalo River Watershed (2009 – 2012) are presented in Figure 13. Precipitation totals varied greatly during this period. Both 2009 and 2010 were relatively wet years with 2009 being about average in the eastern portion of the watershed and wet in the western portion of the watershed where from two to ten inches of additional precipitation fell above the annual mean (Figure 14). Precipitation in 2010 was unusually wet with the entire watershed receiving about 28 to 34 inches of precipitation or between six to ten inches above normal. Precipitation totals for 2011 and 2012 were below normal with 18 to 24 inches in 2011 and 14 to 22 inches in 2012 falling across the watershed.

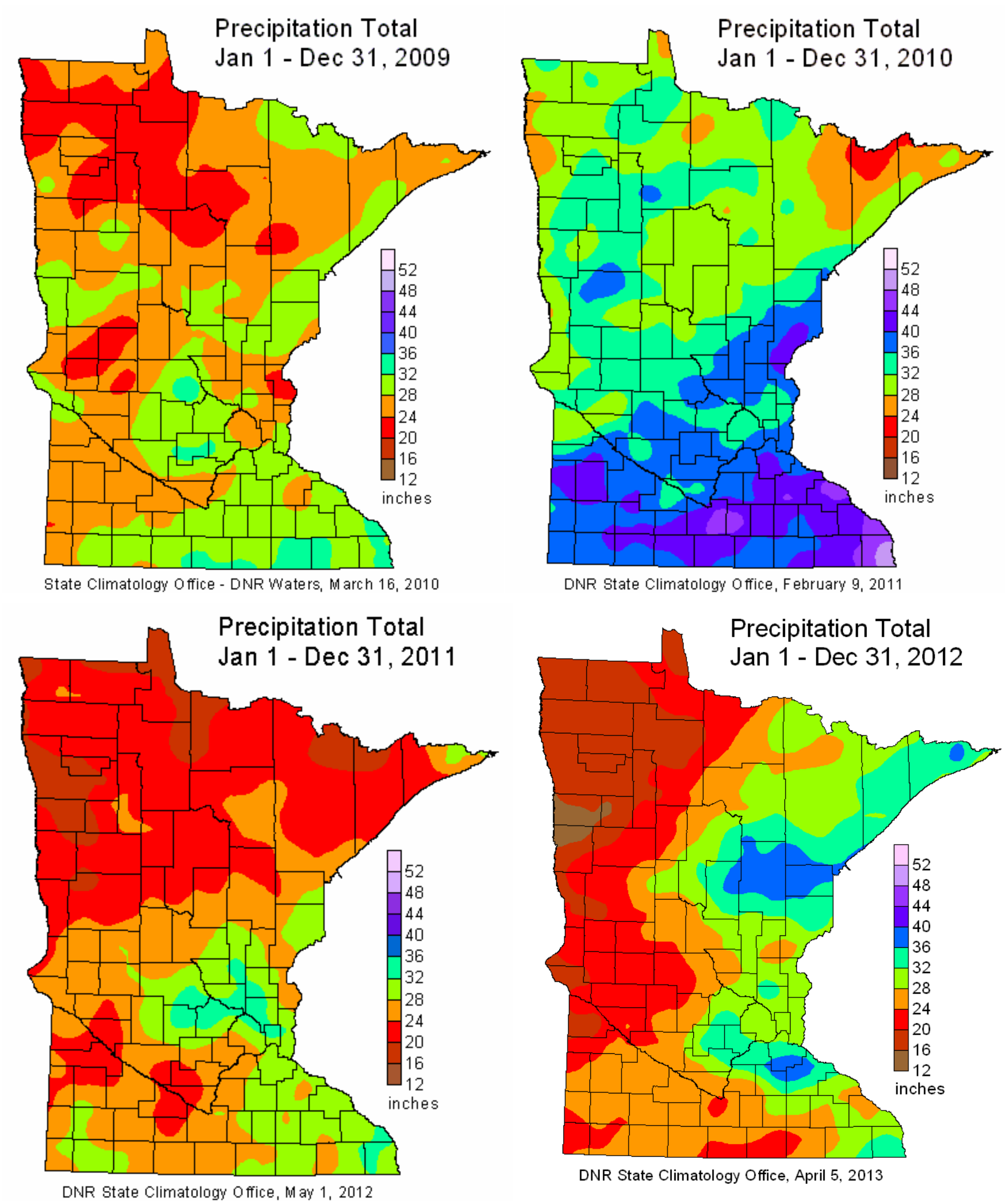


Figure 13. Annual precipitation from 2009 to 2012.

Precipitation data for Moorhead, Minnesota provides the nearest and best long-term record for the Buffalo River Watershed. This record of precipitation spans from 1881 to 2012. The long-term annual mean for this period of record is 21.31 inches. The 30 year average is 22.85 inches and 10 year average is 22.99 inches.

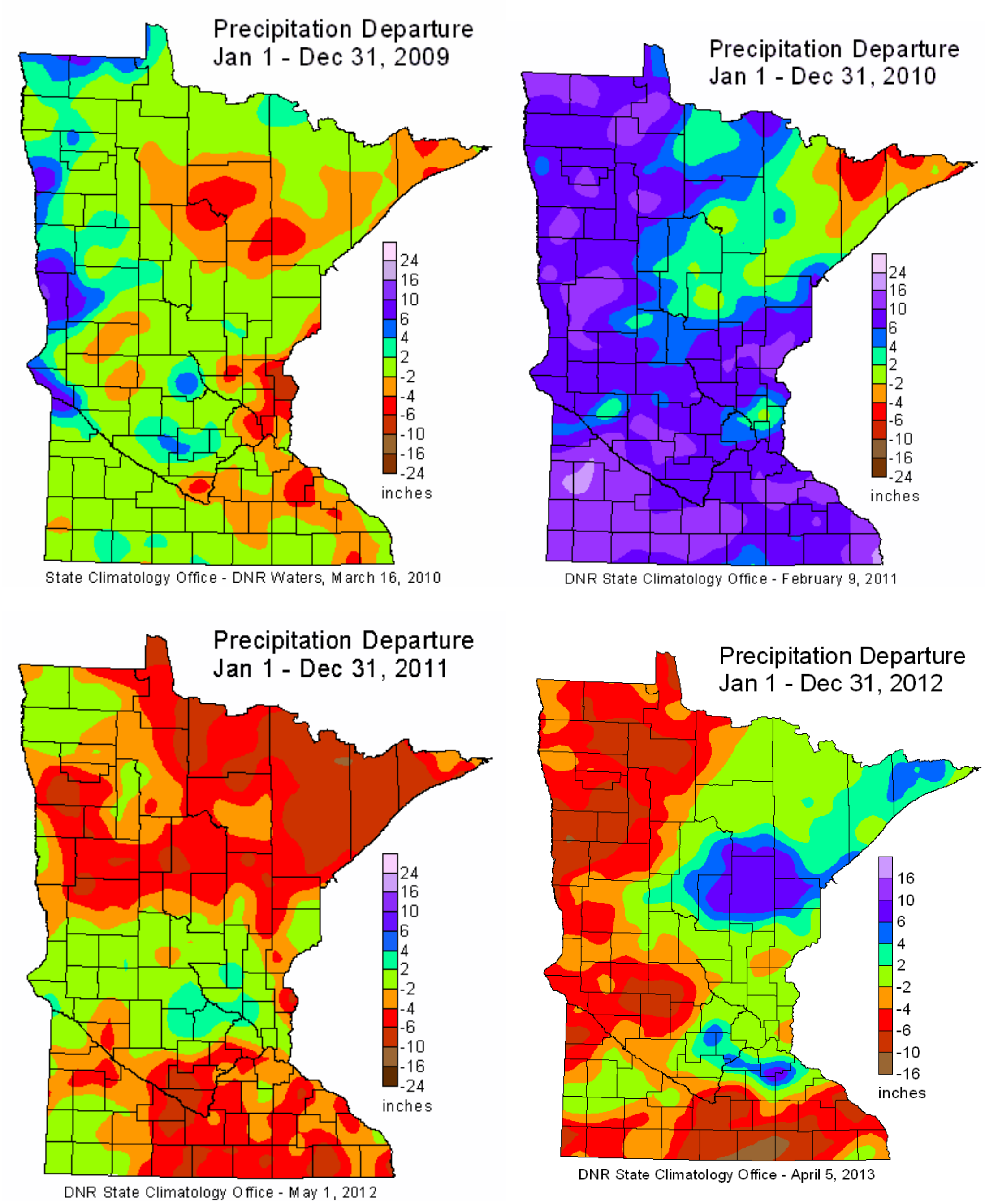


Figure 14. Annual precipitation departure from normal 2009 to 2012.

Hydrology

The hydrologic cycle in the Buffalo River Watershed has seen significant changes since the land was developed for agriculture. The initial loss of the native prairie land cover to the plow had an impact on the fate of precipitation as it contacted the landscape. Runoff, infiltration and evaporation rates all changed during this land cover conversion. Historically, spring melt and storm water recharged wetland basins and groundwater supplies and these supplies slowly released water throughout the spring and summer into the stream system.

The development of the extensive drainage network during the past century was the other large change to the hydrology of the Buffalo River and its tributaries. Agricultural drainage through ditching, channelization and tiling accelerates the movement of water from the land into the river. This associated change in the hydrograph is depicted in Figure 15 that shows the difference in stream flow rates pre and post agricultural development. The increase in peak stream flow rate (Figure 15) results in runoff event flooding, excessive stream/ditch bank erosion, loss of habitat, and degraded water quality. The other impact to the stream from drainage is the reduction of base flow that occurs following the peak and recession limbs of the hydrograph. The combination of increased peak discharge and loss of base flow is often referred to as a flashy hydrograph. Efforts to improve hydrology to a more natural state are aimed at reducing peak rates and adding flow to the recession limb of the hydrograph to improve base flow.

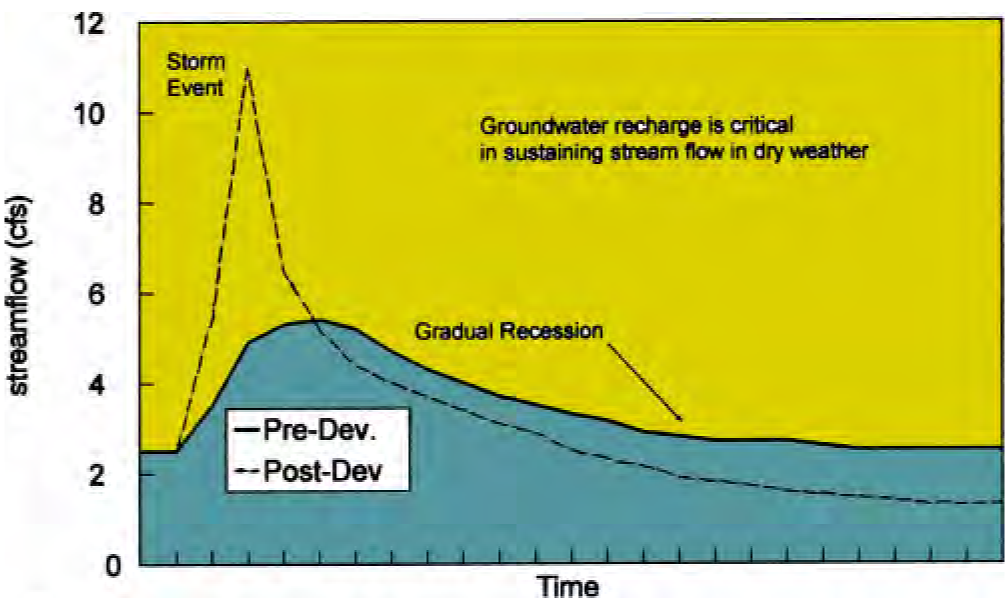


Figure 15. Change in storm event stream hydrograph from pre-development to post development. Note the change in peak stream flow that results from loss of storage within watershed due to drainage (wetland loss, ditching, channelization and tiling). Image credit: Deeproot.com with permission.

The flow duration curve for the USGS station in Dilworth, Minnesota is provided in Figure 16. This chart shows the frequency of occurrence of various hydrologic conditions at this long-term flow station. It also provides the annual hydrographs for the years 2011, 1987 and 1975. Although increased peak flow rates are a driver of the habitat, sediment and altered hydrograph stressors, it is also important to note the period of dry conditions during January and February as well as July, August and September. The flashy hydrograph that results from excessive drainage can increase the intensity and duration of the base flow conditions and this can have an impact on the biota within the system.

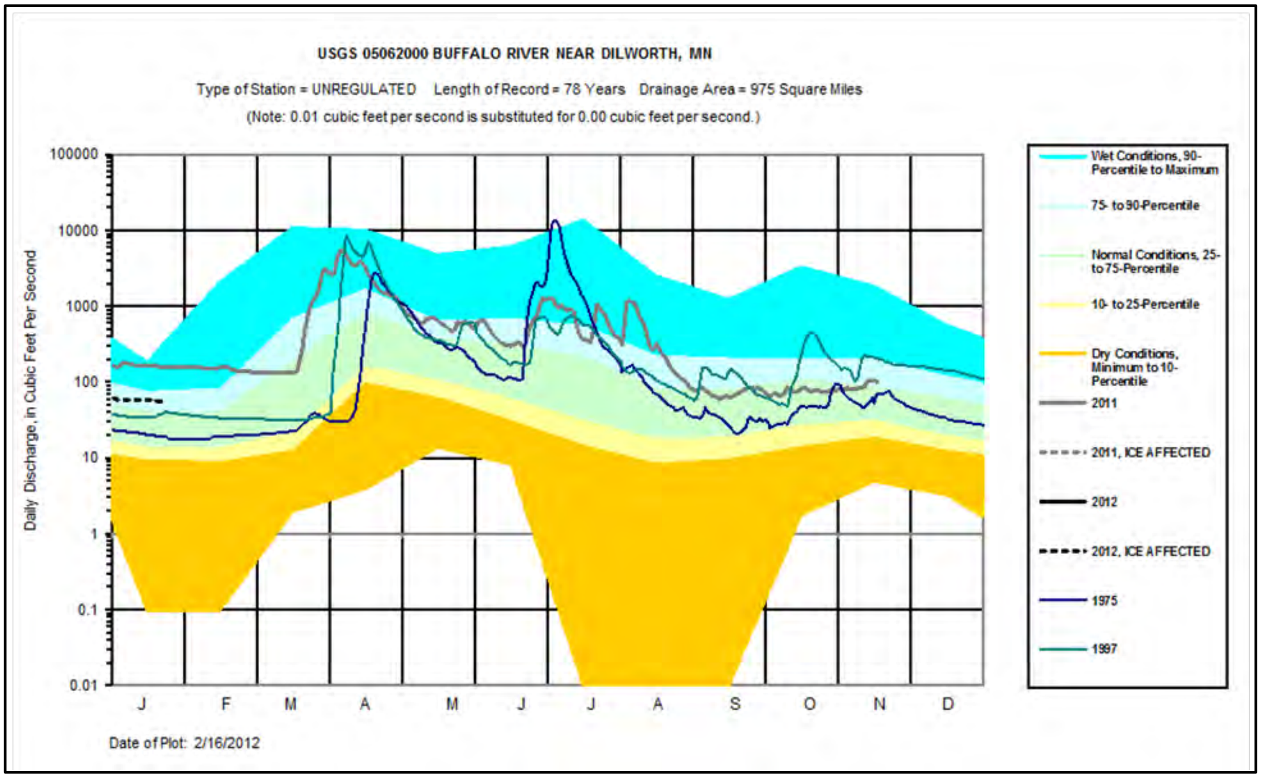


Figure 16. USGS Flow-Duration Hydrograph for Dilworth Station. USGS Website http://mn.water.usgs.gov/flood/duration/index.html

The long-term (1931 to 2012) stream flow record for the Buffalo River at Dilworth, Minnesota (USGS Station) is provided below in Figure 18 (in the following geomorphic assessment section). The mean annual discharge volume for the period of record is 130,400 acre-feet/year. The 30-year running average is 196,500 acre-feet/year and the 10-year average is 258,700 acre-feet/year. Research in agricultural watersheds (Shottler, Ulrich, Engstrom, and Moore 2013) found the increase in discharge volume during the past 30 years is due to increases in drainage and precipitation with drainage accounting for more than 50% of the increase.

State hydrology data was assessed as part of the 2004 MPCA Phosphorus Study commissioned by the Minnesota Legislature (Tomasek 2004). Runoff frequency curves were produced for key flow stations throughout Minnesota as part of this study. The runoff frequency curve for the Buffalo River Watershed, USGS Dilworth Station is shown in Figure 17. The curves show that for gages in the south and west portions of the state, during the period of 1979-2002, flows were consistently above the long-term period of record. The curves indicate that there is a general trend of decreasing runoff from east to west in Minnesota. Lake Superior Basin has the highest runoff with the Baptism River watershed having the highest values within that basin, with average annual runoff of 15.3 inches. Runoff in the Red River of the North Basin had the least runoff, with the Buffalo River Watershed having 2.8 inches of runoff in an average year, which is lowest of the Minnesota gages used in the analysis (Technical Memorandum to MPCA, Barr Engineering Co. 2003)

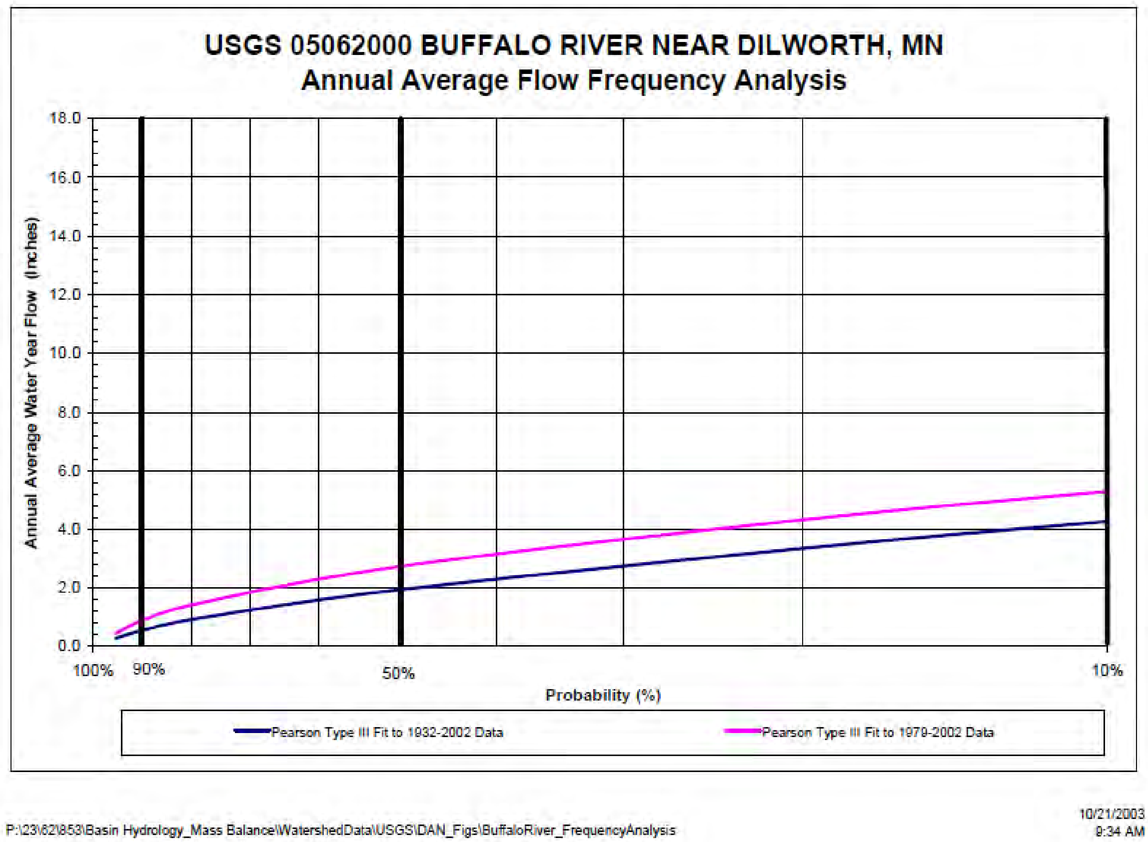


Figure 17. Annual average flow frequency analysis of Buffalo River at USGS Dilworth Station (2003, Technical Memorandum to MPCA, Barr Engineering Co.).

The other hydrologic assessment that is provided below is an assessment of changes in flow verses changes in precipitation. This assessment (in the first part of the geomorphic section immediately below) provides information that will set the stage for the geomorphic discussion and the candidate cause section that follows. An understanding of the system hydrology gives the reader the background to understand the significant role that altered hydrology plays in the stressors acting upon the biology in this watershed.

Altered hydrology is the single most important factor stressing the stream biology as it is the primary driver of the stream biological stressor processes that occur within the Buffalo River Watershed. Sediment dynamics, habitat conditions, nutrient loading and even DO conditions are for a large part in response to changes that result from altered hydrology. Since the hydrology of the Buffalo River has been altered significantly, much of the discussion regarding hydrology is included below in the section that discusses the candidate cause – altered hydrology.

Geomorphic Study of Select Locations

Section authored by Dave Friedl, MDNR with contributions from Jason Vinje, Lori Clark, Emily Sirra.

Study Area

Fluvial geomorphology studies were limited to the main stem of the Buffalo River and tributaries including the Upper South Branch Buffalo River, Whisky Creek, and Lawndale Creek. Large areas of the watershed were not covered during this study and data gaps should be considered and surveyed during the next watershed study cycle. Some inferences between watersheds are possible, considering the boundary conditions and driving variables of each watershed. The use of dimensionless ratios to describe stream morphology conditions would allow comparisons to streams of various sizes.

Methods

Geomorphic studies were completed on the Buffalo River during the 2009, 2010, 2011, and 2012 field seasons. High water during the 2010 field season limited the amount of work that could be completed that year. Several types of investigations were completed including flow versus precipitation comparisons, stream reconnaissance by kayak, intensive geomorphic stations using Rosgen methodology, stream power index field assessments, and a ditch repair assessment.

Changes in Flow versus Precipitation

Altered hydrology is such a substantial driver of fluvial geomorphology it merits an examination as a preface to understand geomorphic assessment results. As in other agriculture dominated watersheds, changes in flow in the Buffalo Watershed cannot be explained by precipitation alone. Land use changes and drainage have a significant influence in altering the flow regime. Annual and 30 year mean flows at the Dilworth USGS gage are increasing at a much faster rate than precipitation (Figure 18). Work done by Schottler, Ulrich, Engstrom, and Moore (2013) apportioned changes in flow between climate, precipitation, crop conversion, and drainage and found greater than 50% of the change in flow was due to artificial drainage and about 1/3 of the change due to precipitation or crop conversion in 21 watersheds they examined. Vandegrift and Stefan (2010) found flow and precipitation relationships that support the Schottler et al findings in agricultural dominated landscapes.

The consequences of an altered hydrograph in the Buffalo River Watershed are channel morphology adjustments including changes to the dimension, pattern, and profile of the channel. Physical changes can include channel enlargement, channel incision, accelerated erosion rates, loss of floodplain, and an increased sediment supply. Negative aquatic habitat responses are associated with these changes. Negative aquatic habitat response include direct loss of habitat by lack of pool scour, fine sediment accumulation in pools and the hyporheic zone, loss of hyporheic zone (region beneath and alongside a stream bed where mixing of ground and surface water occurs) productivity, loss of in-stream and overhead cover, substrate composition degradation, holding cover velocity, increase in temperature, lowered DO, macro macroinvertebrate impacts, loss of spawning gravels, loss of habitat diversity, loss of rearing habitat, lowered IBI scores, increased sediment supply, and accelerated bank erosion.

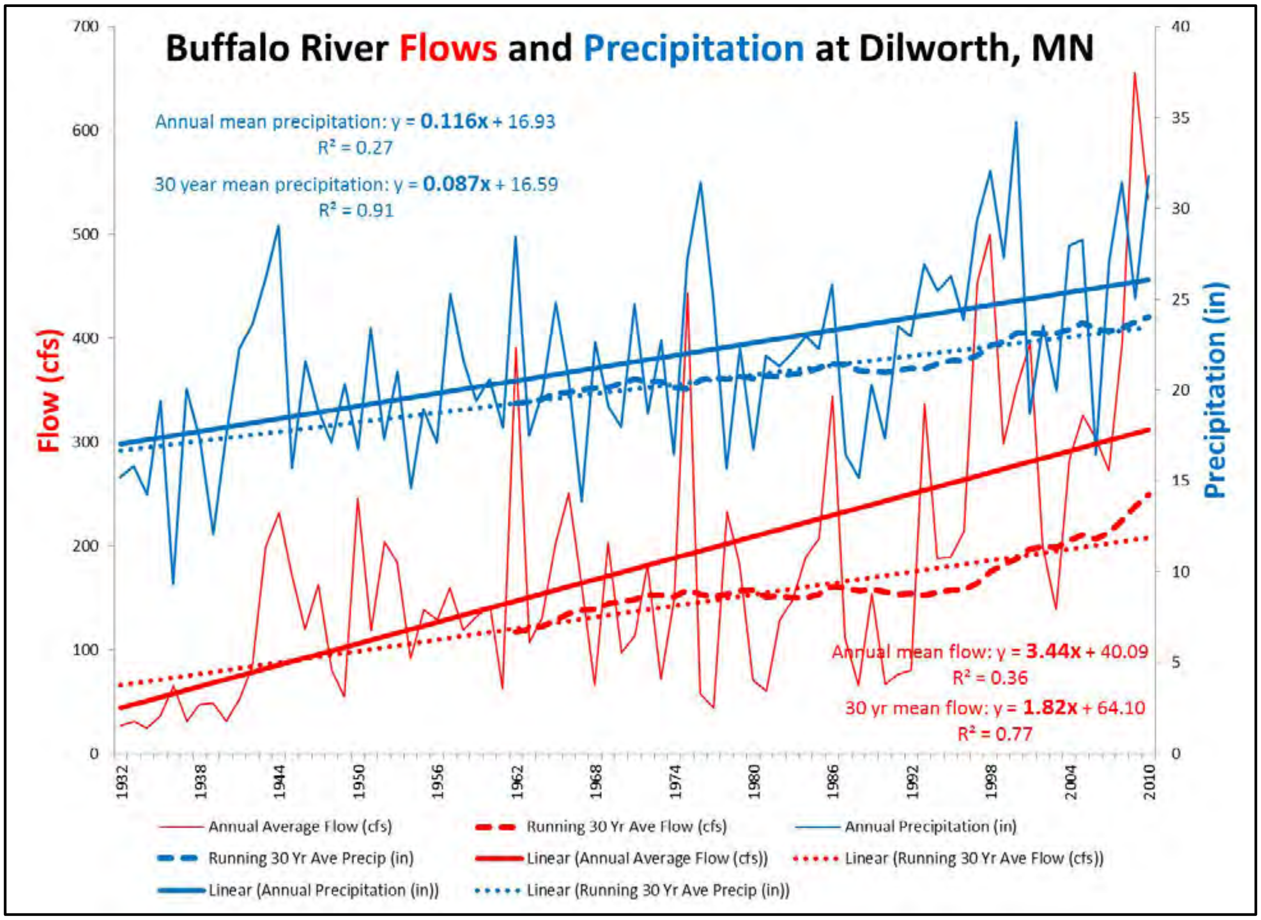


Figure 18. Changes in flow and precipitation in the Buffalo Watershed at Dilworth, Minnesota USGS Station.

Erosion rates measured during reconnaissance and intensive fluvial geomorphology studies were quite high in some areas (Figure 24), even where good boundary conditions (dense perennial vegetation) were present. An example would be the high erosion rates found in the perennial vegetated and non-grazed portion of the Haugen study site near Hawley (Figure 19).

With an increase in artificial drainage (i.e. tiling) occurring in the Buffalo River Watershed, an additional increase in water routed to rivers and increasing stream flow annual yields should be expected, along with further increases in channel adjustments and additional negative aquatic habitat and water quality responses including those listed above along with increased bedload sediment, and loss of nutrient uptake from loss of floodplain connectivity.

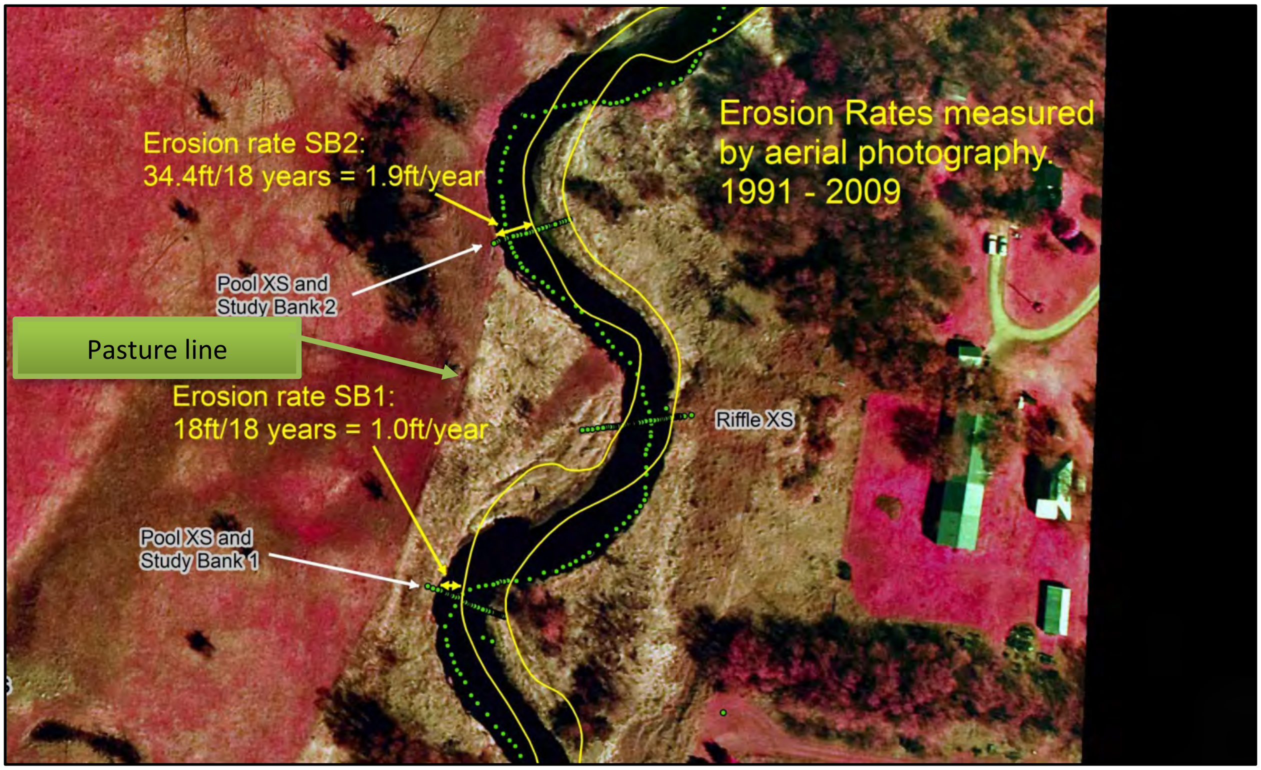


Figure 19. Erosion rates on the Buffalo River near Hawley, Minnesota. The aerial photo is dated 2009 with the 1991 stream channel location shown in yellow.

On-stream Investigations

Four reaches of the Buffalo River were assessed by DNR and MPCA staff from kayaks on four dates during the summer and fall of 2010 and 2011. Locations and dates for these reconnaissance assessments are shown in the Figure 20. These assessments roughly covered representative reaches of the main stem of the Buffalo River in the glacial moraine, beach ridge, and lake plain regions. One station was completed on the South Branch Buffalo River in the area of the confluence of Deerhorn Creek. The goals of the reconnaissance surveys included collecting data on stream morphology and condition, including stream classification, bank erosion potential and volumes, riparian condition, indices of stream stability, identification of biological stressors, identification of representative areas for collection of additional data, identification of potential problem and restoration areas, and suggestions for restoration or protection.

The “Bank Assessment for Non-point source Consequences of Sediment” (BANCS) model (Rosgen 1996, 2001b, 2006b) was used for estimating bank erosion rates and total annual volume of bank erosion during the reconnaissance portion of our investigation. This empirical model uses the Bank Erosion Hazard Index (Figure 21) and Near Bank Stress (NBS) erosion estimation tools. Eroding banks were marked at the start and end of each similar bank with a hand held GPS. Bankfull indicators were noted and used to measure bankfull width (Wbkf) and in recording BEHI parameters. Bank height and BEHI parameters were measured and recorded for each similar length of bank. A high resolution laser range finder was used to measure the height of tall banks and Wbkf.

NBS was later calculated using recorded bankfull widths and radius of curvature measured from aerial photographs (Figure 22 and Figure 23) using GIS software (NBS method 2, Rosgen 2008). This method uses the ratio of the radius of curvature of the meanders to the bankfull width of the channel, and is a measure of the tightness of the bends in the river and the degree of boundary shear stress acting on those banks. Bank lengths were also measured using GIS software from the start and end waypoint of each similar eroding bank. Known erosion rates from developed erosion curves were used with the BEHI, NBS combinations to predict erosion rates in feet per year and total erosion volume in tons/year/mile. This process continued for the entire length of the reconnaissance station which could be up to six stream miles in a day. Geo-referenced photographs were taken for each bank for future reference.

We used the known erosion rates from North Carolina, Colorado, or Yellowstone National Park data to estimate erosion rates for our study. Actual erosion rates were estimated with aerial photography for portions of the study reach and one of the three published erosion rates with the closest match to the reconnaissance estimate was used for the balance of the reconnaissance reach. As we validate more of these erosion rates with bank studies that measure bank profiles over time, we will develop local erosion rate relationships with BEHI and NBS estimates, which should strengthen our BANCS erosion estimates and increase its usefulness as a tool for assessing watersheds.

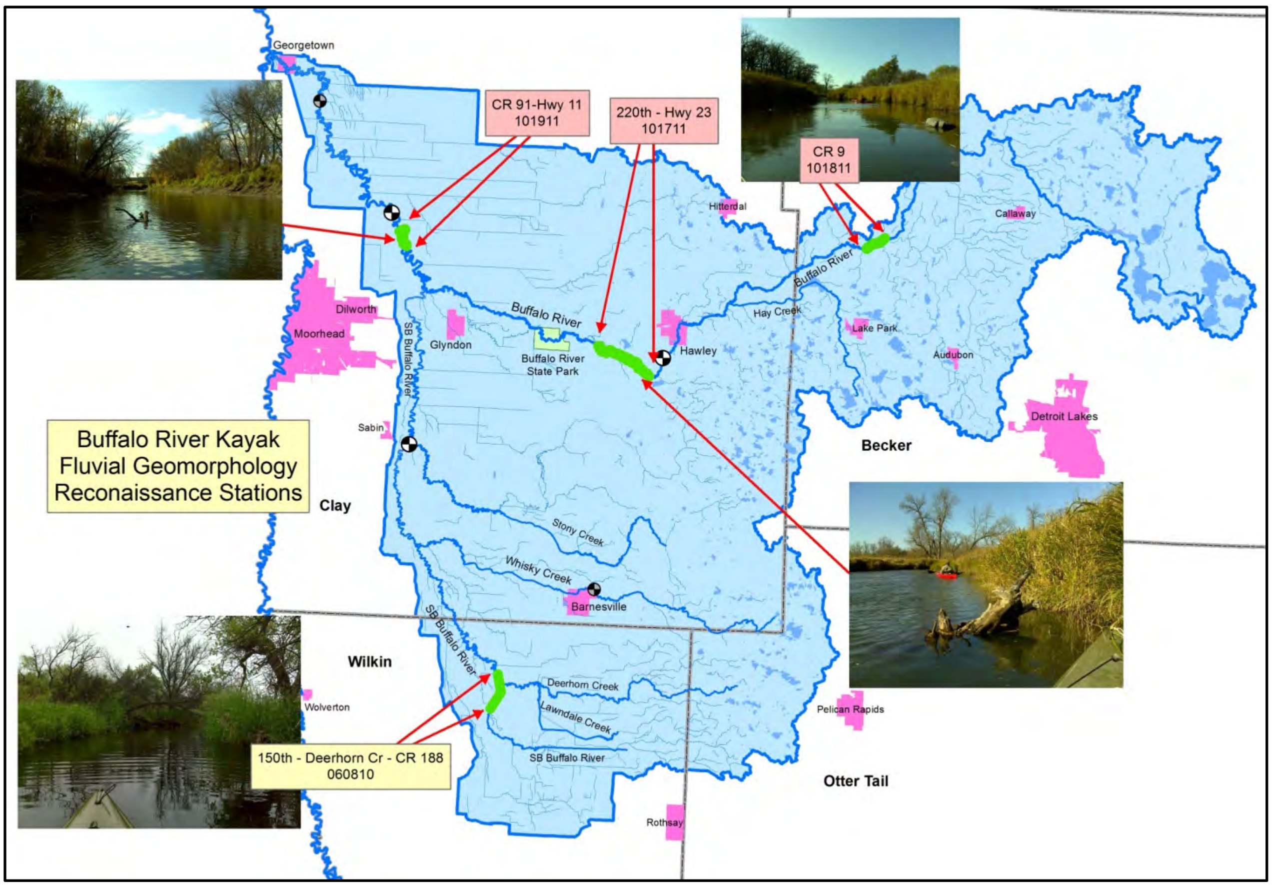


Figure 20. Kayak reconnaissance reaches, Buffalo River Watershed.

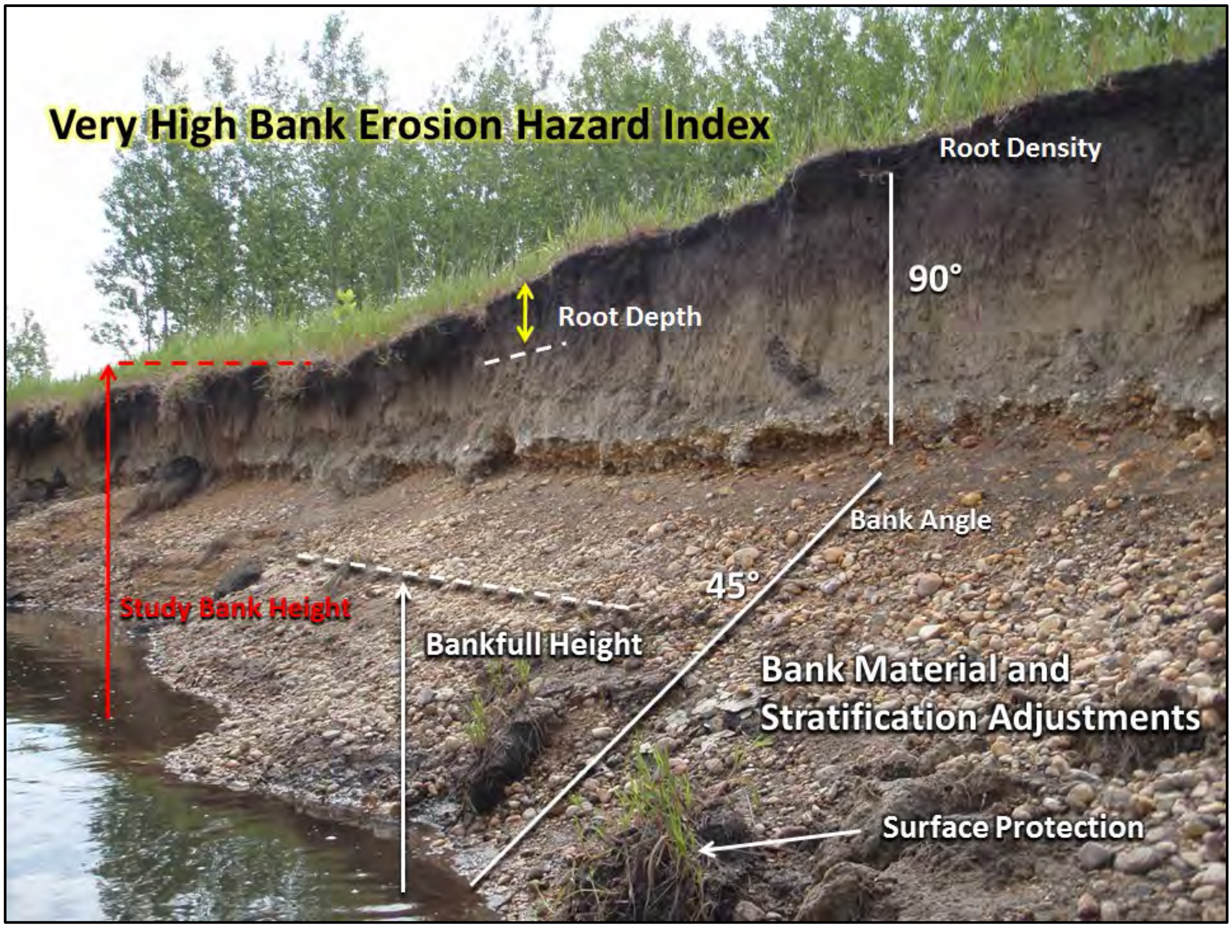


Figure 21. Rosgen Bank Erosion Hazard Index Factors.

Figure 22. Near bank stress estimates using radius of curvature (yellow labels are radii of red or yellow circles that fit stream bends) divided by Wbkf.

Figure 23. Near bank stress estimates using radius of curvature (yellow labels are radii of red or yellow circles that fit stream bends) divided by Wbkf.

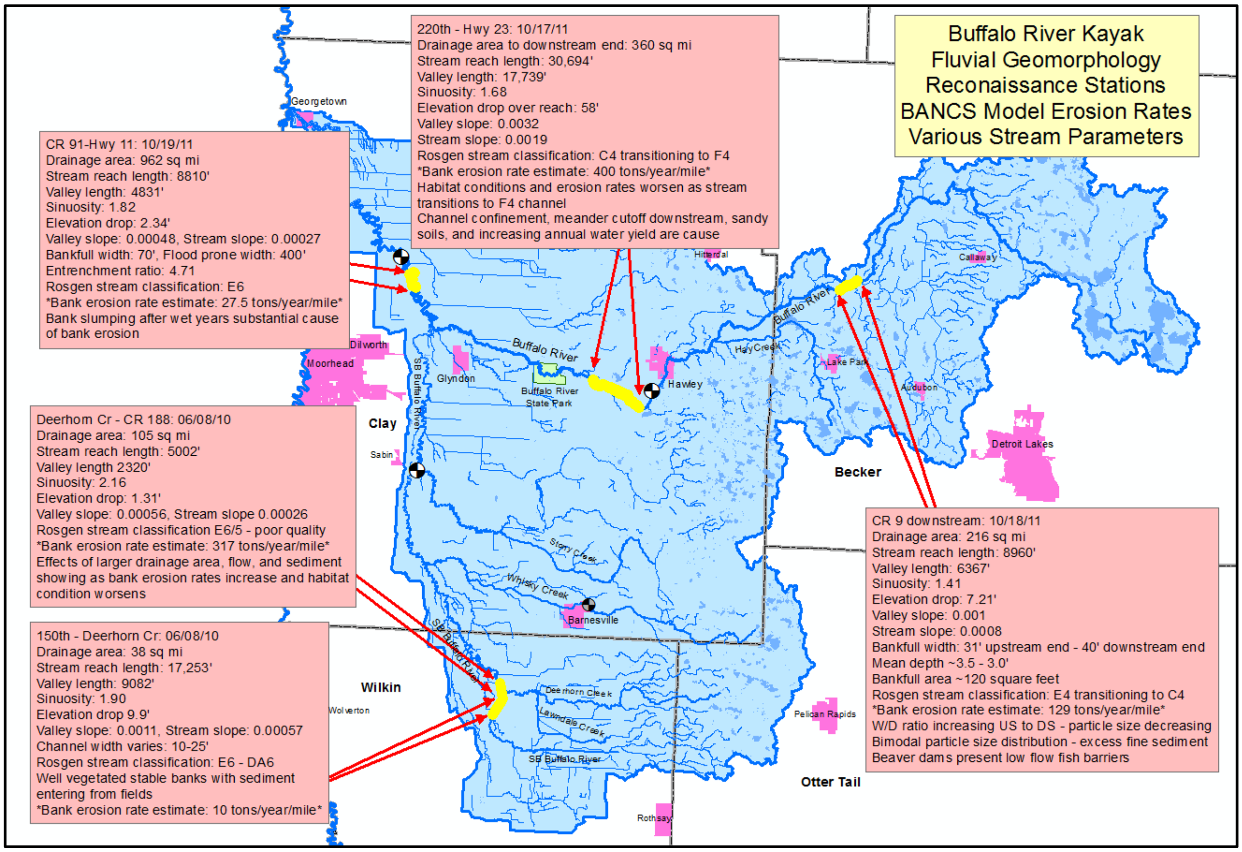


Figure 24. Kayak reconnaissance BANCS erosion and stream parameters

Results

Becker County Road 9 Reach

The Becker County Road 9 reach (Figure 25) had a well vegetated riparian corridor for the most part, however, a substantial gully enters the reach from the left bank approximately a third of the way downstream of CR 9 (waypoint 562, 563) through a narrow area of the riparian buffer that delivered about 131 tons of sediment directly into the Buffalo River. An opportunity exists to place some type of best management practice to control the head cuts that are running up this gully.

A bimodal sediment distribution of fine sediment and gravel exists in the lower part of the reach, demonstrating that an excess supply of fine sediment is being supplied to the stream that is likely dropping out on the descending limb of the large flow events. The higher width depth ratio towards the bottom of the reach has less capacity to move the sediment supply and shows a smaller particle distribution than the upper end of the reach. More depositional features, like center bars appear from about waypoint 562 downstream.

A beaver dam with 16" head exists about mid-way down the reach at waypoint 565 restricting movement of fish during moderate or base flow conditions.

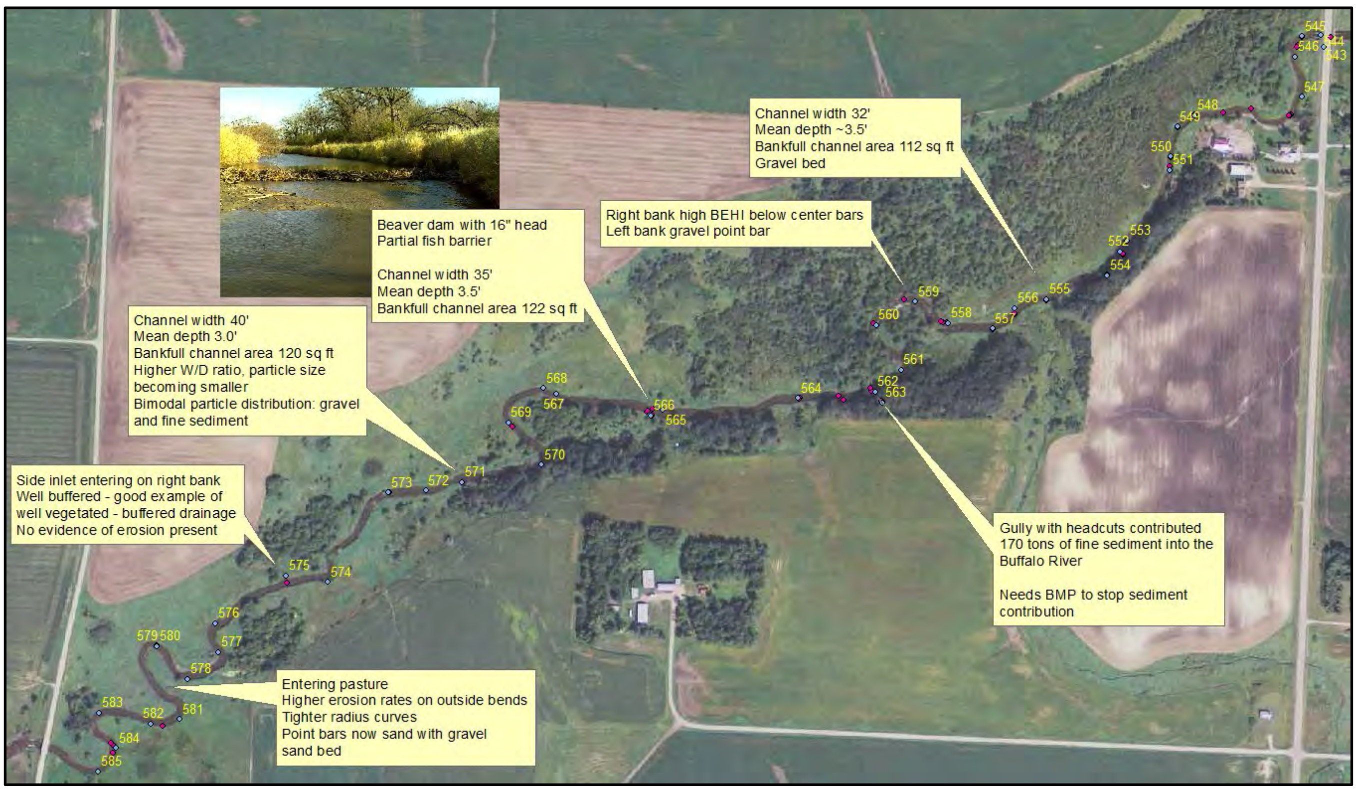


Figure 25. GPS station markers along Becker CR 9 reach.

Recommendations for this and surrounding sites are to maintain and restore strong vegetative boundary conditions on stream banks and riparian corridor, maintain access to floodplain, control specific high erosion sites with best management practices, reduce total sediment supply from overland sources, and look for opportunities to slow runoff and control drainage in the watershed above this site.

Clay County 220th to Hwy 23 Reach

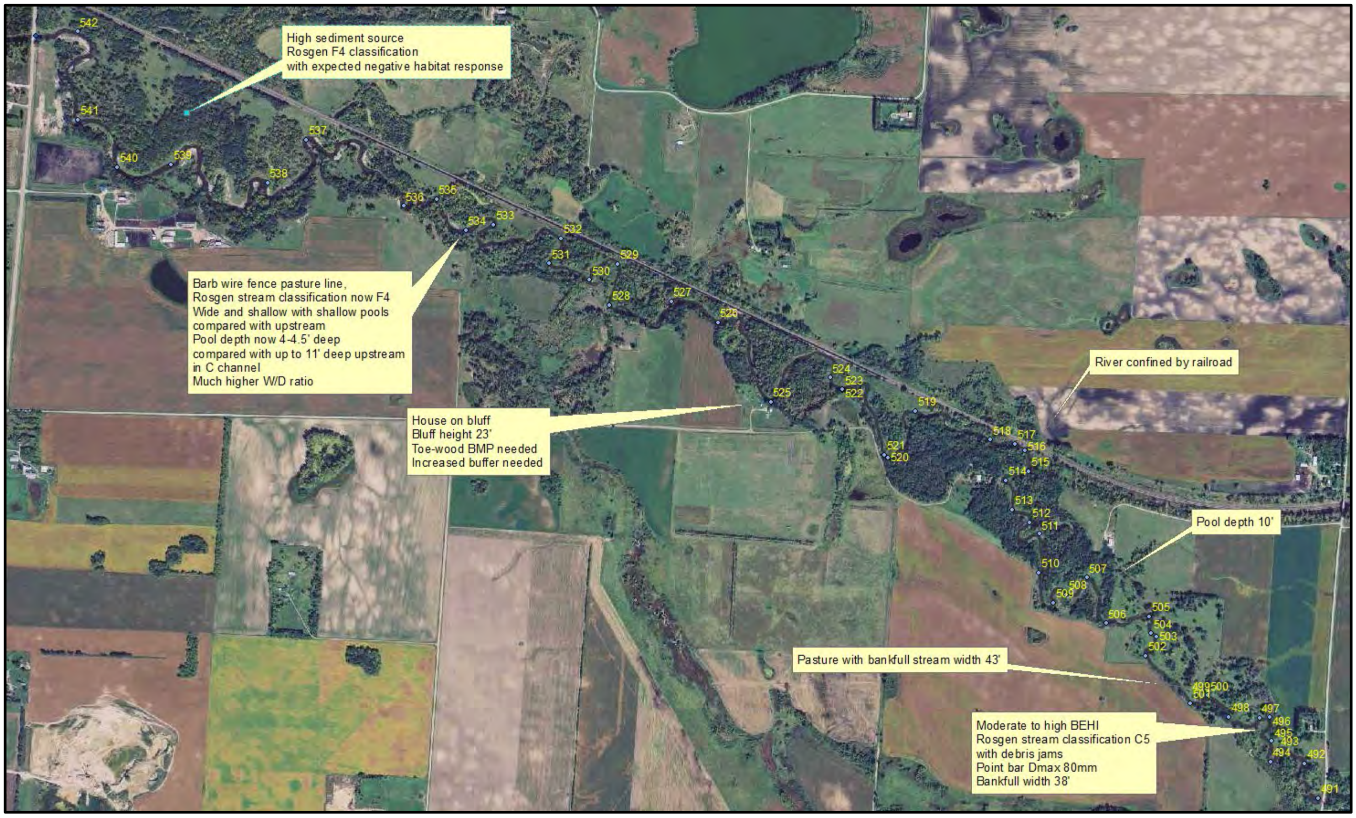


Figure 26. 220th to Hwy 23 reconnaissance, high erosion rates and transition from Rosgen C to F classification with negative aquatic habitat and water quality response.

This higher gradient reach traverses the beach ridge and is characterized by a transition from a Rosgen C4 to F4 classification (Figure 26). The upper end of the reach has pool habitat up to 11 feet deep. The lower end of the reach has fewer and shallower pools of approximately four feet deep along with a higher width to depth ratio. Incision increases and access to the floodplain decreases towards the lower end of the reach. Using raw (Light Detection and Ranging (LiDAR) LAS data and comparing (using LAS cross sections) the cut off channel elevation to the new confined channel just downstream of Highway 23 revealed channel incision greater than five feet in the remaining confined and shortened channel (Figure 26).

The cause of the incision and lack of access to the floodplain in the lower reach is likely a function of shortening the stream by 4580 feet and subsequent 25% increase in slope caused by the railroad cutoff below Highway 23 (Figure 27) along with degraded boundary conditions, or lack of vegetation in the pastured land upstream of Highway 23.

Restoration recommendations include restoring the channel to its former pattern and length, decreasing slope, and restoring grade in the incised portion of the reach. Grazed sections displayed noticeably higher bankfull channel widths and shallower pools (4 feet deep in wider grazed area towards lower end of reach and up to 11 feet deep in narrower upstream portion). Pasture management and vegetation management to maintain boundary conditions resistant to erosion forces are recommended.

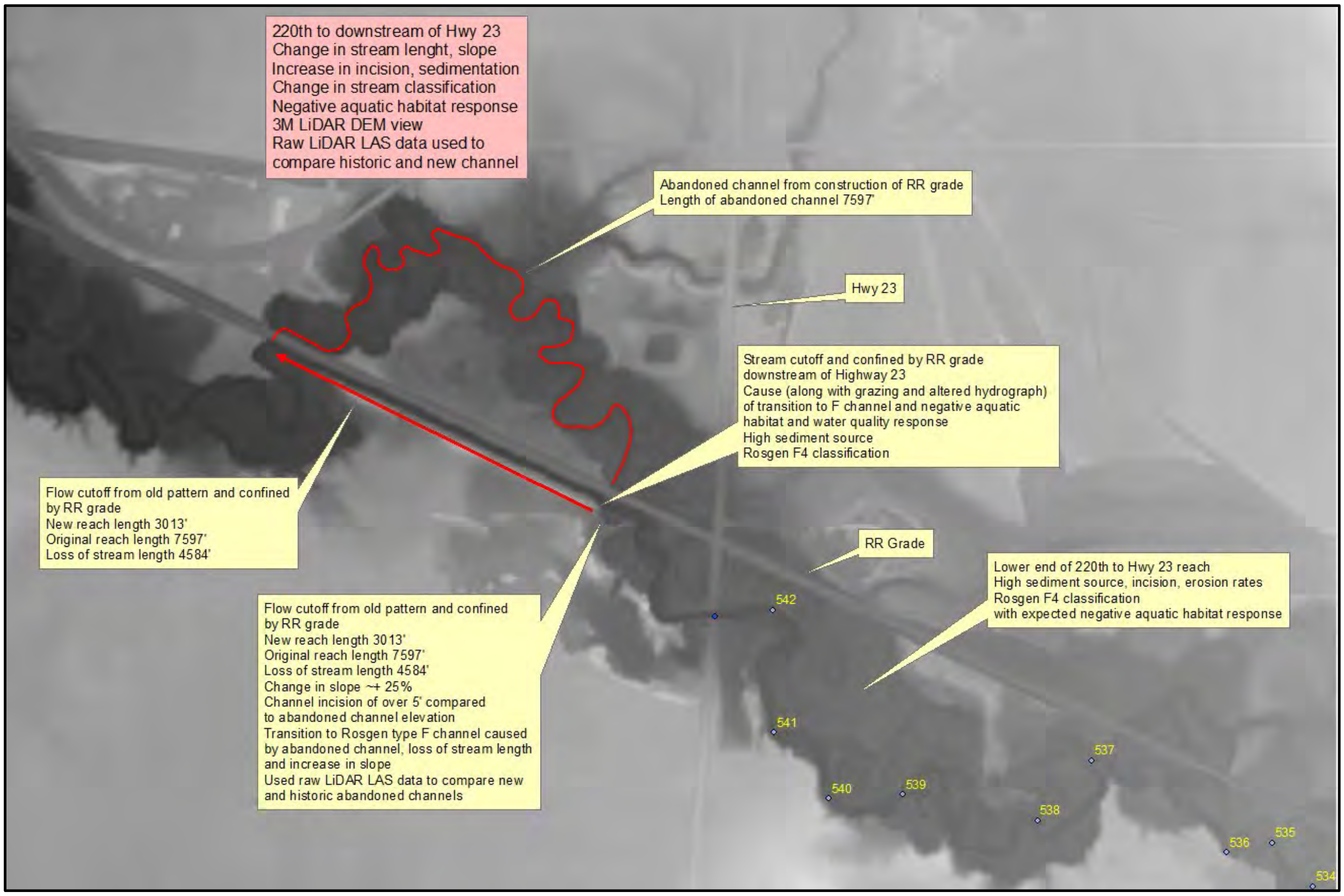


Figure 27. Lower end of 220th to Hwy 23 and meander abandonment downstream of Hwy 23.

Although biological communities meet their respective thresholds, stream health, including aquatic life, habitat, and water quality could be improved with the suggested recommendations. Because we have detailed channel information below Highway 23 based on the intensive geomorphic assessment of the channel and riparian corridor, comparisons are possible during the next clean water cycle for the Buffalo River Watershed to conclude if channel adjustments are still occurring along with negative habitat responses.

Clay County Road 91 to Highway 11 Reach

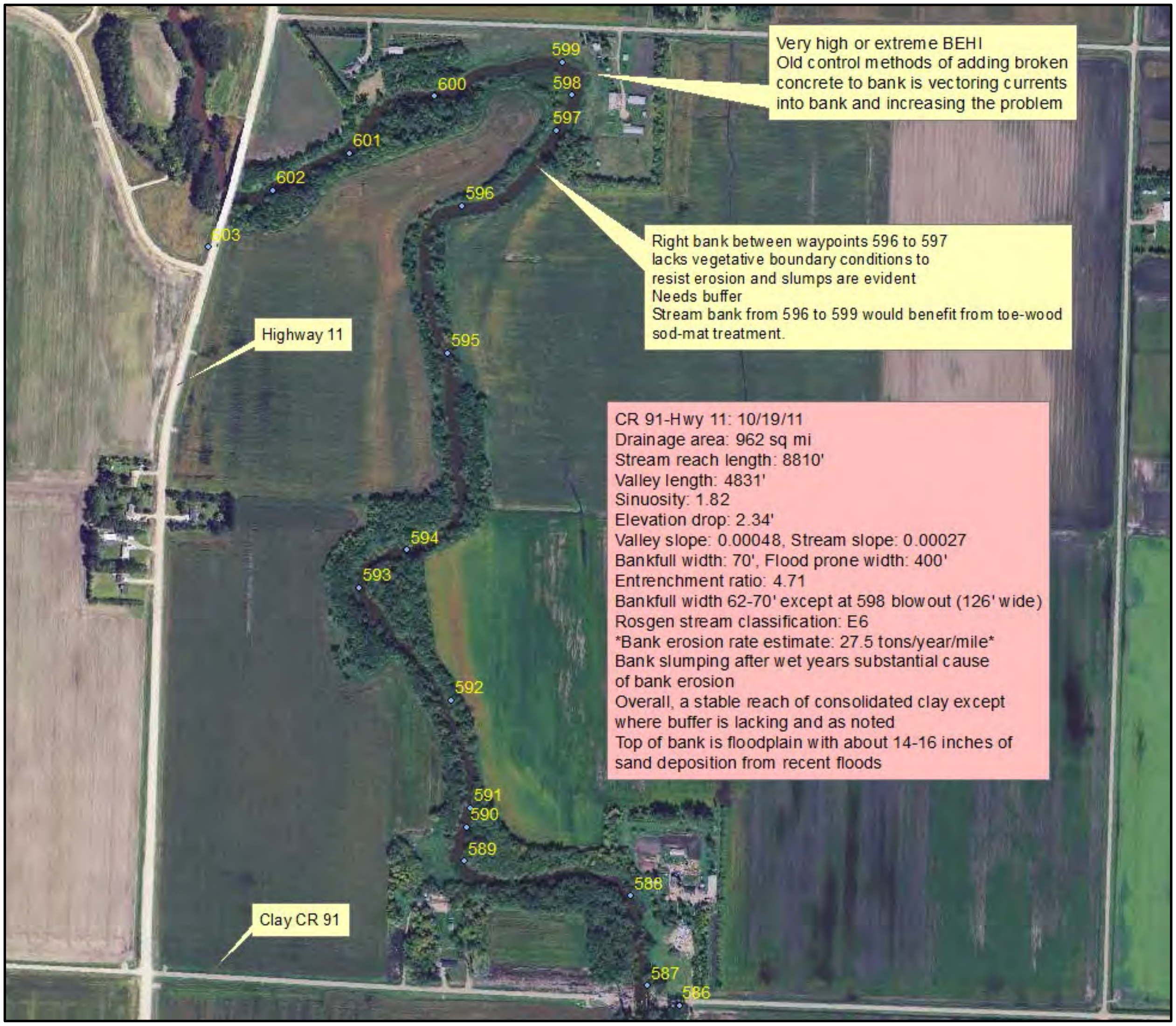


Figure 28. Clay CR 91 to Hwy 11, fairly stable reach on glacial lake plain clays.

This station lies in the glacial lake plain tightly consolidated clays and is a fairly stable reach with adequate access to a flood plain with a few exceptions noted on Figure 28. Deposition of about 14 – 16 inches of sand was evident on the floodplain throughout the reach (Figure 29). Best management options for this area include toe-wood sod-mat bank protection from waypoint 597 through 599 along with improved buffers from 596 through 599 (Figure 30).

Figure 29**. Clay County 91 to Highway 11 reach, deposition of fine sand on floodplain surface.**

Figure 30. Failed erosion prevention efforts near waypoint 598.

South Branch Buffalo River Kayak Reconnaissance Results, Wilkin County 150th to Deerhorn Creek and Deerhorn Creek to Wilkin County 188th

This reach exhibits very low erosion rates and depositional tendencies from Wilkin County 150th to the confluence of Deerhorn Creek, and then erosion and sediment (various depositional patterns with fine sand particle size) are evident below the confluence of Deerhorn Creek (Figure 31). A field gully at waypoint 140 is contributing a substantial amount of sediment into the South Branch Buffalo River.

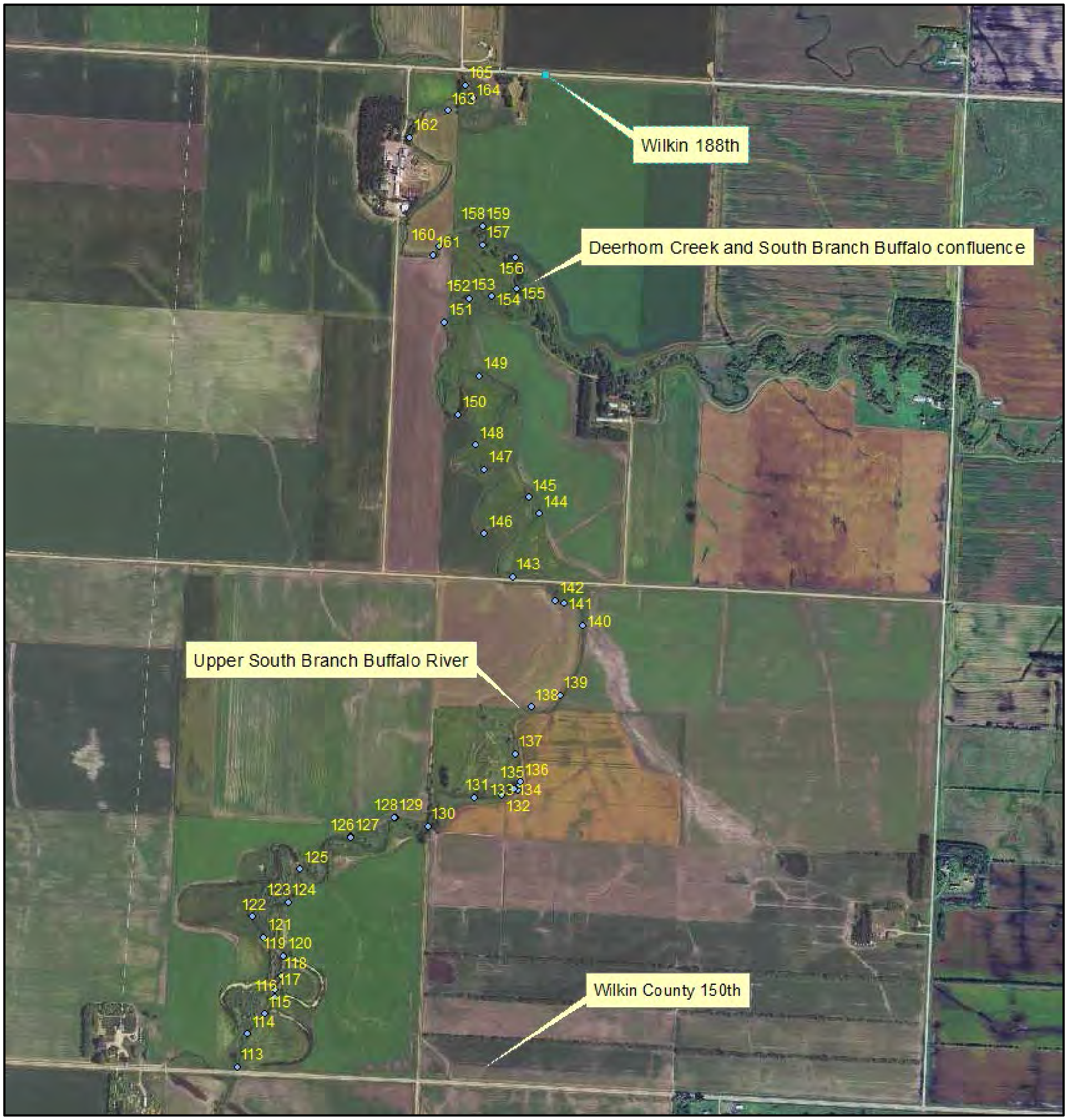


Figure 31. Upper South Branch Buffalo River through Deerhorn Creek confluence.

Part of the reach has been channelized and meanders have been cut off from waypoint 113 to 125. Opportunities for best management practices include restoration of meanders, improvement of buffers where they are too narrow, and control of sediment from the gully at waypoint 140. Deerhorn Creek, with its 67 square mile drainage area appears to be contributing a substantial amount of fine sediment to the South Branch Buffalo River below the confluence. Stream channel bank erosion increases substantially on the South Branch Buffalo River below the Deerhorn confluence. Altered hydrology and channel enlargements are evident on the South Branch Buffalo River below Deerhorn Creek.

Reconnaissance Summary at Biological Impairment Sites

Upper Buffalo Mainstem reconnaissance summary:

Reconnaissance of the County Road 9 reach revealed indications of an increase in flows presenting indicators such as channel enlargement, minor channel incision, accelerated erosion rates, and bimodal sediment distribution of gravel and fine sediment in the lower wider end of the reach. An accumulation of fine sediment negatively affects the hyporheic zone and the fish and macroinvertebrate production associated with it. Fine sediment in pools is also an indicator of poor pool scour and depth and a direct loss of fish habitat. Sources of sediment for this reach appear to be both stream bank and off-channel field source (218 tons of bank erosion and the presence of gully erosion – a single gully entering this reach produced 170 tons of sediment). Beaver dams were also present and prevent upstream movement of fish, macroinvertebrates, and macroinvertebrate host fish at low to moderate flows. Channel incision reduces access to the floodplain, reducing water quality, accelerating bank erosion, and degrading habitat with excess sediment.

Upper South Branch Buffalo River below confluence of Deerhorn Creek summary:

The Upper South Branch Buffalo River from Wilkin County 150th to the confluence of Deerhorn Creek is relatively stable and well vegetated, but is exhibiting depositional tendencies, indicating an abundant source of fine sediment from upstream. Virtually no bank erosion exists in this reach and for much of the South Branch Buffalo River upstream, so sediment supply is largely field source. Main stressors are altered hydrology and excess fine sediment (Figure 32).

Figure 32. Field source erosion on the Upper South B above Wilkin County 150th.

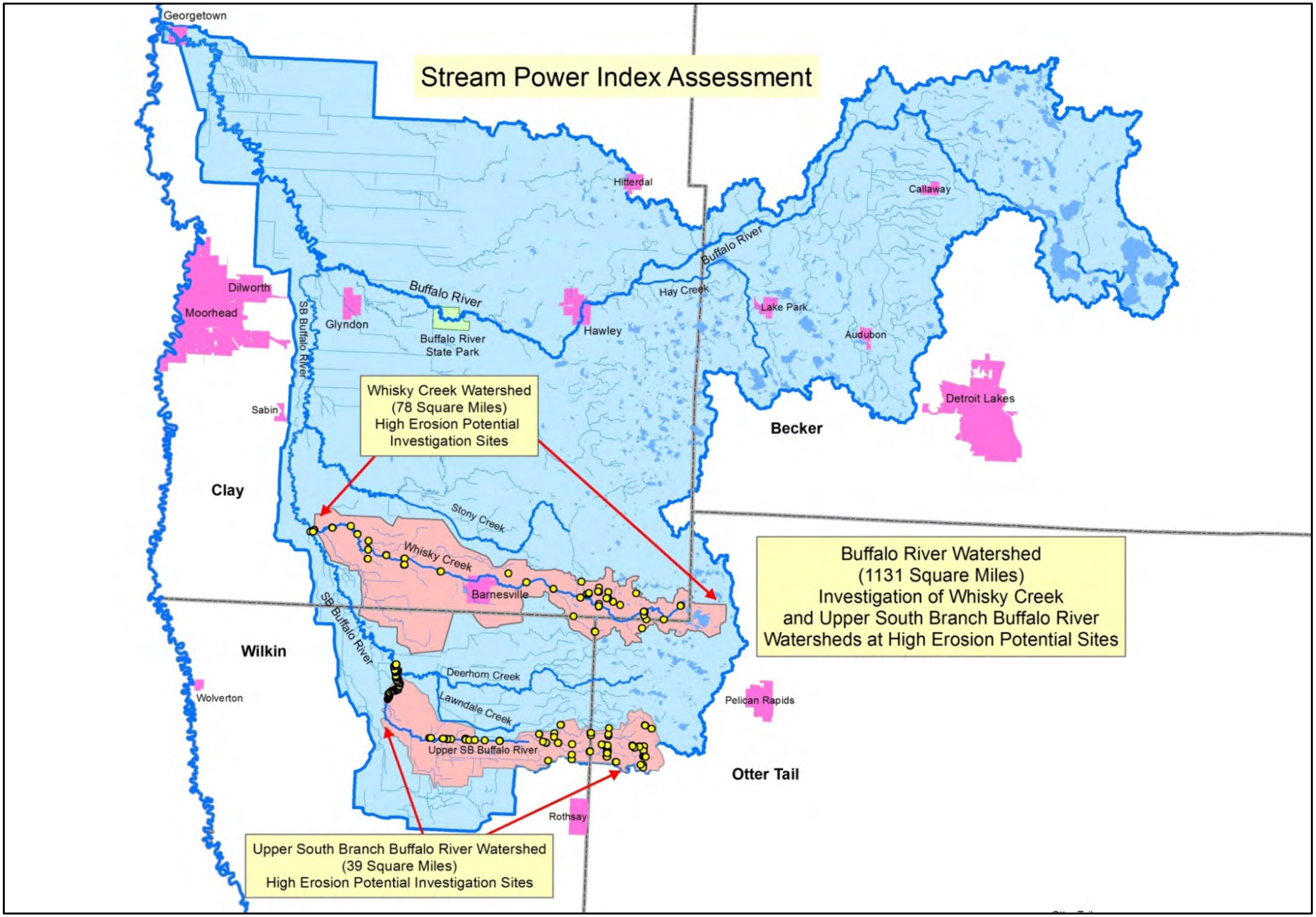


Figure 33. Stream Power Index (SPI) inventory locations for Whisky Creek and Upper South Branch Sub-watersheds of the Buffalo River.

Stream Power Index Field Assessment

A field gully inventory based on a hydrologically-corrected LiDAR (light detection and ranging) based digital elevation model (DEM) and SPI analysis was completed by MPCA and MNDNR staff. The work was focused on the Whisky Creek and Upper South Branch Buffalo River sub-watersheds of the Buffalo River HUC-8 Watershed during the summer of 2010 (Figure 33). The SPI analysis was completed through MPCA contracts to Houston Engineering. The purpose of the SPI analysis was to determine the relative erosion potential at a given location based on accumulation of flow (area) and slope at that location. This type of analysis is primarily intended to assess gully erosion in field drains or first and second order channel erosion potential. Color coded maps were created showing the relative SPI rating from low to high (Figure 34). This flow network is mostly made up of 1st and 2nd order streams, with many now farmed through. These maps were used to guide MPCA and DNR investigators during the field assessment.

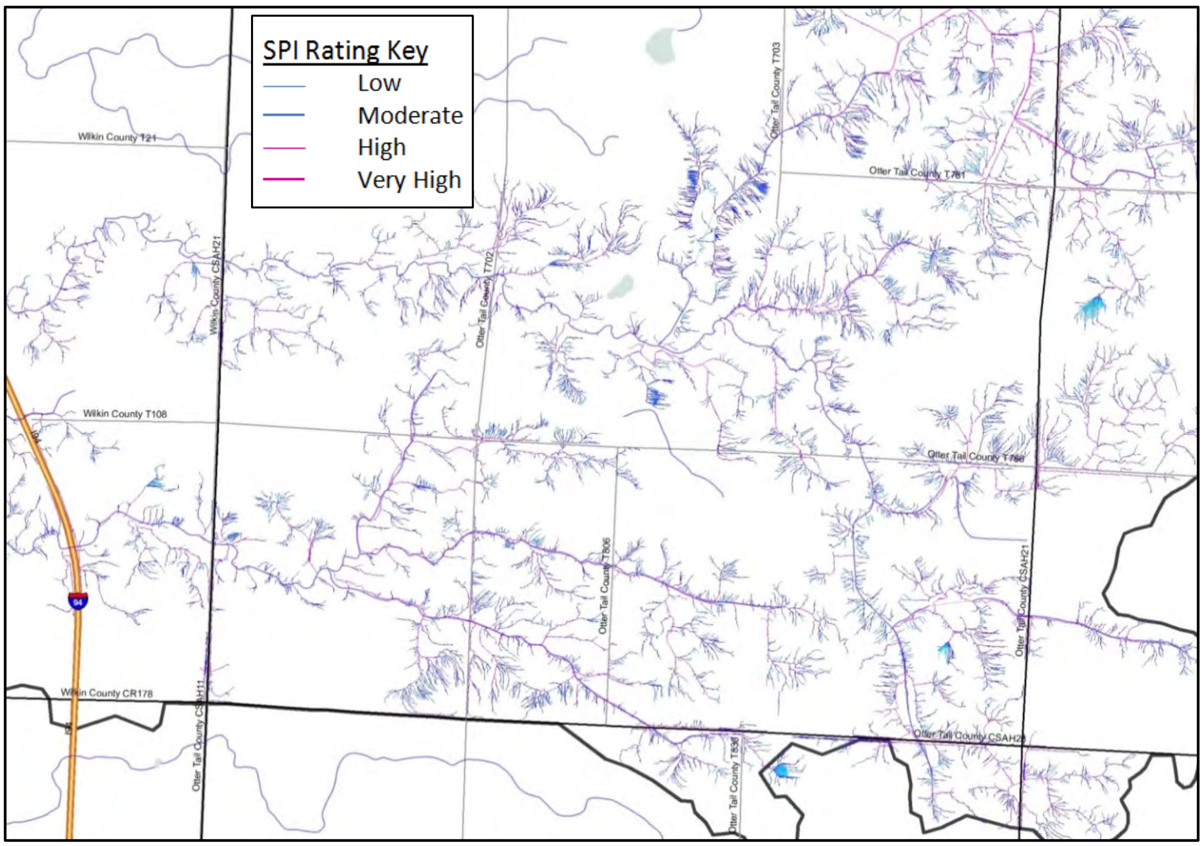


Figure 34. Stream power index map of the Upper South Branch Buffalo River.

Field assessments revealed substantial erosion at high SPI sites without adequate vegetation and little or no erosion at sites with adequate perennial vegetation in most cases (Figure 35 and Figure 36). This revealed how important good perennial cover is as a boundary condition for controlling erosion. A spreadsheet was developed to record conditions at SPI assessment locations (Table 16). Stream Power Index rating, coordinates, and various key parameters including erosion problems encountered and recommended site-specific best management practices are recorded in that spreadsheet.

Figure 35. High SPI sites with gully erosion evident.

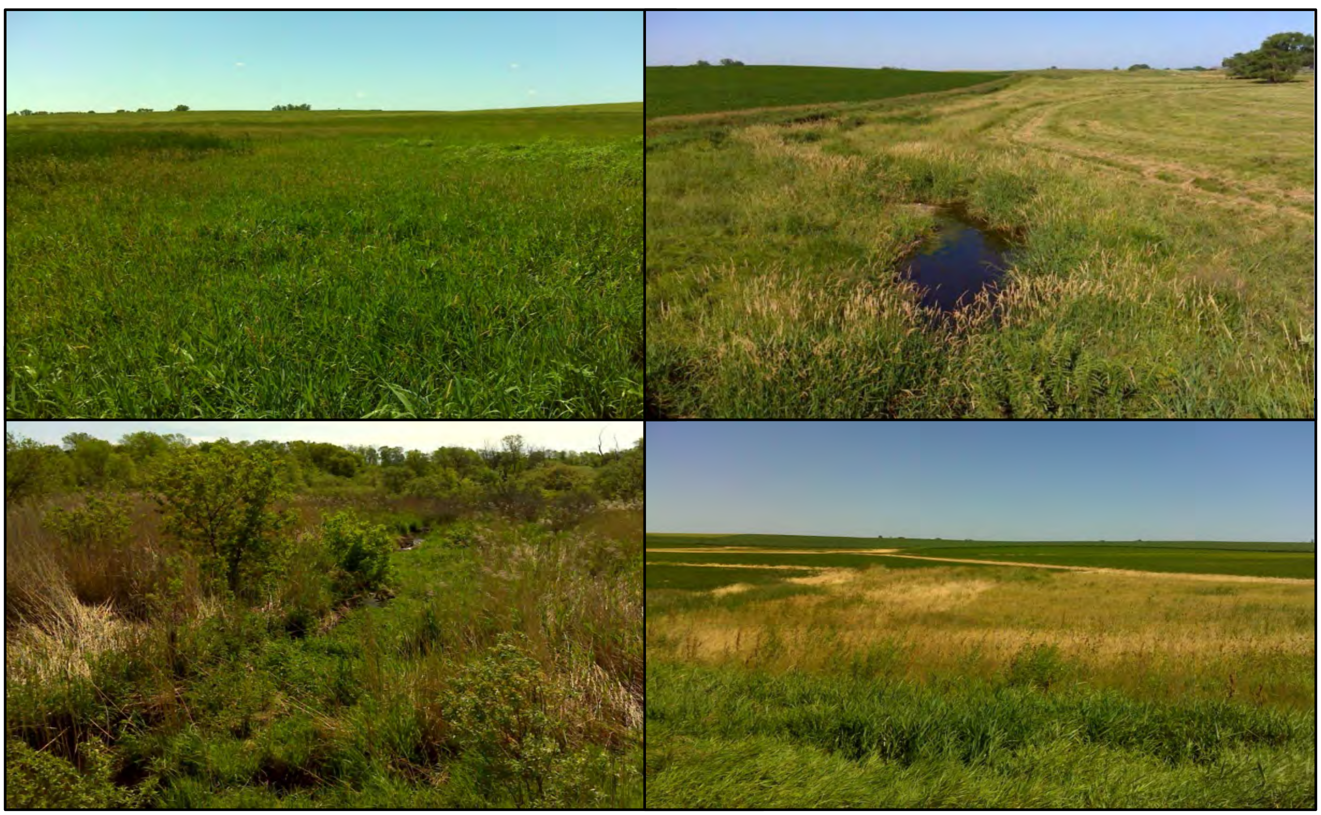


Figure 36. High SPI sites with little or no erosion evident.

[Appendix 6](#) contains an outline of implementation goals and restoration and protection activities that can be useful when planning for and applying for clean water funds for best management practices, especially when coupled with appropriate prioritization systems (as they are developed) for the Buffalo Watershed.

Both Whisky Creek and the Upper South Branch Buffalo River sub-watersheds span from the higher elevation glacial moraine, through the beach ridge, and onto the lake plain of glacial Lake Agassiz (Figure 37). Despite covering a range of gradients from moderately high to very low, the same relationship of adequate vegetation preventing erosion at high SPI locations held true.

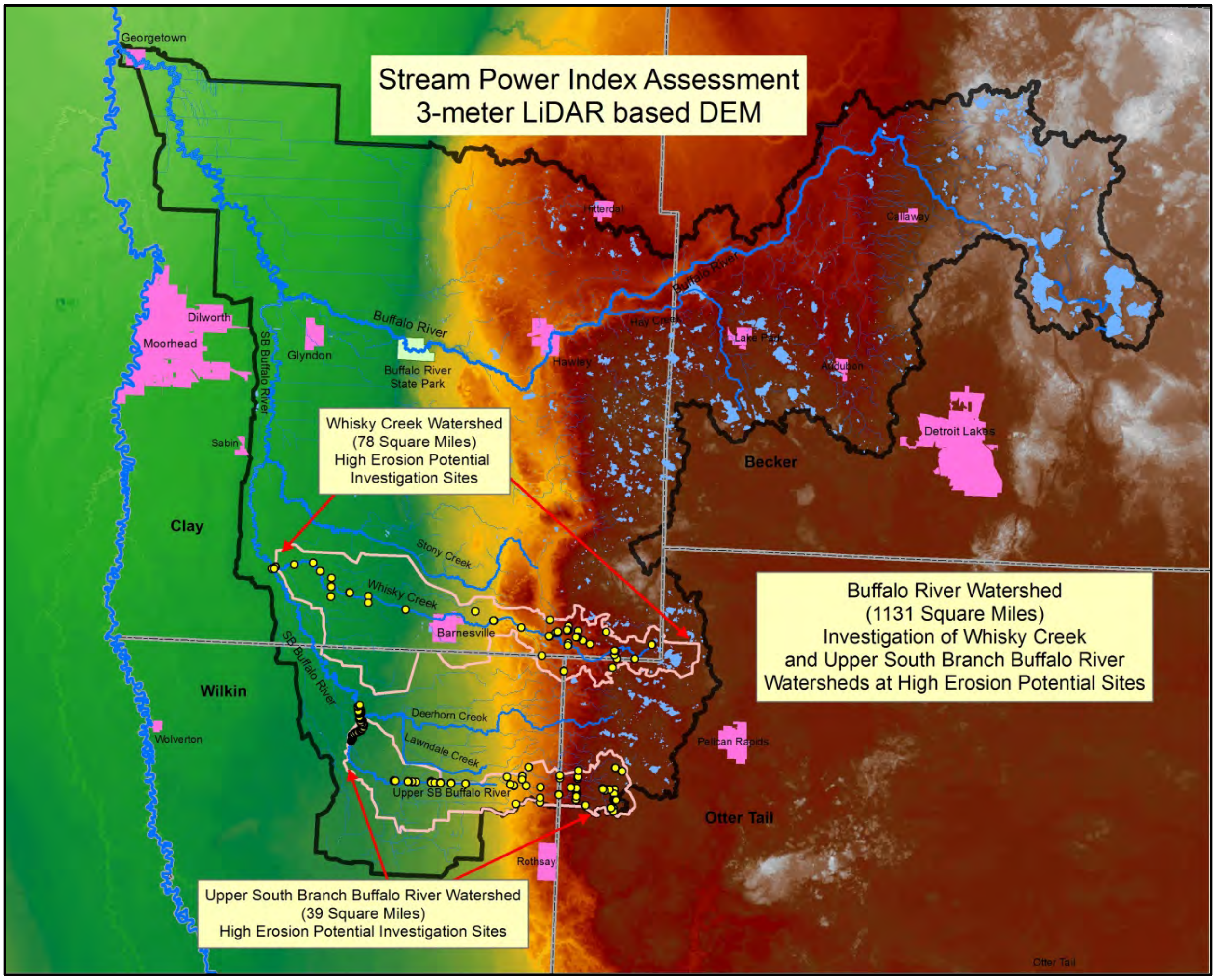


Figure 37. Whisky and Upper South Branch Buffalo River LiDAR (light detection and ranging) elevations.

A consequence of gully erosion in the upper watershed's glacial moraine area is that numerous wetlands, including numerous small wetlands to large DNR Wildlife Management Areas are incrementally filling with sediment, resulting in loss of wetland quality, water quality, and loss of flood storage capacity which contributes to altered hydrology. Along with deposition in wetlands, some of the sediment eroded from gullies in this region is transported directly to Whisky Creek and the Upper South Branch Buffalo River or through drainage ditches and tributaries. Sediment from gully erosion in the lake plain is either transported directly into the streams or it accumulates in the drainage ditches and smaller tributaries under low or moderate flows. Much of that deposition is then transported into Whisky Creek and Upper South Branch Buffalo River during major high flow events.

Fluvial Geomorphology Stations

Fluvial geomorphology assessments were completed at 12 locations including the beach ridge area of the Buffalo River and Lawndale Creek (Figure 38). Only a brief summary of geomorphology results, specifically a few that relate to biological stressors (Figure 39) and an example of more detailed data from one station (the Haugen site) are reported here. This Haugen site data provides an example (Figures 23-31) of some of the data that are available in the more detailed report (MNDNR in preparation) that will contain the complete data set and analysis.

Data collected at sites included bankfull determinations, longitudinal profiles, permanently marked (GPS survey grade end points at all cross sections with steel survey pins and caps at some) cross sections, BANCS erosion model estimates and validations, bank profiles permanently located with survey toe pins, riparian vegetation assessment, Pfankuch stability ratings, active bed and reach pebble counts, bar samples, and particle size analysis of bank erosion materials for select sites. Analysis of data yielded bankfull cross sectional mean depth, width, and area; reach bankfull slope; velocity estimates from roughness formulas for stage and discharge estimates away from gage sites; channel competence calculations; dimensional and dimensionless ratios of channel cross sections, sinuous pattern, and longitudinal profile; bank erosion rates, and total bank erosion contributions for the reach.

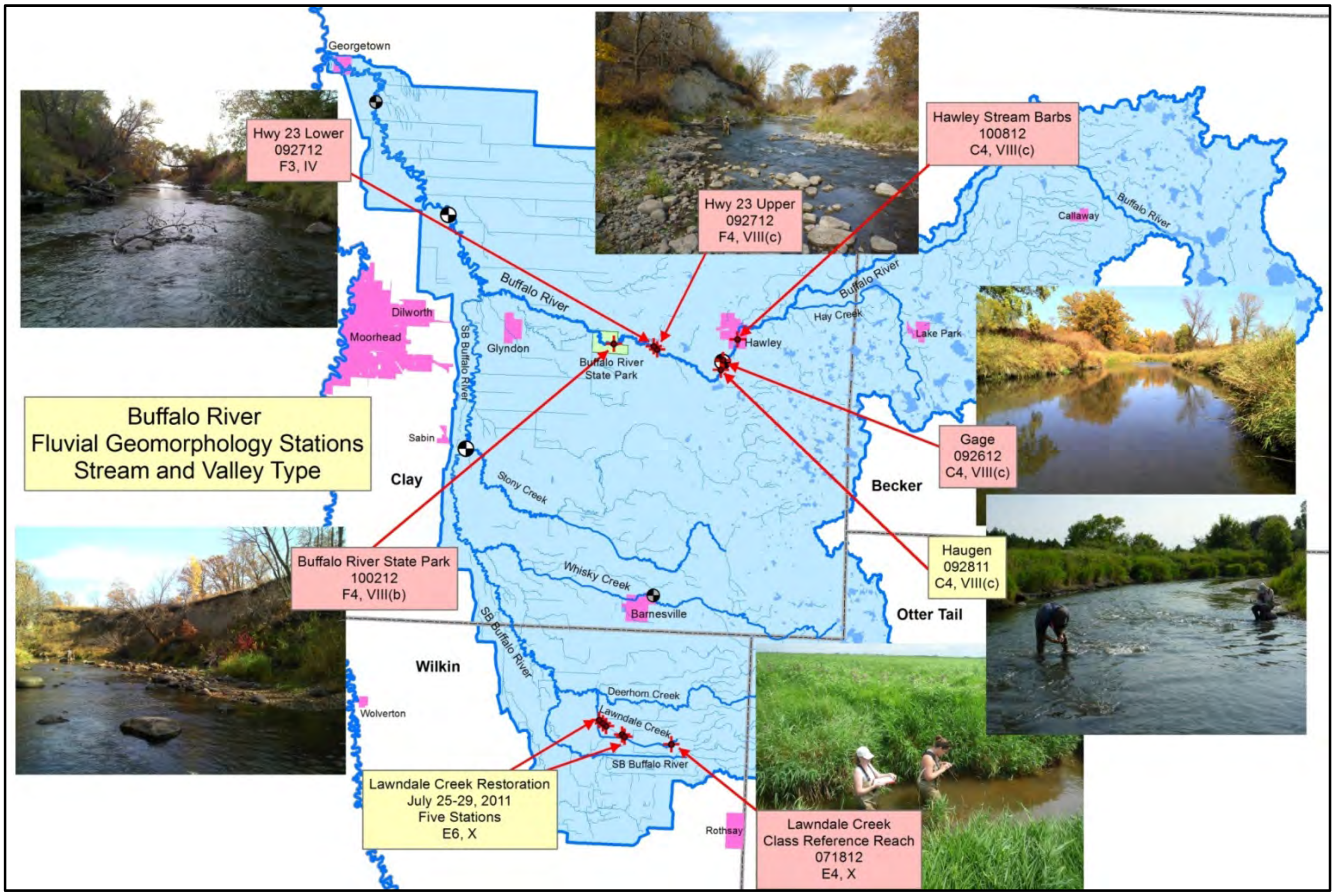


Figure 38. Fluvial geomorphology stations.

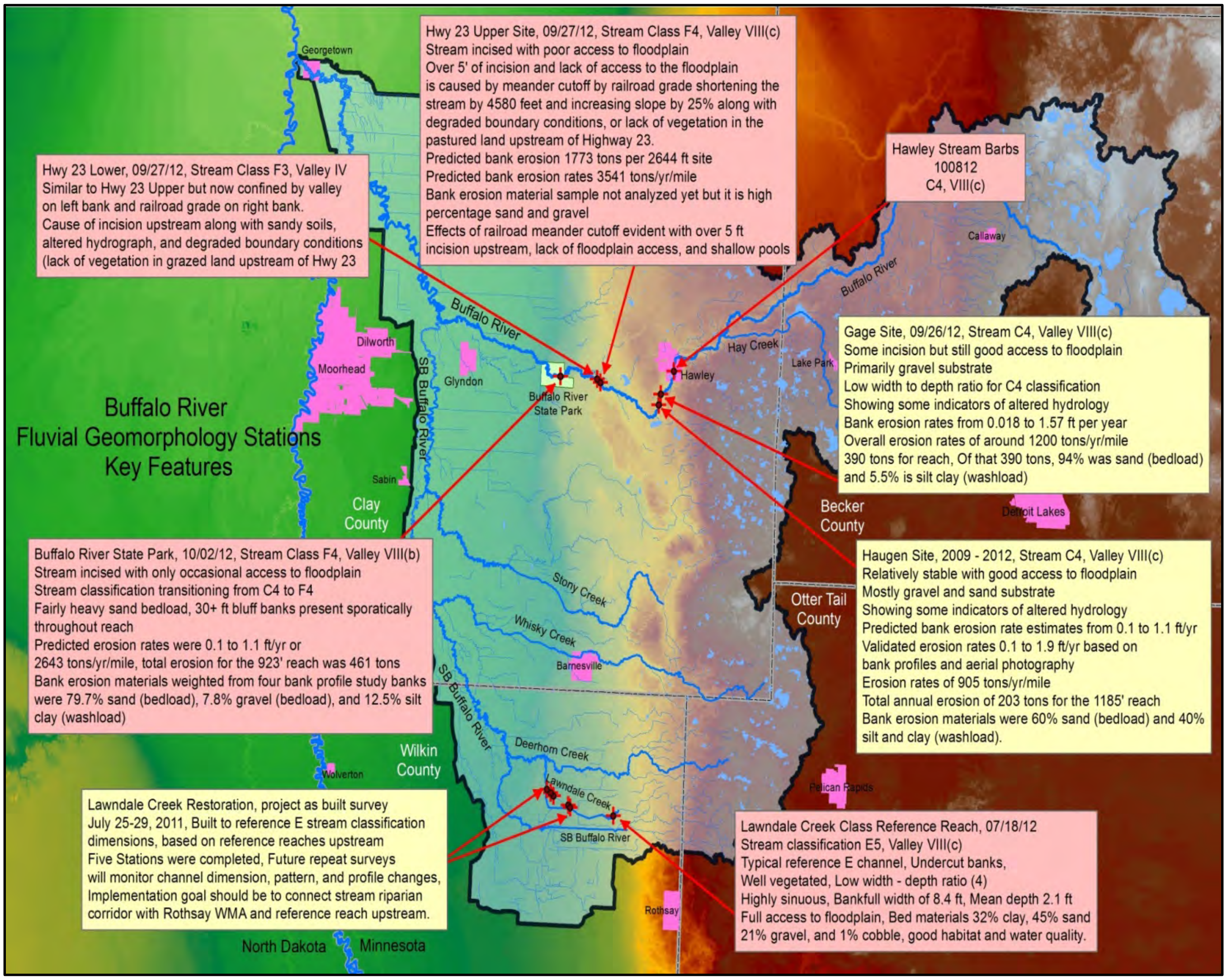


Figure 39. Key features of geomorphic stations related to biological impairments and stream health.

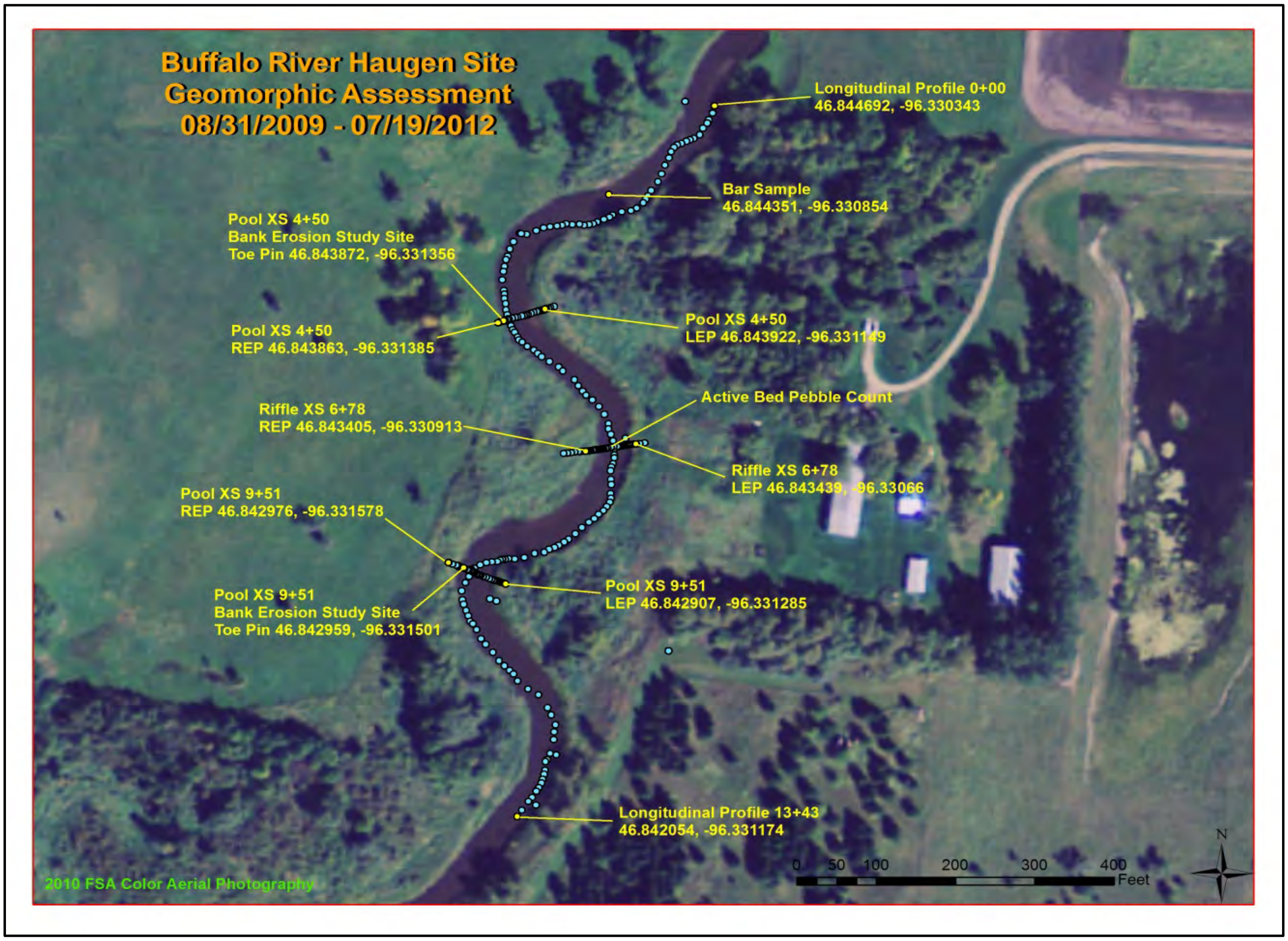


Figure 40. Haugen geomorphic assessment station (only one station shown as example).

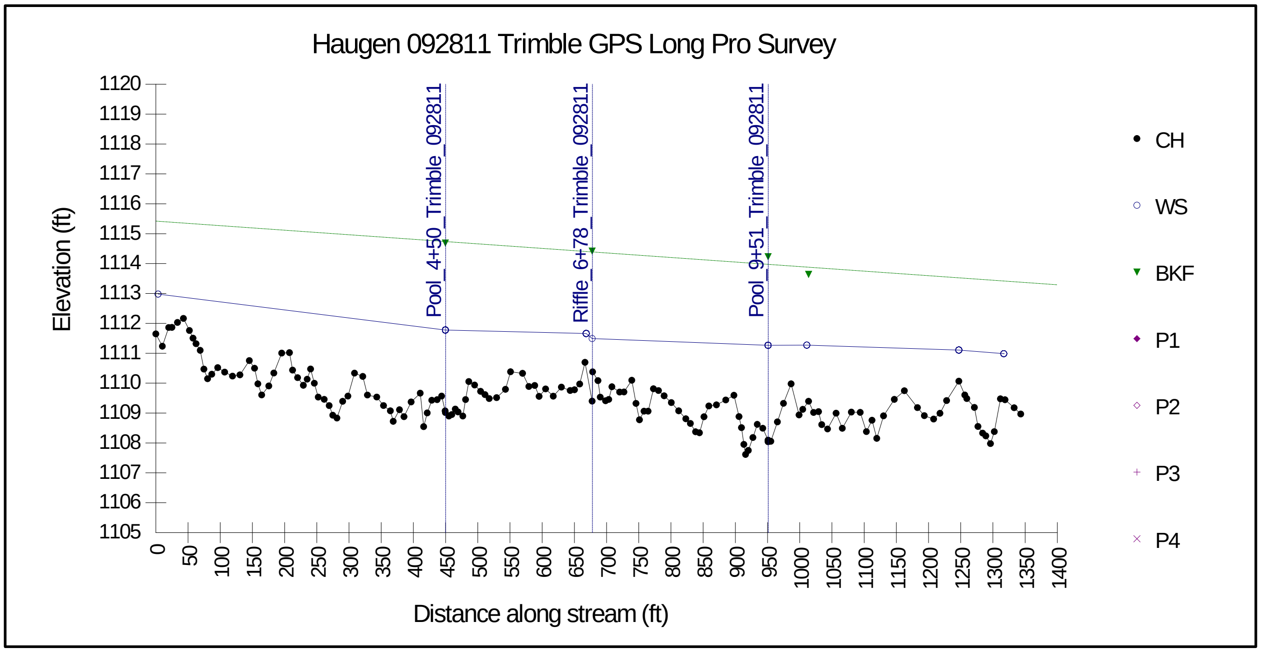


Figure 41. Haugen site longitudinal profile.

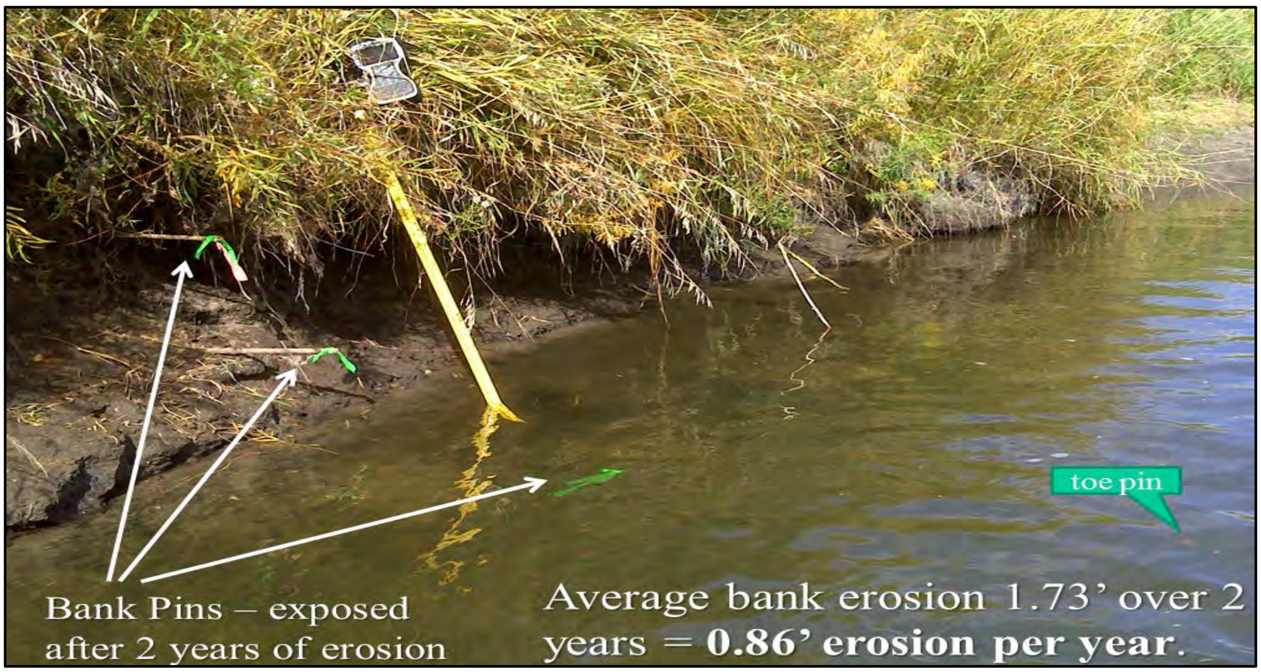


Figure 42. Validated erosion rate of 0.86 ft/yr over two year period. Predicted erosion rates ranged from 0.76 to 1.0 ft/yr based on BEHI and NBS.

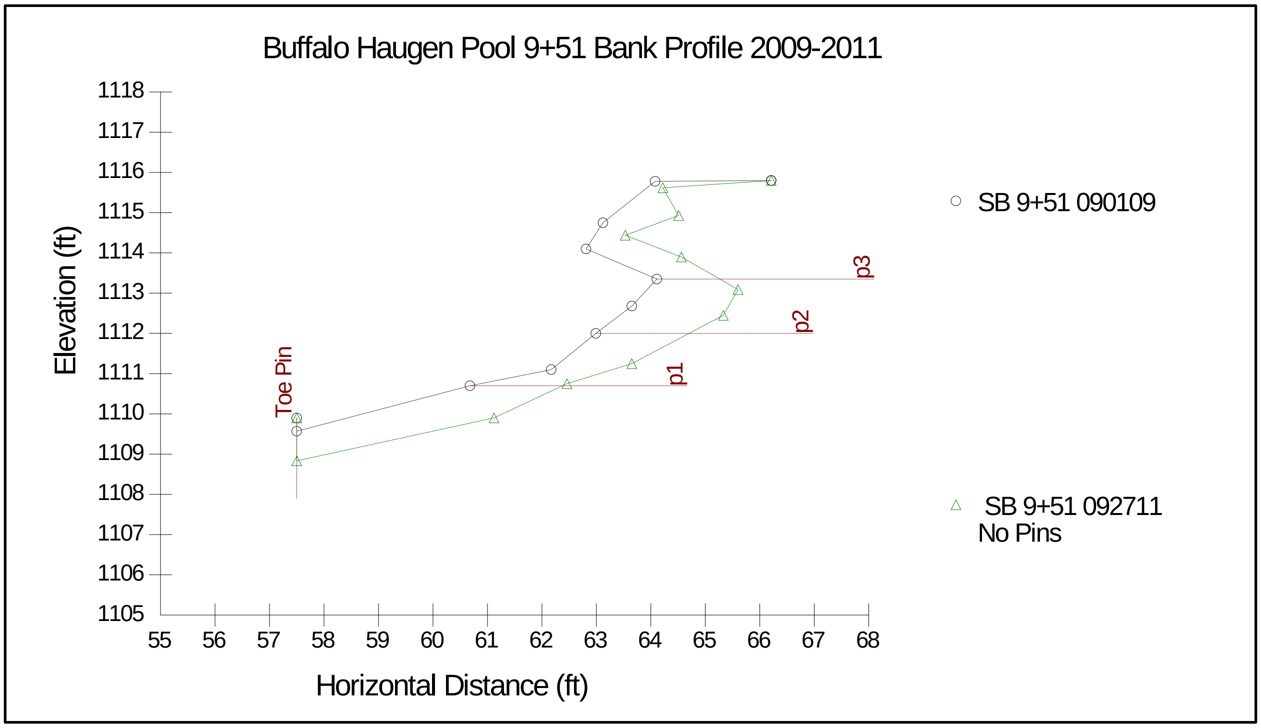


Figure 43. Haugen study bank one profile erosion validation, actual erosion rate of 0.86 ft/yr.

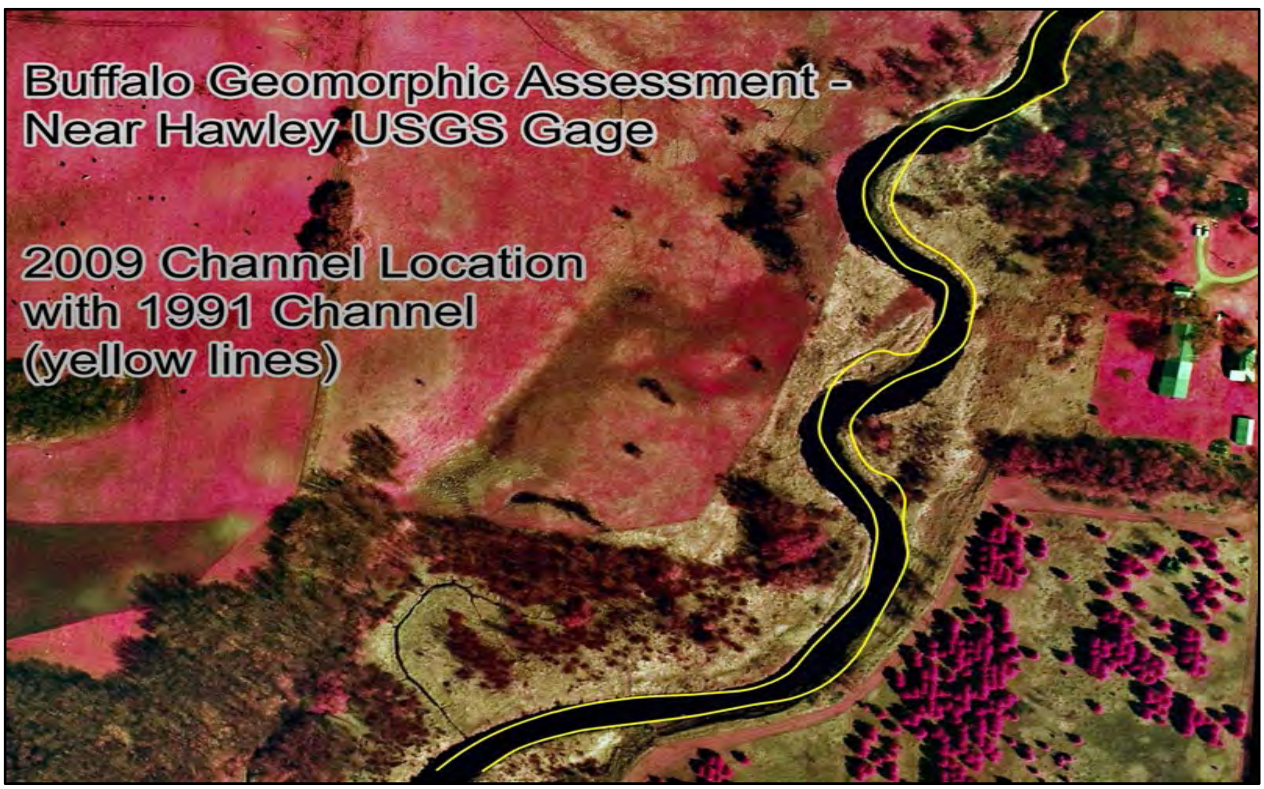


Figure 44. Aerial photography validation of bank erosion rates at the Haugen site.

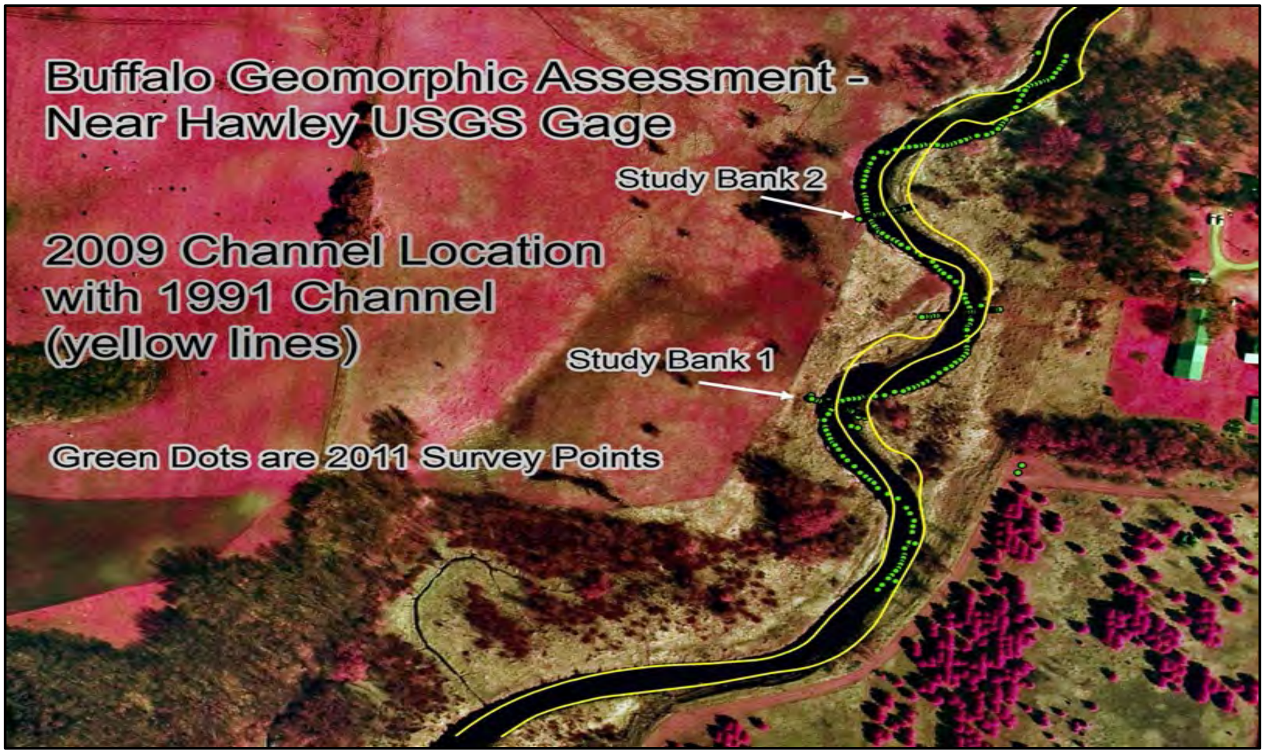


Figure 45. Aerial photography validation of bank erosion rates at the Haugen site.

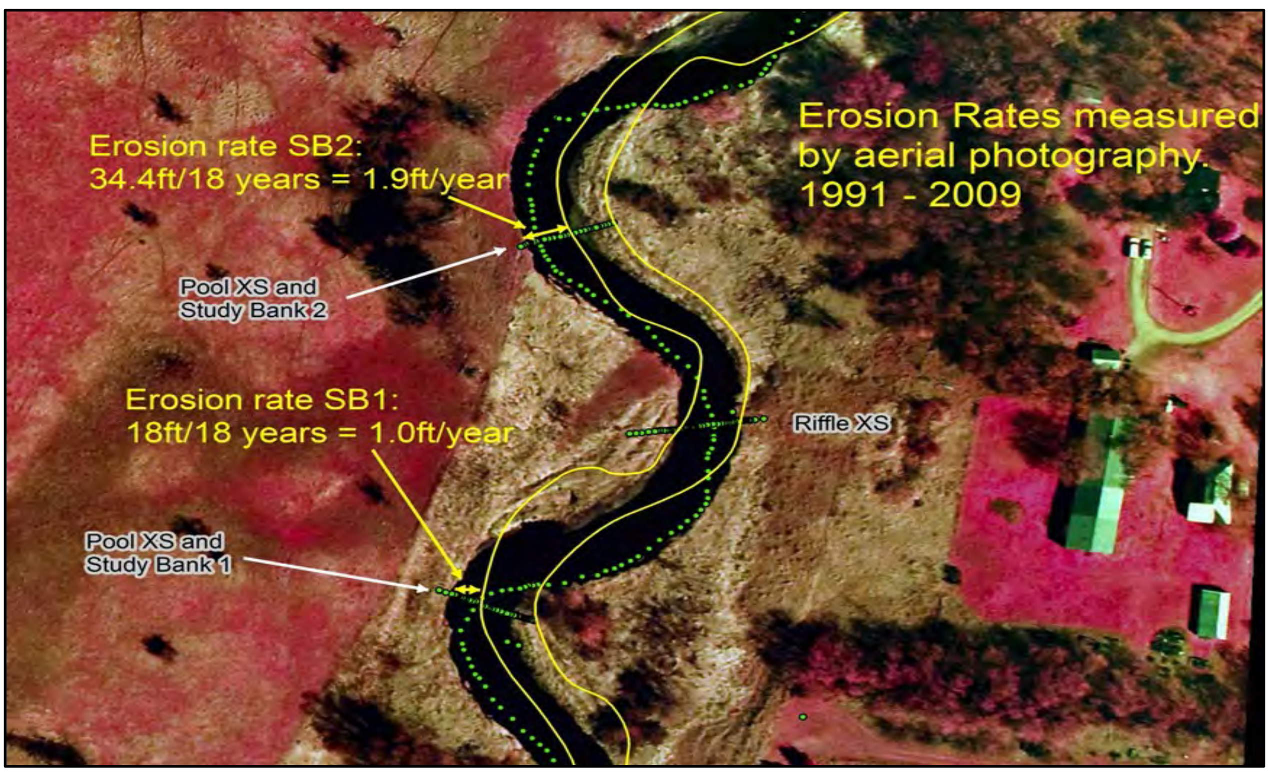


Figure 46. Aerial photo validation of study bank one and two erosion rates. Note accelerated rates nearly twice as high at pasture site study bank two.

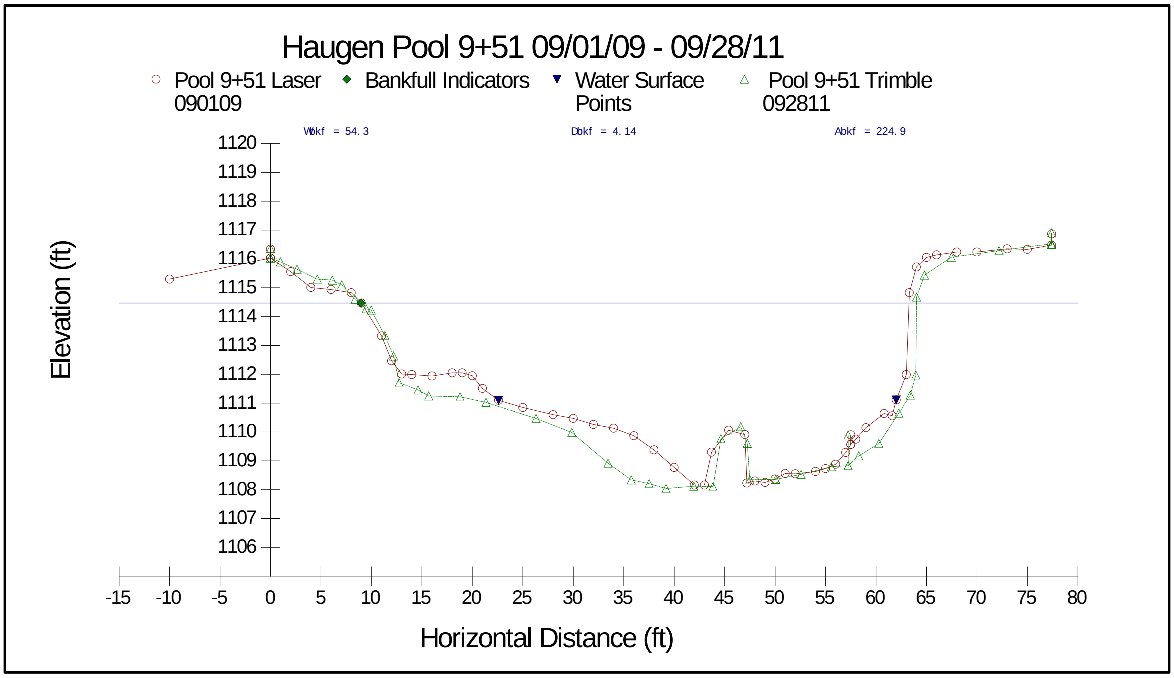


Figure 47. Haugen site pool cross section overlay, 2009 and 2011. 2011 cross section was 28 sq ft larger than 2009 showing increased pool scour during that high-flow timeframe.

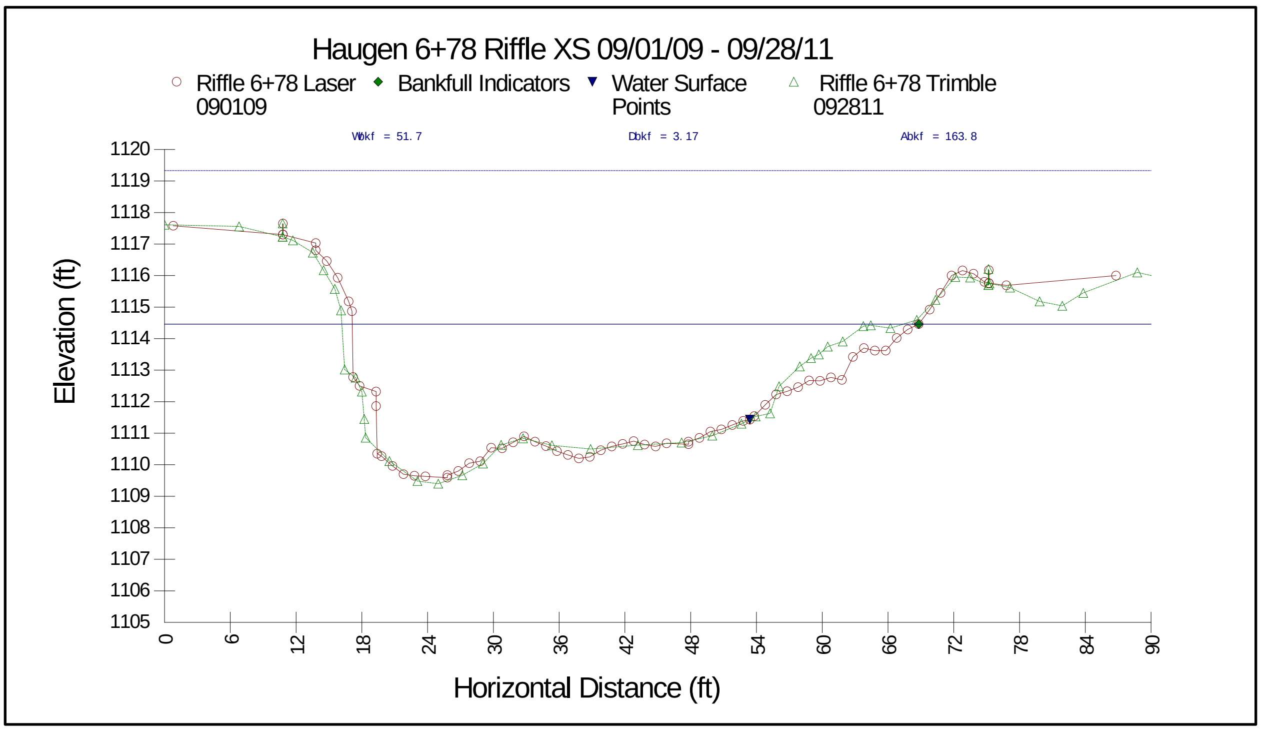


Figure 48. Riffle cross section overlays for trend analysis. Virtually no change between 2009 and 2011 at the riffle (hydraulic control point) showing overall station stability.

Channelization and Channel Repairs

Much of the stream network of the Buffalo watershed consists of legal ditches. Some of these channelized streams have been left alone since the 1950s and have evolved back to a stable form with reasonably good habitat. An example of one such stream is Upper Whisky Creek with its well vegetated riparian corridor, stable channel, and diverse fish and macroinvertebrate habitat with high IBI's.

The South Branch Buffalo River between Rothsay Wildlife Management Area and Western Prairie Scientific and Natural Area was another example. A stable E channel had formed (narrow, deep, well vegetated, efficiently transported water and sediment) within the ditch banks with diverse and high quality plant and fish community. This stream (County Ditch 44) had no record of a cleanout since the 1950s until 2010 at the request of landowners for increased flow capacity. The channel was transformed from a stable and efficient stream with course sediment bottom to a high width to depth ratio ditch with fine silt and organic bottom substrate. This change is conducive to growing cattails and potentially losing efficiency of water and sediment transport as well as the ability to absorb nutrients on the floodplain benches that had formed. The ditch is now likely a sediment sink during low to moderate flows that will likely require periodic cleanouts to remove cattail vegetation and sediment accumulation.

The following figures (Figures 49 to 57) are in chronological order and tell a story of a ditch law system that is not conducive to long term stream stability, biological health and water quality. Recommendations for implementation strategies include discussions on revising ditch law to fit with the goals of improving water quality, providing storage and reducing biological impairments.

Figure 49. South Branch Buffalo River before ditch repair. Note the rich, diverse riparian vegetation comprised of native grass and forbs.

Figure 50. Stable form, native vegetation, gravel substrates, efficient water and sediment transport.

Figure 51. Riffle area with cobble and gravel substrate.

Figure 52. Low flow channel at near bank full. The meander pattern adds storage and reduces velocities.

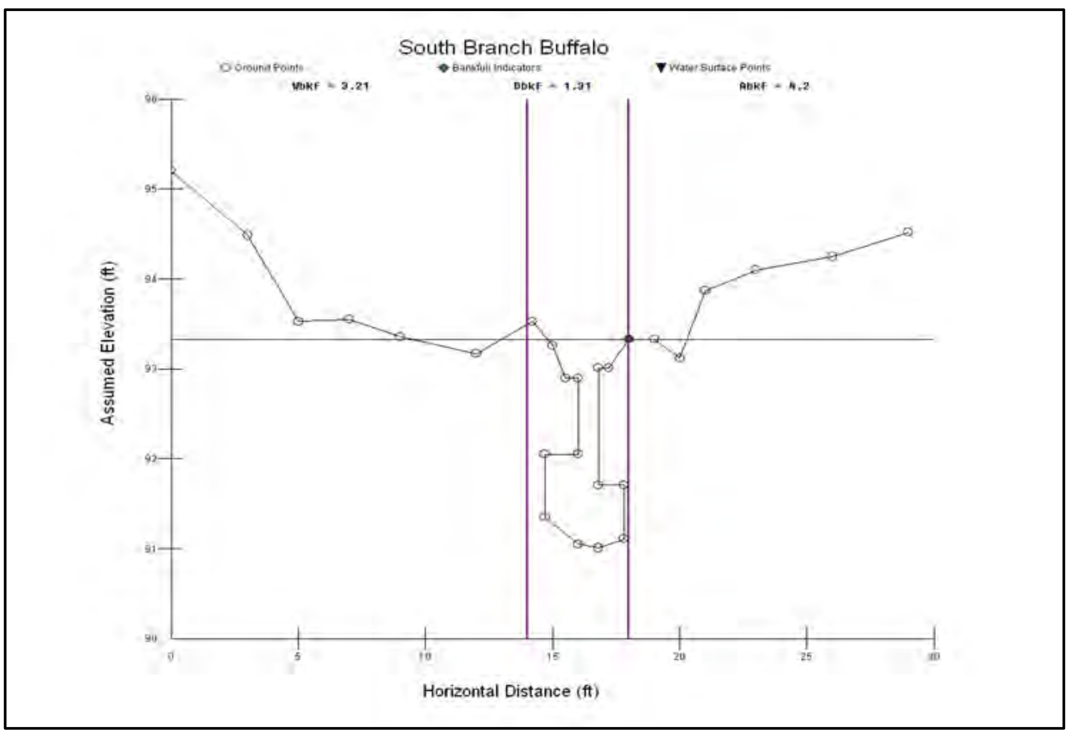


Figure 53. Cross section before cleanout showing undercut bank habitat.

Figure 54. Ditch repair in progress.

Figure 55. Photo after repair showing high width depth ratio, fine sediment, and cattail colonization.

Figure 56. Herbicide application destroying high quality riparian vegetation.

Figure 57. Bottom composed of fine sediment and organic material after cleanout.

Candidate Cause of Biological Impairments

The next section of this paper will outline the suspected stressors or causes of biological impairments of the four impaired reaches of the Buffalo River Watershed. A brief description of each candidate cause will be presented with supporting evidence for its inclusion in the list. The candidate causes are: water quality, sediment/turbidity, lack of habitat, connectivity, and flow alteration (Figure 58).

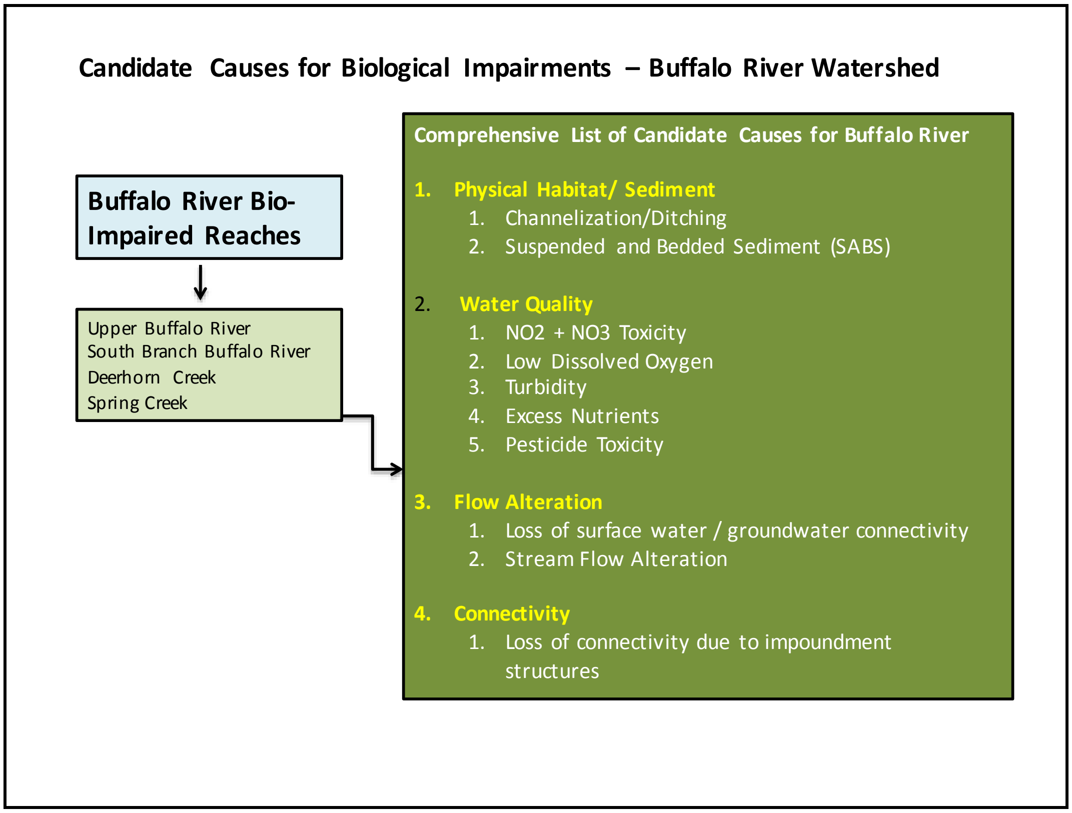


Figure 58. Candidate Causes for Biological Impairment in the Buffalo River Watershed.

Candidate Cause: Lack of 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 et al., 2010). Physical habitat is often interrelated to other stressors (e.g., sediment, flow, DO) and will be addressed separately. Fish passage or stream connectivity will be addressed in a separate section.

Physical habitat diversity enables fish and macroinvertebrate habitat specialists to prosper, allowing them to complete their life cycles. Some examples of the requirements needed by habitat specialists are: sufficient pool depth, cover or refuge from predators, and riffles that have clean gravel or cobble which is and are unimpeded by fine sediment (Griffith et al., 2010).

Specific habitats that are required by a healthy biotic community can be minimized or altered by practices on our landscape such as row crop and animal agriculture, resource extraction, 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 et al. 2010).

One of the more significant impacts to the Buffalo River biota is the loss of headwater streams to agriculture through cultivation, ditching, filling and tiling. In the agricultural portions of the watershed (78% of the total watershed area) headwater streams are typically farmed through. These old stream beds are often “cleaned out” with laser guided scrapers in the fall (if field moisture conditions allow) so that any high spots or obstacles to efficient drainage are removed. Spring field work often occurs when these low areas have sufficiently dried out to allow for tillage and planting. Although they flow with runoff during spring melt and storm events, they no longer provide habitat characteristics necessary for aquatic life.

In addition to the impacts to the biota from the cumulative loss of headwater stream habitat in the watershed, there is a secondary impact, and that is the erosion and transport of soil from these relic stream beds to the downstream receiving water body. The tillage of the intermittent stream course creates an ideal scenario for erosion as the loose soil is easily washed with the concentrated flow during runoff events. Following significant events, the farmed-through stream can cut a new channel into the field, flushing the loose topsoil, and in some cases the subsoil, downstream. The impacts to the receiving stream include high turbidity, the filling of pool habitat, embedded coarse riffle habitat, low DO, increased nutrient levels, and filling of floodplain wetlands.

Headwater streams are to a river system what capillaries are to the circulatory system. These streams connect upland and riparian systems with river systems. Headwater streams dominate surface water drainage networks in terms of stream miles present. If we define headwaters streams as all first and second order streams, then, in total, these streams compose over two-thirds of the total stream length in a river network (Leopold et al., 1964 in Freeman et. al., 2007). Every large river is fed by literally hundreds of thousands of small headwater streams (Leopold et al., 1964). The cumulative effect of the loss of this habitat on biodiversity, community structure and biomass is tremendous. The loss of headwater streams has the potential to reduce ecological integrity at large spatial scales especially in vulnerable systems, such as the Buffalo River, already affected by major landscape changes and downstream stressors including dams and altered hydrology.

Water Quality Standards

There currently is no applicable standard for lack of habitat for biotic communities.

Habitat characteristics in the Buffalo River

Habitat conditions are usually vital in understanding the biological communities. Qualitative habitat was measured in the Buffalo River Watershed with the Minnesota Stream Habitat Assessment (MSHA) during the time the fish surveys were conducted. The MSHA is useful in describing the aspects of habitat needed to obtain an optimal biological community. It includes five subcategories: land use, riparian zone, substrate, cover, and channel morphology. The following paragraph from the Buffalo R Watershed Assessment Report (Dingmann, et.al. 2012) provides a good summary of the MPCA habitat findings for the Buffalo River system.

> *Fish and Macroinvertebrate IBI scores in the Buffalo River Watershed often tended to contradict what would be expected based on land use patterns alone. Both F-IBI and M-IBI scores often increased further downstream in the watershed in contrast to habitat conditions that became degraded as one moved downstream into the higher intensity agricultural landuse. Overall habitat conditions as measured by the MSHA did not appear to explain the different patterns observed in the biology. Correspondence*

between F-IBI and M-IBI results and overall habitat score were generally weak. For example, in the Upper Buffalo reach the highest overall habitat scores were found at the most upstream monitoring locations in a forested setting and at the most downstream location, while F-IBI and M-IBI varied considerably at these sites (F-IBI range = 27-50, M-IBI range = 41-55). Habitat at the most downstream sites was typified by low land use and riparian cover scores, while high geomorphology and fish cover scores were more prevalent in the headwater reaches and reflected the better overall habitat conditions in the upstream portions of the watershed.

Sources and causal pathways model for habitat

The causes and potential sources for lack of habitat in the Buffalo River Watershed are modeled at EPA's CADDIS Physical Habitat webpage and shown in Figure 59. Many riparian areas along the Buffalo River and tributaries are influenced by row crop agriculture and cattle that decreases the condition and extent of riparian and bank vegetation. Along with altered hydrology, the alteration of habitat caused by channelization and impoundments, has numerous pathways of influence affecting the biological community.

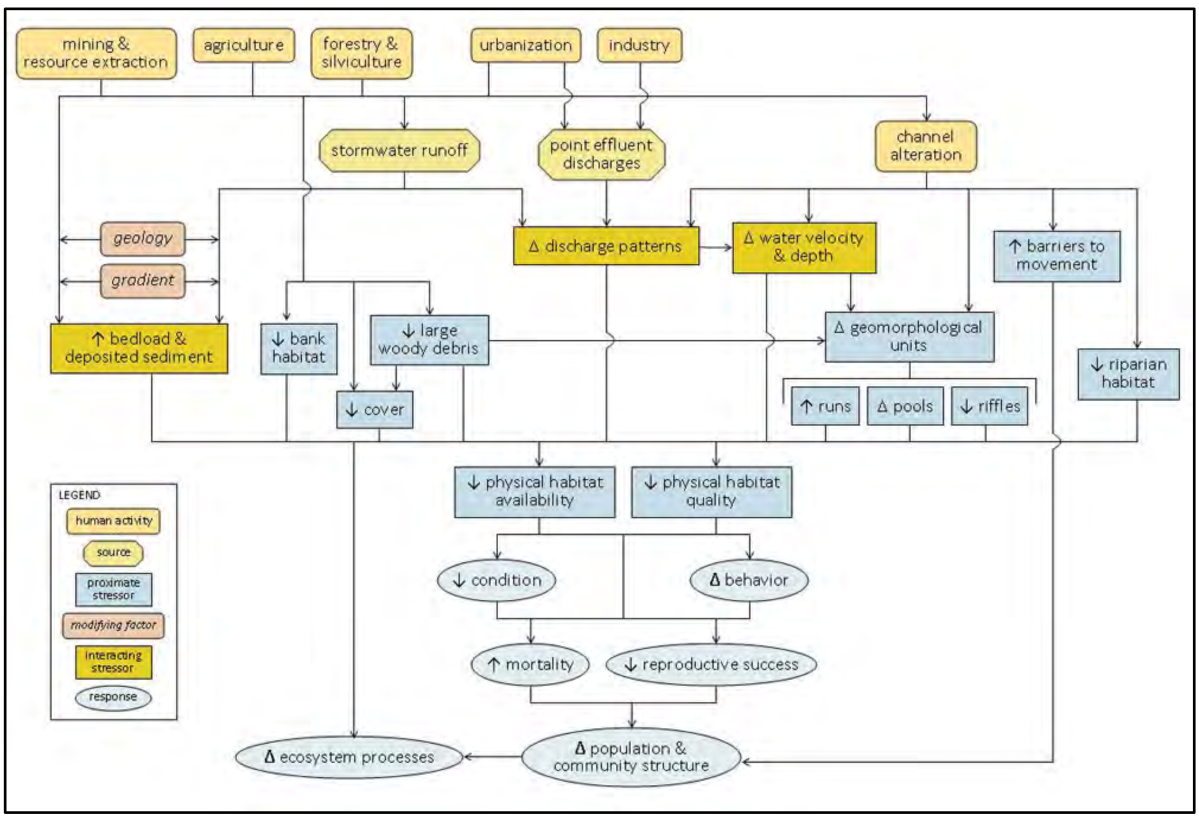


Figure 59. Physical Habitat: Simple Conceptual Diagram (source EPA website).

Candidate Cause: Sediment/Turbidity

Turbidity is a measure of reduced transparency that can increase due to suspended particles such as sediment, algae and organic matter. Increases in suspended sediment and turbidity within aquatic systems are now considered one of the greatest causes of water quality and biological impairment in the United States (U.S. EPA, 2003). Although sediment delivery and transport are important natural processes for all stream systems, sediment imbalance (either excess sediment or lack of sediment) can result in the loss of habitat in addition to the direct harm 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 turbidity levels and TSS (total suspended solids) concentrations can reduce the penetration of sunlight and thus impede photosynthetic activity and limit primary production (Munavar et al., 1991; Murphy et al., 1981).

Elevated VSS (volatile suspended solids) concentrations can impact aquatic life in a similar manner as TSS – with the suspended particles reducing water clarity – but unusually high concentrations of volatile suspended solids (VSS) can also be indicative of nutrient imbalance and an unstable DO regime.

Water quality standards

The water quality standard for turbidity is 25 Nephelometric Turbidity Units (NTUs) for the protection of aquatic life in Class 2b waters. Because turbidity is an optical measurement and not a measure of mass, TSS “surrogate” standards for turbidity were developed for ecoregions of the state and are applicable to water quality data collected within each respective ecoregion.

A strong correlation exists in the Red River basin between the measurements of TSS concentration and turbidity (Paakh, 2006). In 2010, MPCA released draft TSS standards for public comment (Markus, 2010). The new TSS criteria are 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. A regression of the Total Suspended Solids (TSS) to turbidity indicates impairment at 65 mg/L for waters within the Lake Agassiz Plain Ecoregion. For assessment, this concentration is not to be exceeded in more than ten percent of samples within a ten year data window.

Sestonic algae can also lead to increases in turbidity and can be evaluated by tests which measure the percentage of the solids from a sample that are burned off such as VSS. There are no current standards for VSS. Algae typically do not play a large role in turbidity levels within the Red River basin. Heiskary and Markus (2003) studied river phosphorus and chlorophyll relationships in Minnesota Rivers. He noted that of the major river systems in the state, the Red River basin has the weakest phosphorus/chlorophyll relationship. Higher phosphorus levels do not correlate well with higher chlorophyll concentrations due to the fine clay particles that tend to stay in suspension and cause prolonged high turbidity levels. High turbidity levels limit light penetration and significantly reduce algal growth, well below what would be expected with the phosphorus concentrations present in Red River basin streams.

For the purposes of stressor identification, transparency tube measurements, TSS, VSS, and HSPF modeling results will be relied upon to quantify the suspended material present from which inferences can be made regarding the effects of suspended solids on fish and macroinvertebrate populations.

Turbidity in the Buffalo River Watershed

The Buffalo River Watershed had greater than ten percent of the TSS samples at or above the 65 mg/L draft TSS standard, and thus is considered out of compliance for waters within the Lake Agassiz Plain ecoregion (MPCA 2009). In 2008, the percent of TSS samples that exceeded the 65 mg/L surrogate standard in the Buffalo River was 88 percent while the FWMC (flow weighted mean concentration) was 82.9 mg/L. In 2009, 42 percent of the samples collected exceeded the standard and the FWMC was 54.5 mg/L. In 2010, 78 percent of the samples collected exceeded the standard and the FWMC was 65.3 mg/L. The biota impaired sections of the Buffalo River, the Buffalo River - Headwaters reach, South Branch Buffalo River and Deerhorn Creek are also listed for turbidity. More information about the turbidity in the Buffalo River Watershed can be found in the Buffalo River Monitoring and Assessment Report.

Sources and causal pathways for turbidity

The causes and potential sources for increases in turbidity in the Buffalo River Watershed are modeled at EPA's CADDIS Sediments webpage. High turbidity 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 row crop agriculture, ditch maintenance/repair, construction, mining, insufficiently vegetated pastures, or livestock access to stream banks. Since 78% of the Buffalo River Watershed is comprised of row crop agriculture and the soils are often insufficiently protected (without a crop canopy for seven to eight months) this is the leading source of soil into rivers and streams. The simple conceptual design (EPA Caddis website) is presented in Figure 60.

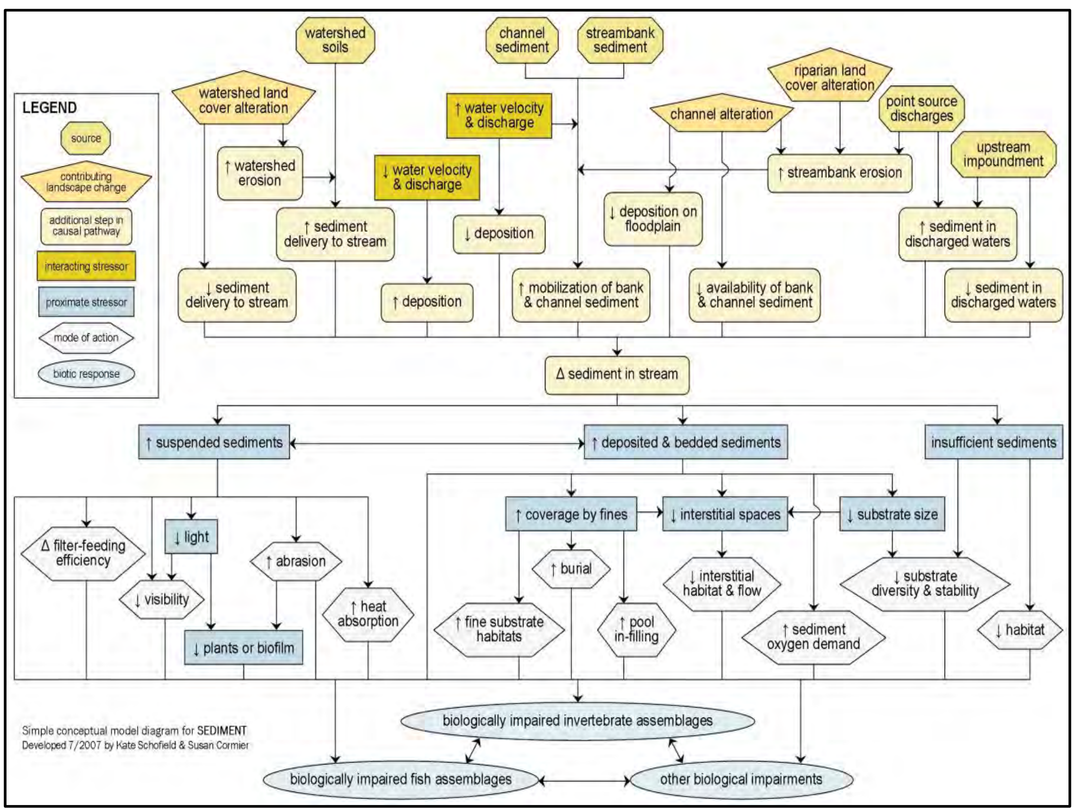


Figure 60. Sediment: Simple Conceptual Diagram (source EPA website).

Another significant source of soil loss and high stream turbidity levels is eroding stream channels (often referred to stream channel instability) where sediment/soil is eroded from the stream banks and stream bed. This destabilization is often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, increases in impervious surfaces, and livestock access to the stream channel however the leading cause of stream channel instability is increases in stream flow due to agricultural drainage (ditching, tiling, and wetland drainage or filling). As previously discussed, intensive agricultural drainage in the Buffalo River Watershed has changed the hydrograph to one with increased peak discharge rates (Figure 15). The sheer stress on the stream bank and bed increases with peak discharge rates and this is a primary mode of channel instability in agricultural watersheds, such as the Buffalo River.

Candidate Cause: Dissolved Oxygen

Dissolved oxygen refers to the concentration of oxygen gas within the water column. Low or highly fluctuating concentrations of DO can have detrimental effects on many fish and macroinvertebrate species (Davis 1975; Nebeker et al. 1991). Dissolved oxygen concentrations change seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan 1995). Some macroinvertebrates that are intolerant to low levels of DO include mayflies, stoneflies and caddisflies (Marcy 2007). Many species of fish (i.e. walleye, smallmouth bass, greater redhorse, hornyhead chub, and northern redbelly dace) avoid areas where DO concentrations are below 5 mg/L (Raleigh et al., 1986). Additionally, fish growth rates can be significantly affected by low DO levels (Doudoroff and Warren 1965).

In most streams and rivers, the critical conditions for stream DO usually occur during the late summer season when water temperatures are high and stream flows are reduced to base flow. As temperatures increase, the saturation levels of DO decrease. Increased water temperature also raises the DO needs for many species of fish (Raleigh et al. 1986). Low DO can be an issue in streams with slow currents, excessive temperatures, high biological oxygen demand, and/or high groundwater seepage (Hansen 1975).

Water quality standards

In Class 2B streams, the Minnesota standard for DO is 5.0 mg/L as a daily minimum. 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.

Types of dissolved oxygen data

Point measurements

Instantaneous DO data is available throughout the watershed and can be used as an initial screening for low DO. These measurements represent discrete point samples, usually conducted in conjunction with surface water sample collection utilizing a YSI sonde. Because DO concentrations can vary significantly as a result of changing flow conditions, temperature, and time of sampling, instantaneous measurements need to be used with caution and are not completely representative of the DO regime at a given site.

Longitudinal (synoptic)

Longitudinal synoptic DO surveys were conducted in the Buffalo River Watershed during 2012. A synoptic monitoring approach aims to gather data across a large spatial scale and minimal temporal scale. In terms of DO, the objective was to sample a large number of sites from upstream to downstream under comparable ambient conditions. The longitudinal surveys were used to better understand differences in DO conditions along the stream as well as document DO levels contributed from the various tributaries near pour points entering the stream. Tributaries with low DO levels can be targeted for follow-up study and potential implementation while those tributaries with high DO levels might be suited for protection. The results of this work are included in the subwatershed specific sections later in the report.

Overview of dissolved oxygen in the Buffalo River Watershed

The Buffalo River biological impaired reaches were also assessed for DO. None of the biological impaired reaches had a DO impairment, however the South Branch Buffalo River reach immediately upstream of the bio-impaired South Branch Buffalo River reach had significant DO issues and is listed as impaired for low DO. The water quality station (S003-148) located just upstream of confluence with Deerhorn Creek had a DO impairment rate of 14/95 or 14.7%. These exceedances were measured from July to September during 2009, 2010 and 2012. During July, August and September 2009 six of the nine DO samples collected were less than five mg/L. Due to the proximity of this site to the biological impaired (macroinvertebrates) reach on the South Branch Buffalo River there are concerns that DO could be a factor in the poor IBI score there.

A longitudinal sonde survey conducted on Deerhorn Creek in May and June of 2012 documented impacts from a storm event in the upper reaches. DO concentrations collected during the storm event were noticeably lower than the levels collected a few weeks prior during base flow conditions. Additional monitoring with the use of deployed sondes will need to be conducted during future work in this watershed to determine the degree of DO flux present in the system. This work should be focused during the mid to late summer months during base flow conditions when a higher percentage of the stream flow is from groundwater sources and when water temperatures are near summer peaks.

Sources and causal pathways model for low dissolved oxygen

Dissolved oxygen concentrations in lotic (flowing water) environments are often 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 water body. 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 in the Buffalo River Watershed is modeled at EPA's CADDIS Dissolved Oxygen webpage and provided in Figure 61.

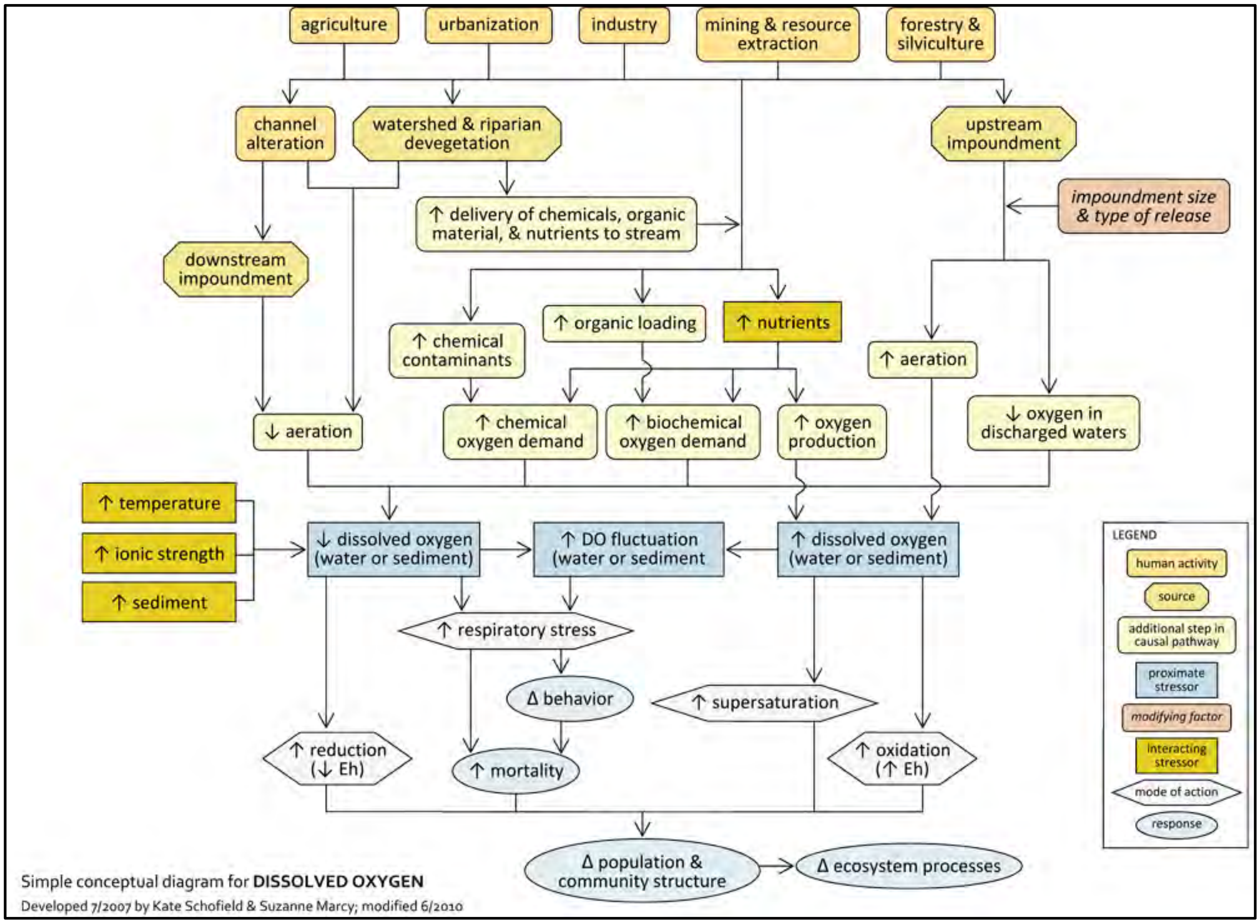


Figure 61. Dissolved Oxygen: Simple Conceptual Diagram (source EPA website).

Candidate Cause: Nitrate - Nitrite

Exposure to elevated nitrite or nitrate concentrations can lead to the development of methemoglobinemia. The iron site of the hemoglobin molecule in red blood cells preferentially bonds with nitrite molecules over oxygen molecules. Methemoglobinemia ultimately limits the amount of oxygen which can be absorbed by fish and 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). The most sensitive macroinvertebrate and fish taxa and life stages are typically impacted at nitrate levels above 1 mg/L (Monson, P. and Preimesberger, 2010).

Water quality standards

Streams classified as Class 1 waters of the state, designated for domestic consumption in Minnesota have a nitrate-N (nitrate plus nitrite) water quality standard of 10 mg/L. At this time, none of the AUIDs in the Buffalo watershed that are impaired for biota are classified as Class 1 streams. Minnesota currently does not have a nitrate standard for waters of the state other than for Class 1.

Ecoregion data

McCollor & Heiskary (1993) developed a guidance of stream parameters by ecoregion for Minnesota streams. The Buffalo River Watershed encompasses portions of three ecoregions: North Central Hardwood Forest (NCHF), Red River Valley (RRV) (a.k.a. Lake Agassiz Plain) and a small portion of Northern Lakes and Forests (NLF). The annual (1970 to 1992) 75th percentile nitrate-N values were used for comparison (Table 4). The majority of the Buffalo is within RRV and NCHF Ecoregions with only 16 square miles within NLF.

Table 4. Ecoregions in the Buffalo River Watershed with the associated annual 75th percentile nitrate-nitrite level.

Ecoregion	75th Percentile value (mg/L)
North Central Hardwood Forest (NCHF)	0.26
Red River Valley	0.21
Northern Lakes and Forests	0.09

Collection methods for nitrate and nitrite

Water samples analyzed for nitrate-N were collected throughout the watershed for purposes of assessment and stressor identification. Nitrate-N is comprised of both nitrate (NO_3^-) and nitrite (NO_2^-). Typically water samples contain a small proportion of nitrite relative to nitrate due to the instability of nitrite, which quickly oxidizes to nitrate. The water samples collected were analyzed for nitrate-N at RMB Environmental Laboratories, a Minnesota State certified lab.

Nitrate and nitrite in the Buffalo River Watershed

Calculations of the Buffalo River's nitrate plus nitrite-nitrogen loads for the years of 2008 to 2010 at Georgetown indicate a range of 239,600 kg (2009) to 410,810 kg (2008) (see Buffalo River Watershed Monitoring and Assessment Report for more information). The FWMC ranged from .409 mg/L in 2009 to 1.16 mg/L in 2008.

Nitrate samples were collected as part of the biological monitoring field work. The results of these samples are presented in Figure 62. The nitrate results range from non-detect to .35 mg/L in the limited sampling that occurred. Only the highest result falls out of the range of expected ecoregion values that are presented in Table 4.

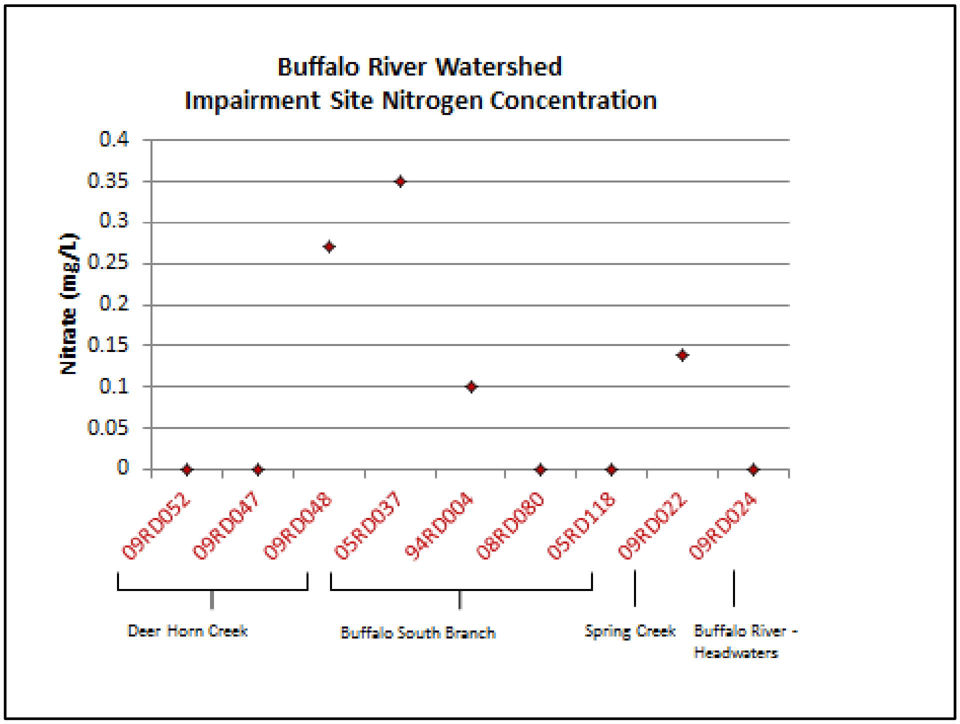


Figure 62. Nitrate concentrations collected during bio-sampling runs on bio-impaired reaches.

Nitrate concentration data collected during water quality sampling work in the four bio-impaired reaches (during the past ten years) is presented in Figure 63. Those data above 1mg/L have the dates displayed to allow for the assessment of possible seasonal patterns. Of the seven readings above 1 mg/L, three of them were in April, three were in September/October and one was in June. The fall and early spring pattern could be a response to fall application of fertilizer but that is only conjecture.

There appears to be a relationship to the high nitrate levels and precipitation based on climate data (Minnesota Office of Climatology) from a precipitation station near Rothsay, Minnesota. The timing of the two April 2, 2007 results is such that spring melt would typically be under way. The fall of 2006 was very wet with 12.44 inches of rainfall (half the annual total) coming during the months of August, September and October. This precipitation would certainly charge the surface and groundwater and set up a good frost seal and high runoff rates for the following spring. The remainder of the nitrate data above 1 mg/L came at times of very high precipitation. Rather than dilute the nitrate this precipitation appears to drive the high nitrate levels. The June 18, 2009 sample came during a 7.37" precipitation month with 4.08" of that rain falling during the day of sampling and the two previous days. The October 2009 sample came during a 6.03" rainfall month of which 2.81" came during the five days preceding the sampling event on the 7th. The fall of 2010, with the two high nitrate values was extremely wet with 6.56" in July, 5.05" in August, and 5.51" in September, and 3.05" falling in October.

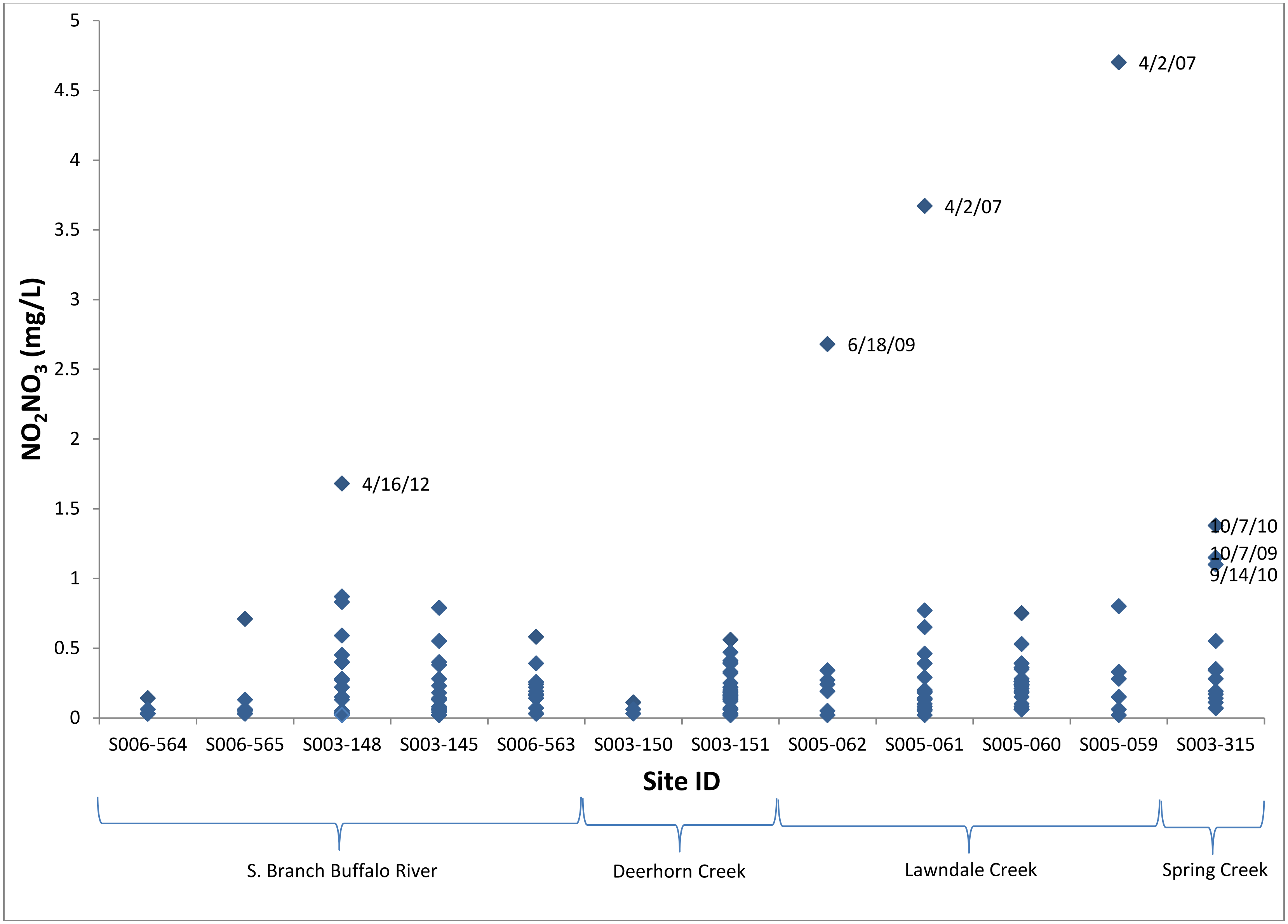


Figure 63. Nitrate results for bio-impaired reaches of the Buffalo River Watershed.

Sources and causal pathways model for nitrate and nitrite

The causes and potential sources for nitrate-nitrite in the Buffalo River Watershed are provided in Figure 64 (EPA Simple Conceptual Model for Nitrate Pathways). Helsel (1995) reported nitrate concentrations were the highest below agricultural or urban areas. A look into the impact of precipitation on nitrate levels found in the four impaired subwatersheds (Figure 63) indicates that the highest nitrate concentrations are related to snow melt and rain events.

Nitrogen fertilizer in the form of nitrate and ammonia is commonly applied as a crop fertilizer throughout the watershed. The Buffalo watershed is comprised of 78% agricultural cropland (Figure 5) with nitrogen being most commonly applied during the spring planting season (April through late-May). In the Buffalo River Watershed the primary crops grown with heavy nitrogen inputs include corn and sugar beets. Corn production has increased significantly during the past 20 years and this has increased the annual N application. The analysis of nitrogen isotopes could assist in the source identification of excess nitrate in future monitoring.

Agricultural tiling is a major conduit for nitrogen in shallow groundwater to discharge into surface waters. Wall (2013) estimated that cropland tile drainage and cropland groundwater contributes 37% and 30% respectively to the estimated statewide N contribution to surface waters during an average precipitation year. If excessive agricultural tiling continues to take place in this watershed nitrate levels in the Buffalo River system can be expected to rise as they have in the more heavily tiled areas in Minnesota and Iowa. It is not unreasonable to expect that nitrates could become a biological stressor in this watershed if the trend of tile installations continues at the current rate.

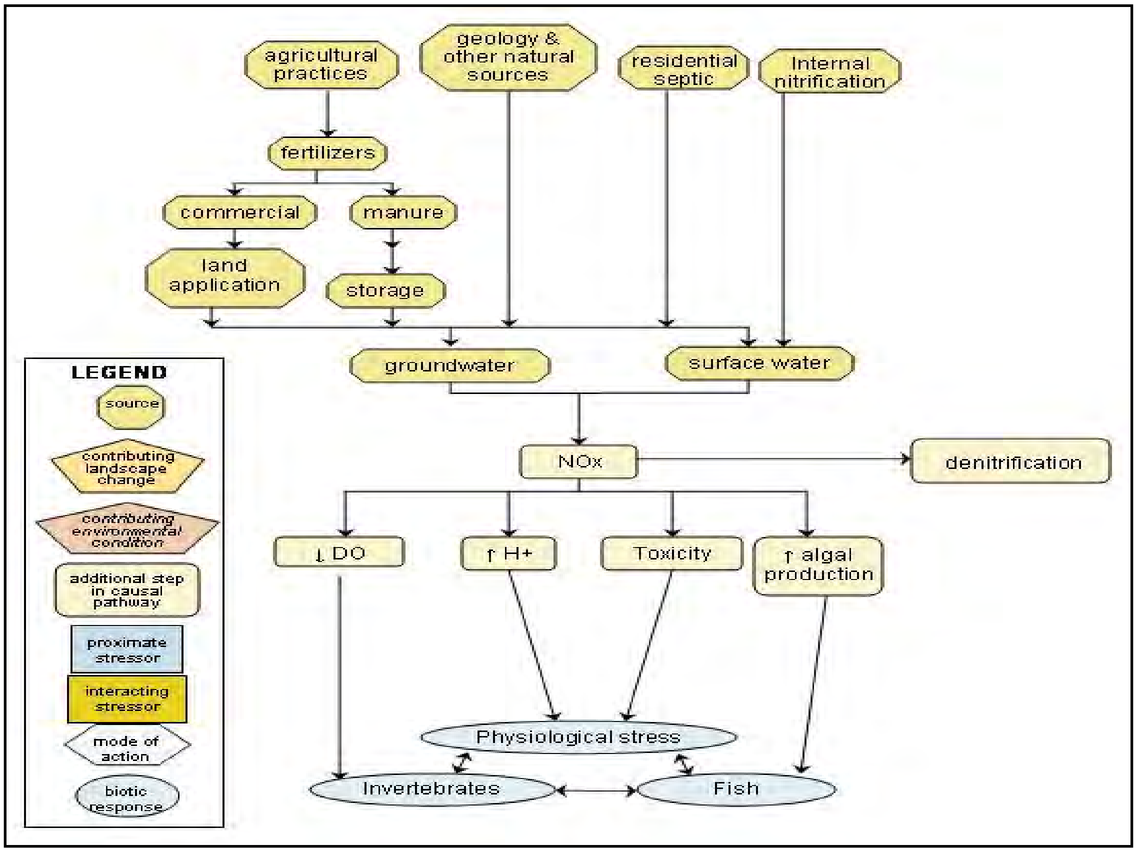


Figure 64. Simple conceptual model for nitrate as a stressor on the biotic community (source EPA).

Candidate Cause: Excess Phosphorus

Phosphorus is an essential nutrient for all aquatic life, but elevated phosphorus concentrations can result in an imbalance that can impact stream organisms. Excess phosphorus does not result in direct harm to fish and macroinvertebrates. Rather, its detrimental effect occurs as it alters other factors in the water environment. Dissolved oxygen, pH, water clarity, excessive plant growth and changes in food resources and habitat are all stressors that can result when there is excess phosphorus.

Water quality standards and ecoregion norms

There is no current water quality standard for total phosphorus; however there is a draft nutrient standard for rivers of Minnesota as well as ecoregion data to show if the data is within the expected norms. The current draft standard is a maximum concentration of .15 mg/L with at least one response variable for the Buffalo River. For more information, please reference the Buffalo River Watershed Monitoring and Assessment Report.

Phosphorus in the Buffalo River Watershed

The Buffalo River Assessment Report (Dingmann 2012) provides the following summary for phosphorus in the Buffalo River Watershed. "*Average nutrient concentrations of phosphorus were approaching or exceeding the proposed eutrophication threshold of .150 mg/L across the watershed. In 2008 the percent* *of TP samples that exceeded the .150 mg/L proposed standard was 77 percent while the FWMC (flow weighted mean concentration) was .257 mg/L. In 2009, 75 percent of the samples collected exceeded the standard and the FWMC was .219 mg/L. In 2010 75 percent of the samples collected exceeded the standard and the FWMC was .233 mg/L.*

Total phosphorus concentration data for the four biological impaired reaches is presented in Figure 65. These data show elevated phosphorus levels in all four reaches with very high levels exceeding .50 mg/L in the South Branch Buffalo River and Deerhorn Creek. The proposed phosphorus standard of .150 mg/L is highlighted with a red line.

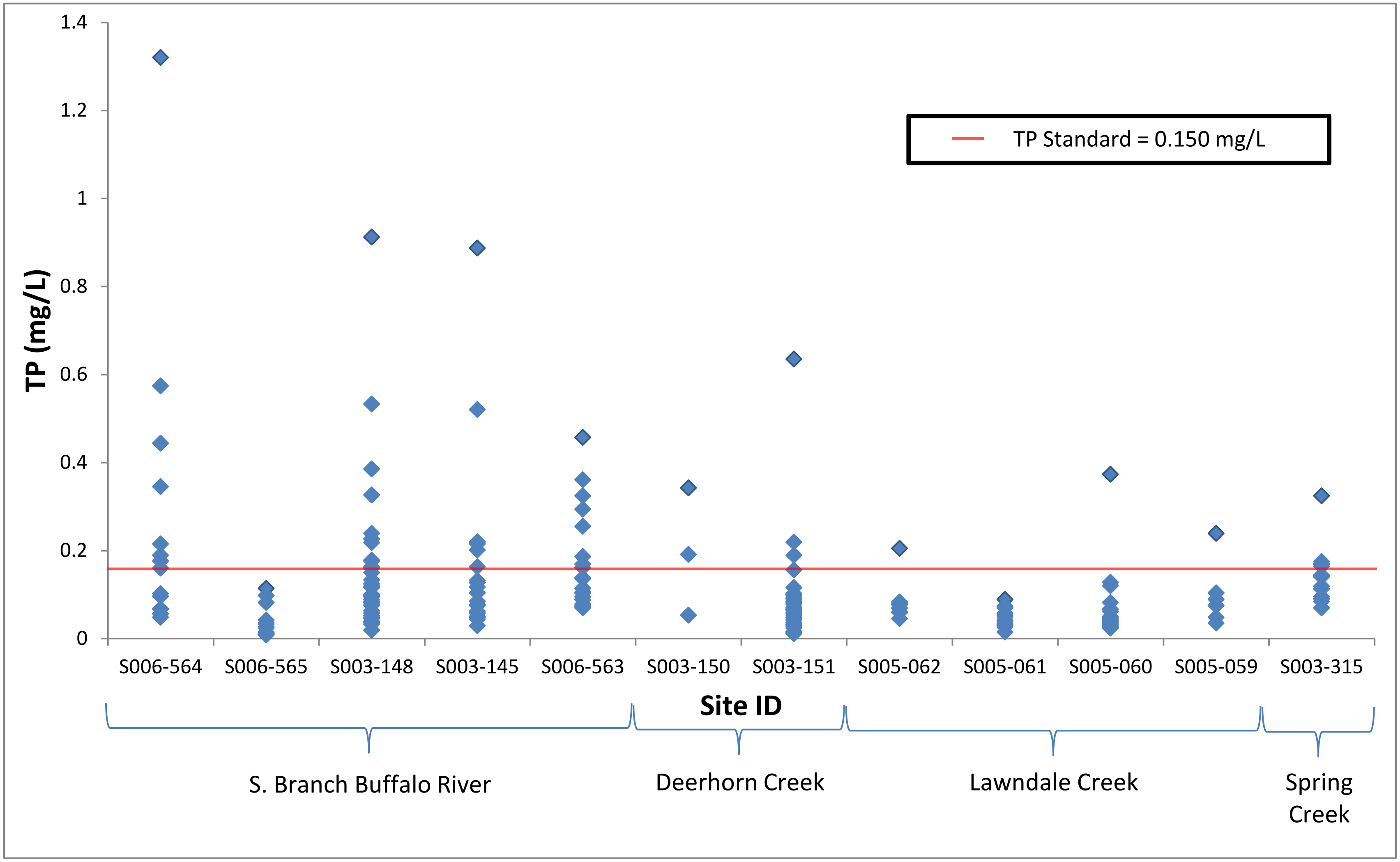


Figure 65. Total phosphorus concentration data from 2002 to 2012 within the Buffalo River bio-impaired reaches. Sites are listed from up-stream to down-stream in each reach.

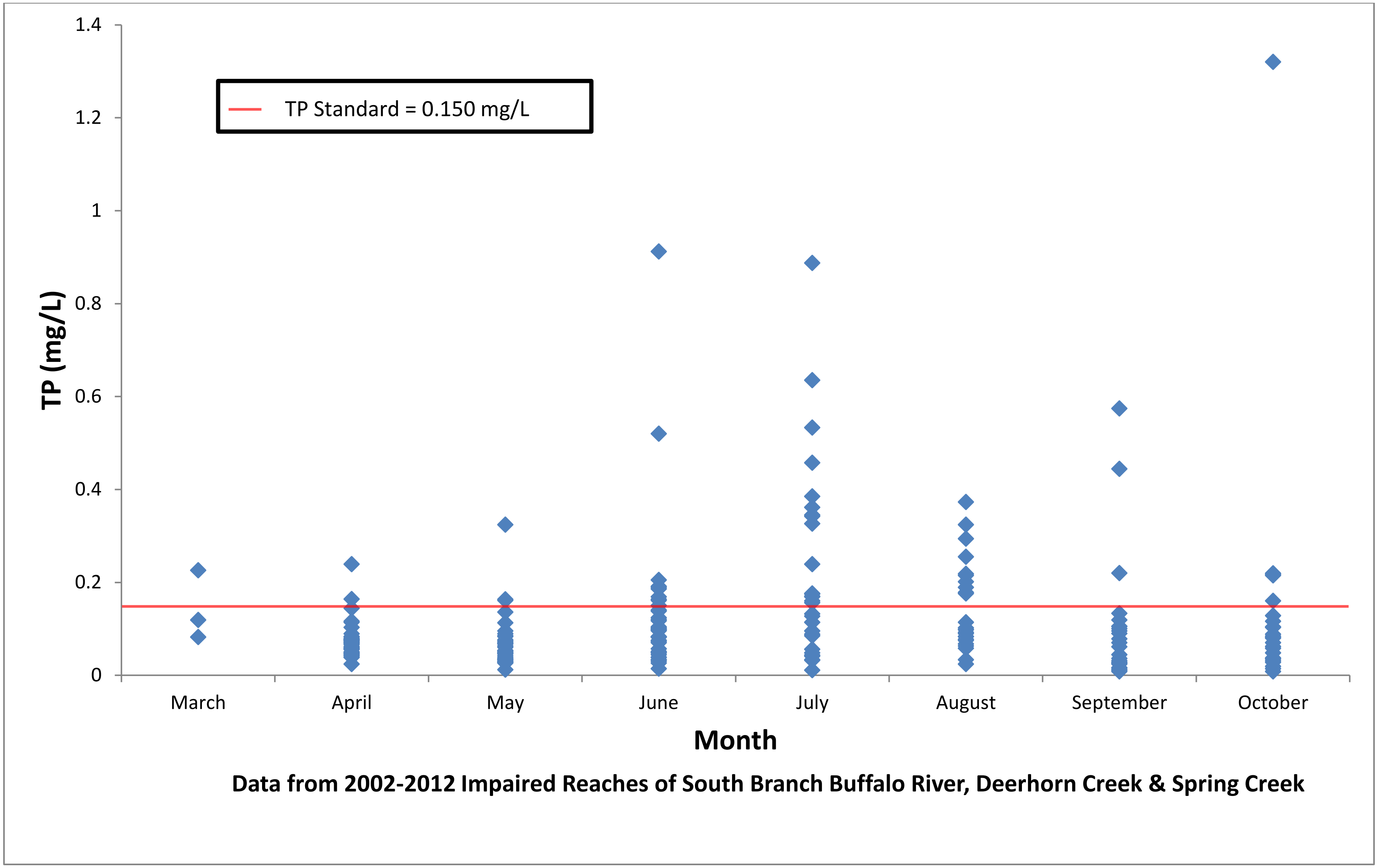


Figure 66. Total phosphorus concentration data for the bio-impaired reaches of the Buffalo River Watershed graphed for seasonal pattern assessment.

The same data displayed in Figure 65 is also presented in Figure 66 in order to look at potential seasonal patterns in phosphorus concentration. The data, displayed by month sampled shows that the majority of the results that exceed the proposed standard were sampled in June, July and August. Since these months are characterized by base flow conditions (in the absence of summer storm event flows) it can be assumed that these high concentrations are likely tied to summer storm event runoff.

Sources and causal pathways for excess phosphorus

Phosphorus is delivered to streams by agriculture, wastewater treatment facilities, urban storm water, and direct discharges of sewage. A further breakout of agricultural sources includes erosion and drainage from row crop production, feedlots, pastures, winter application of manure, and watercourse (stream and ditch) bank and bed erosion due to altered hydrology as a result of drainage. The western half of the Buffalo River Watershed is strongly dominated by agriculture (91% agriculture) and this correlates with elevated stream phosphorus concentrations. Two exceptions to this are the 32.9 square mile Clay County Ditch 2 site where the mean TP result was .062 mg/L (ns = 13) and the Whisky Creek subwatershed where the mean TP was .069 mg/L (ns = 16). Both of these watersheds outlet in the Lake Plain region however the primary water source for each is the Beach Ridge Zone with less intensive agriculture, coarser soils, and more water storage in the form of wetlands, ponds and natural stream channels remaining. The causes and potential sources for excess nutrients, including phosphorus in the Buffalo River Watershed are modeled at EPA's CADDIS Nutrients webpage and provided in Figure 67.

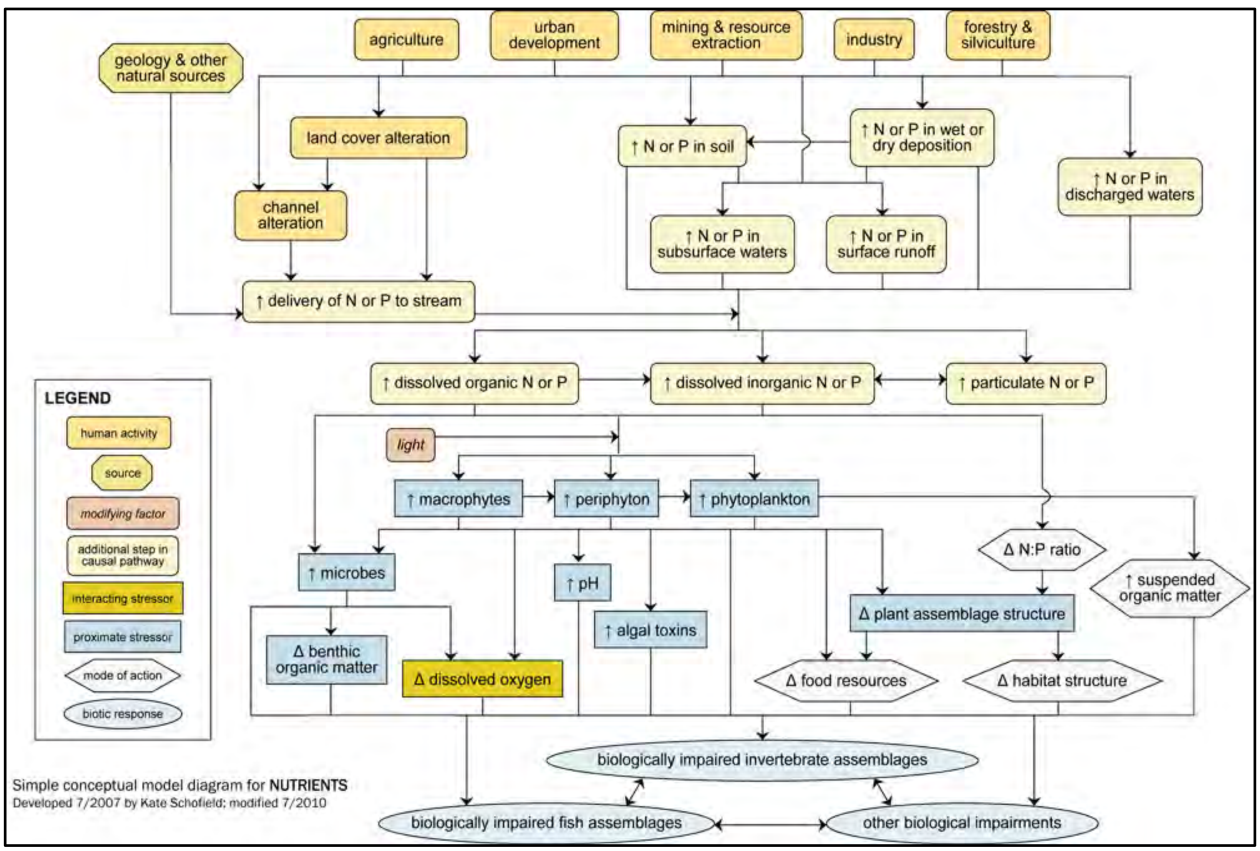


Figure 67. Simple conceptual model for nutrients (phosphorus and nitrogen) as a stressor on the biotic community (source EPA).

Lake eutrophication from excess phosphorus is a significant problem in the Buffalo River Watershed. Lakes in the agriculturally dominated landscape are often found to be impaired for excess phosphorus when sufficient data is collected to allow for assessment. *"Based on recent monitoring, more than one-third of all monitored lakes (16 of 43) exceed the eutrophication standard and are impaired for aquatic recreation use, and several more are very close to the standard. Impairments are found across the watershed, with the exception of the two eastern subwatersheds that are headwaters in nature, with more intact (forested) watersheds than the rest of the agriculturally dominated watersheds*" that discharge to the Buffalo River (Dingmann, 2012).

The U.S. portion of the Red River contributes up to 43 percent of the total phosphorus load to Lake Winnipeg (Bourne, et. al., 2002). While phosphorus concentrations don't appear to be causing significant ecological problems in the streams within the Buffalo River Watershed, they are degrading lakes within the watershed and contributing a disproportionate phosphorus load to the eutrophication of Lake Winnipeg. Lake Winnipeg provides important commercial and recreational benefits to Manitoba and the eutrophication of the lake poses a serious threat to the economy and aesthetics of the area.

Candidate Cause: Connectivity

Connectivity in river ecosystems refers to how water bodies and waterways are linked to each other on the landscape and how matter, energy, and organisms move throughout the system (Pringle, 2003). There are many components of connectivity, but this section will only address the physical barriers of dams and culverts that restrict the migration of fish and macroinvertebrates.

Dams, both human made and natural, can cause changes in flow, sediment, habitat and chemical characteristics of a water body. They can alter the hydrologic connectivity, which may obstruct the movement of migratory fish causing a change in the population and community structure. The stream environment is also altered by a dam to a predominately lentic (still water i.e. ponded) surrounding (Mitchell and Cunjak, 2007).

Humans have placed dams on the landscape for many reasons including flood control, livestock watering, power generation, lake level control, and irrigation. Beavers build dams to create impoundments with adequate water depth for a winter food cache (Collen and Gibson, 2001). Beaver dams, even though natural, can also be barriers to fish migration.

Beaver dams likely have the greatest impact to migration during low to moderate flow conditions when the dams restrict discharge to levels that many fish are unable to navigate. During these flow conditions the discharge can be through the dam or over the top in places that don't allow for fish navigation. In addition, beaver dams provide places where predation by mink, raccoon, otter, herons and other predators can be excessive as migrating fish become concentrated in shallow, confined areas at these obstructions.

Culverts can also be a barrier to fish migration. Culverts that are installed improperly can prevent fish movement when the lower, downstream end of the culvert is placed above the stream bottom. This is often referred to as a "perched culvert." Figure 68 provides an example of such a culvert on Deerhorn Creek where fish are unable to move upstream through the culvert under low to moderate flows.

Figure 68. A perched culvert on Deerhorn Creek prevents the upstream migration of fish during low to moderate flow conditions.

Culverts that are installed properly can also become perched (Figure 68). A downstream head cut (Figure 69) can move upstream as it erodes the stream bed. As the headcut reaches the culvert, the stream bottom, now eroded and lower than when the culvert was installed, ends up leaving the culvert end elevated above the stream bottom. The head-cut in Figure 69, as evidenced by the sharp drop in stream elevation, also results in bank erosion as visible on the far bank. The deepening and widening of the channel is a clear sign of stream instability. An example of this type of problem is shown in Figure 80.

Figure 69. A head-cut in the Buffalo River system works its way upstream by eroding the stream bed.

Water quality standards

There is no applicable water quality standard for connectivity impacts.

Connectivity in the Buffalo River

Loss of connectivity is a significant problem in the Buffalo River Watershed. The single most harmful structure to the Buffalo River fishery is likely a dam near Glyndon which was constructed sometime near the early 1900's presumably to pond water for loading railroad water tanks to supply water for steam engines (Dave Friedl, personal communication). This dam acts as a major fish barrier on the South Branch Buffalo River (Figure 70). The dam, located only a few miles from the confluence of the South Branch Buffalo River and the Buffalo River main stem affects fish passage from the Red River and Buffalo River to almost the entire length of the South Branch Buffalo River and its tributaries, roughly half of the stream miles in the Buffalo River Watershed. Removal or modification of this dam should be a top priority for efforts to restore the biological integrity of the Buffalo River system. This dam acts as a fish barrier during low to moderate flows.

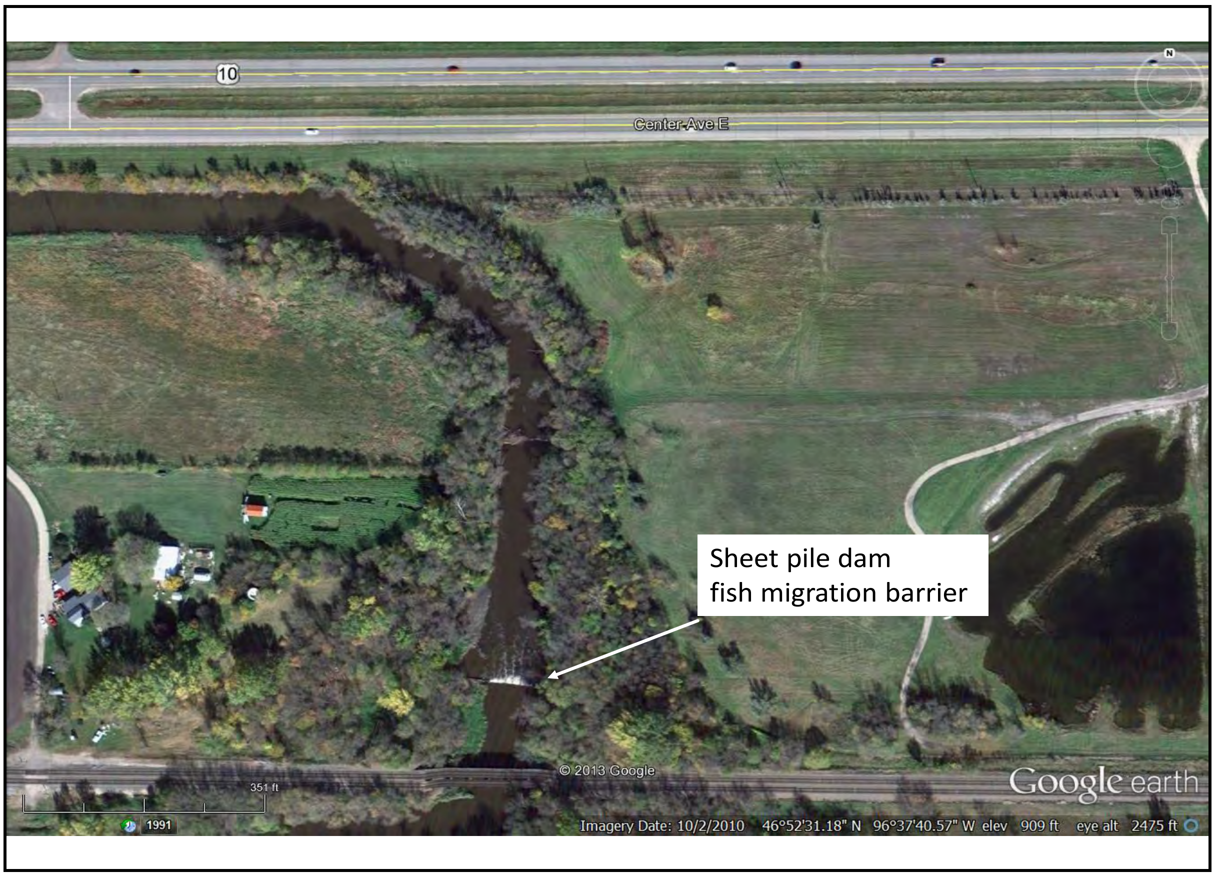


Figure 70. Aerial photograph of the sheet pile dam on the South Branch Buffalo River located 1.7 miles west of Glyndon.

Sources and causal pathways model for connectivity

The causes and potential sources for connectivity in the Buffalo River Watershed have been covered above. The EPA simple conceptual model for connectivity is provided below in Figure 71.

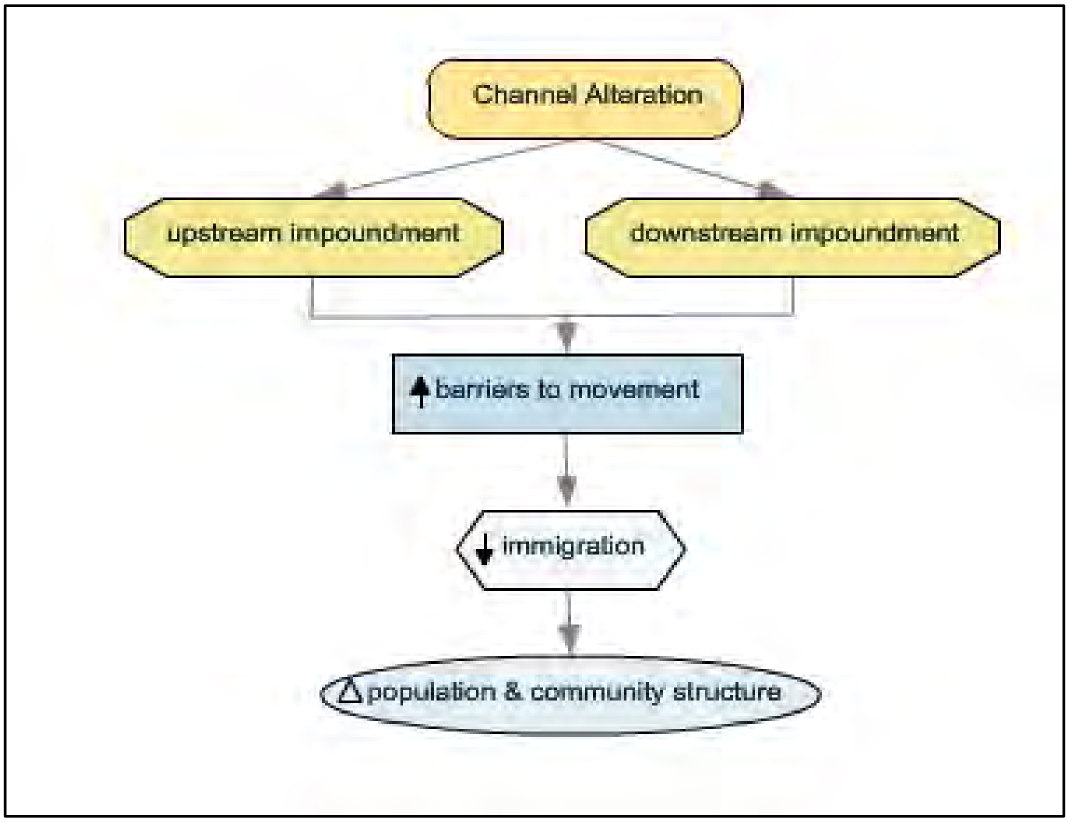


Figure 71. Simple conceptual model for connectivity (source EPA).

Candidate Cause: Flow Alteration

Flow alteration or altered hydrology is a major influence affecting the biological integrity of the streams within the Red River Basin, including the Buffalo River. Increased flows may directly impair the biological community and or may contribute to additional stressors. Increased channel shear stresses, associated with increased peak flow rates, often results in 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.

High flows can also cause the displacement of fish and macroinvertebrates downstream if they cannot move into tributaries or refuges along the margins of the river. High velocities and the mobilization of sediment, woody debris and plant material can also be detrimental to fish and macroinvertebrates as this can cause significant dislodgement. When high flows become more frequent, species that do not manage well under those conditions will be reduced, leading to altered community structure. Macroinvertebrates may shift from those of long life cycles to short life cycles needing to complete their life history within the bounds of the recurrence interval of flow conditions (CADDIS, 2011).

Base flow, which sustains river flow between runoff events, is supplied by aquifers (derived from various subsurface paths). Impermeable surfaces, reduction or change in vegetative cover, channelization and extensive drainage occur in both urban and agricultural land areas in the Buffalo River Watershed. All of these conditions can cause an increase in the surface runoff flow component produced by a given runoff event. The increased surface runoff rate can result in a long-term reduction in infiltration, which lowers the water table and reduces the seasonal base flow component (Poff et al., 1997).

Across the conterminous U.S., Carlisle et al. (2010) 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 a decreased wetted width, cross sectional area, and water volume. Aquatic organisms require adequate living space and when flows are reduced beyond normal base flow, competition for resources increases. Pollutant concentrations often increase when flows are lower than normal, making it more difficult for populations to maintain a healthy diversity. Dissolved oxygen concentrations often decrease during low flow conditions as groundwater makes up a larger proportion of the flow and summer peak temperatures that coincide with the timing of typical base flow conditions reduce the solubility of oxygen in water. Tolerant individuals can often out-compete more sensitive types in limiting situations. Low flows of prolonged duration tend to lead to macroinvertebrate and fish communities that have preference for standing water or are comprised of generalist species (CADDIS, 2011).

When base flows are reduced, fish communities respond with an increase in nest guarding species rather than simple nesters (Carlisle et al., 2010). This adaptation increases the reproductive ability for nest guarders by protecting from predators and providing “continuous movement of water over the eggs, and to keep the nest free from sediment” (Becker, 1983). The most common nest guarding species in the Buffalo River system are fathead minnows and brook stickleback.

Flow conditions can affect the type of fish species that are present. Active swimmers, such as the green sunfish, contend better under low velocity conditions (Carlisle et al., 2010). Streamlined species have bodies that allow fish to reduce drag under high velocities (Blake, 1983). Similarly, the macroinvertebrate communities exhibit changes with increasing swimming species and decreasing taxa with slow crawling rates with increased duration and intensity of low-flow conditions. EPA’s CADDIS lists the response of low flow alteration with reduced total stream productivity, elimination of large fish, changes in taxonomic composition of fish communities, fewer species of migratory fish, fewer fish per unit area, and a greater concentration of some aquatic organisms (potentially benefiting predators).

Water quality standards

There is not a specific standard regarding the alteration of maximum peak flows. The standard for minimum streamflow, according to Minnesota State Statute 7050.0210 Subpart 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.*

Flow alteration in the Buffalo River Watershed

The Buffalo River Watershed has transitioned from perennial to agricultural land cover, with loss of wetlands, increases in groundwater withdrawal, channelization, and increased surface and subsurface drainage. The combination of these landscape altering modifications has led to alteration of the river’s hydrologic regime. The significant loss of upland storage through wetland drainage, channelization, ditching and tiling has increased peak flow rates and shortened the duration of the runoff hydrograph for both spring and summer discharge events.

Channelization has occurred on ditches that have replaced first, second and third order streams. In the intensely farmed Lake Plain portion of the watershed, entire sub watersheds have been converted to ditch systems such as County Ditches 10 and 39. It is only the upper parts of these watersheds, in the Beach Ridge zone, where natural channels remain in these systems. Sixty two biological sites were selected for monitoring the fish community in the Buffalo River Watershed. Of these 62 sites, 33 or 53.2% are channelized. This level of channelization suggests that the flow regime of the watershed is such that spring runoff and event flows are higher than normal and base flow levels much lower than normal. A "boom and bust" hydrology in a stream along with the loss of pool and riffle stream habitat, inherent with channelization, results in a loss of fish diversity and a tendency toward more tolerant species and those that are adapted to migration.

The increase in peak flows in the Buffalo River has been documented in the Hydrology and Geomorphic sections above. Altered hydrology has caused significant channel instability issues within the Buffalo River Watershed. Altered hydrology is a major factor in the presence and severity of the sediment and habitat stressors on the biology within the Buffalo River.

With the increase in peak flow rates comes a corresponding loss of base flow in the system. Surface and groundwater storage has been greatly reduced through drainage and these results in diminished supplies for charging the system during low-flow conditions. The loss of base-flow in some of the tributaries appears to be a significant factor in reduced biological integrity. These issues will be addressed later in the report when the individual impaired reaches are discussed.

Sources and causal pathways model for altered flow

The causes and potential sources for altered flow in the Buffalo River Watershed are provided in Figure 72.

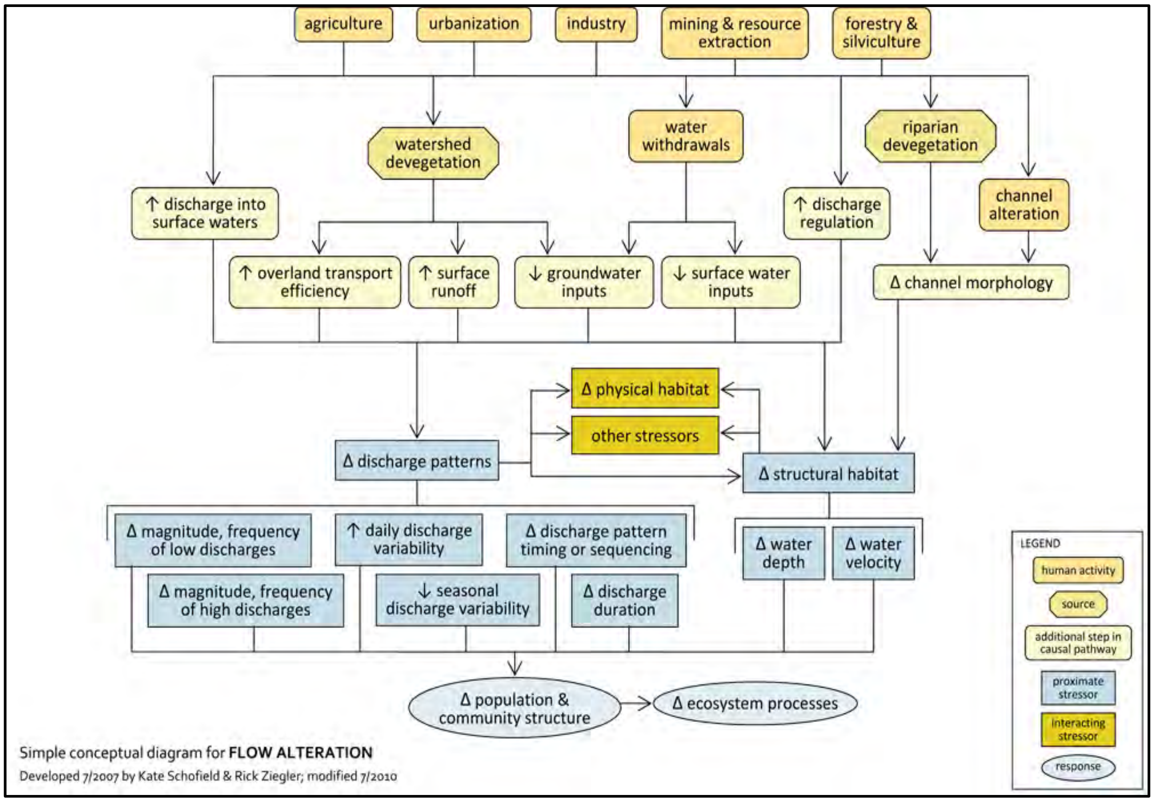


Figure 72. Conceptual Model for Flow Alteration (Source EPA).

Candidate Cause: Pesticides

Pesticides Monitoring in the Buffalo River Watershed

- Section authored by David Tollefson, MDA)

The Minnesota Department of Agriculture (MDA) has been monitoring for pesticides in surface waters since 1991. Annually, MDA collects approximately 1,000 samples from rivers, streams, and lakes across the state. In general, MDA looks for pesticides that are widely used and/or pose the greatest risk to water resources. The purpose of MDA's pesticide monitoring program is to determine the presence and concentration of pesticides in Minnesota waters. Samples are collected statewide during the late spring and throughout the summer when the potential for pesticide movement is the greatest.

The MDA has conducted a substantial amount of pesticide monitoring in the Buffalo River Watershed. Since 2002, the MDA has collected and analyzed 118 pesticide samples from 11 different river and stream locations, and 3 different lakes since 2007. Most of the river and stream samples were collected at the Buffalo River near the Georgetown, Minnesota location, where MDA has a fully automated pesticide water quality station. This station is considered a Tier 3 station in MDA's design document, and these stations receive the most intensive and comprehensive pesticide monitoring effort in the state. This station represents one of the seven Tier 3 sites that MDA operates. In addition to this location, ten additional locations in the watershed were sampled once in 2010. Finally, three lakes were sampled and serve as a reference for lake pesticide water quality data in the watershed. Pesticide monitoring locations in the Buffalo River Watershed are presented in Figure 73. For more information about MDA's monitoring, please refer to: http://www.mda.state.mn.us/chemicals/pesticides/maace.aspx.

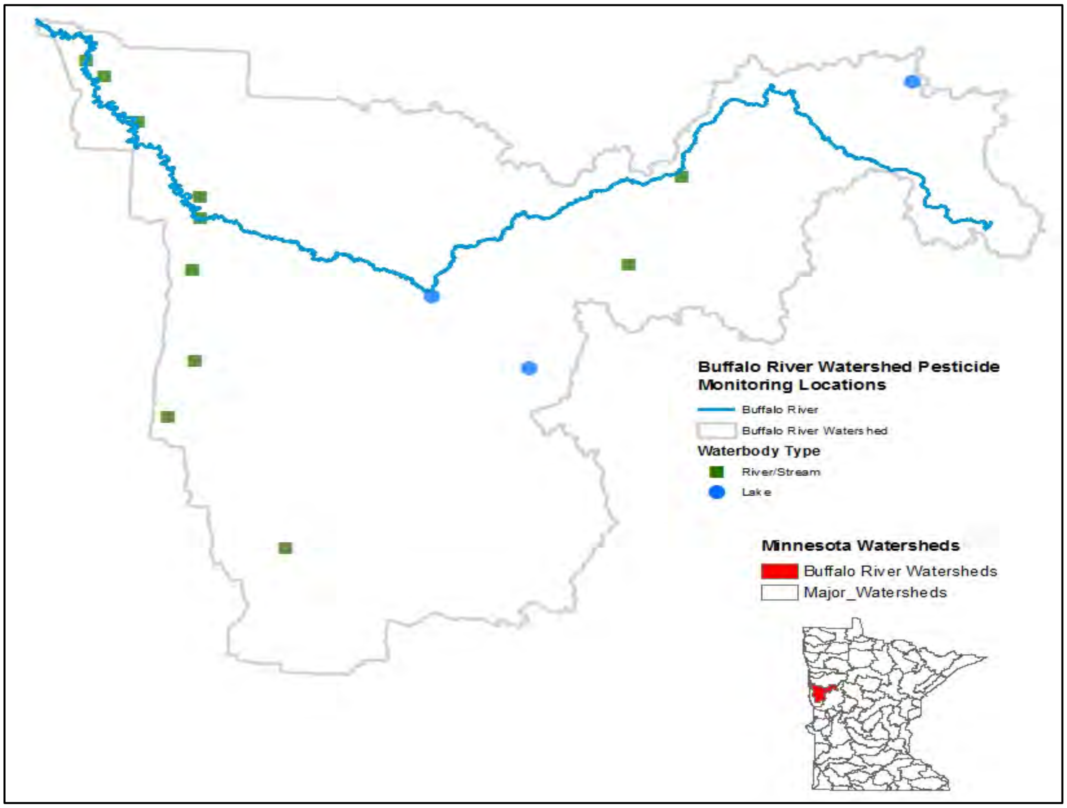


Figure 73. Map showing river, stream, and lake locations where pesticide data has been collected.

Pesticides (including herbicides, fungicides, and insecticides) are considered as potential stressors in the Buffalo River Watershed due to the surrounding land use. Pesticide results are presented in Table 5 (rivers) and Table 6 (lakes) below. Since 2002, a total of 39 different pesticide or pesticide degradates have been detected in rivers or streams, and ten different pesticide or pesticide degradates have been detected in lakes in the Buffalo River Watershed. When comparing water quality pesticide results to standards and reference values, duration of pesticide occurrence in a water body must be assessed in conjunction with the numeric result. For example, MPCA Class 2B Chronic Standards are developed with a duration exposure of four days. Therefore, concentration data cannot solely be used for assessment. All of the data collected by MDA is reviewed annually by MPCA for the assessment of water quality standards. As of 2013, there is no water quality impairment related to pesticides in the Buffalo River Watershed.

All of the detections in lakes were well below applicable water quality standards or reference values. For rivers and streams, 36 of the 39 detected pesticide compounds were well below applicable water quality standards or reference values. Three different pesticides were detected at the Buffalo River near Georgetown location at values approaching the applicable numeric reference value: acetochlor, chlorpyrifos, and terbufos. Acetochlor had a maximum concentration of 3.31 µg/L, however, the 95th percentile of the data is 0.514 µg/L. Chlorpyrifos and terbufos both have been detected infrequently (<5% detection frequency) at the "Present", but below laboratory method reporting limits (MRL's). These detections are relevant due to the magnitude of the laboratory MRL and applicable water quality standards or reference values. Neither chlorpyrifos nor terbufos have had detection at concentrations quantifiable by the laboratory. Pesticide monitoring will continue at the Buffalo River near Georgetown, Minnesota for the foreseeable future and will provide additional information related to insecticide detections in the Buffalo River.

Table 5. Buffalo River Watershed River and Stream STID Pesticide Sampling.

Pesticide Name[1]	Pesticide Type	Detects	Total Samples	Detection Frequency	Detection Concentration Distribution					Water Quality Standards and/or Reference Values (µg/L)			
					Median	75th %-tile	90th %-tile	95th %-tile	Maximum	MPCA Class 2Bd[5] Chronic Standard[3]	MPCA Maximum Standard[4]	EPA Acute Value Aquatic Life BenchMark (µg/L)[2]	EPA Chronic Value Aquatic Life Benchmark (µg/L)[2]
2,4-D	Herbicide	37	67	55%	0.011	0.044	0.085	0.143	2.640	70 H	--	12,075 (f)	13.1 (v)
Acetochlor	Herbicide	44	118	37%	nd	0.000	0.262	0.514	3.310	3.6 T	--	na	na
Acetochlor ESA	Degradate	45	92	49%	nd	0.068	0.210	0.281	0.768	--	--	> 62,500 (i)	9,900 (n)
Acetochlor OXA	Degradate	35	92	38%	nd	0.062	0.248	0.362	1.060	--	--	–	–
Alachlor ESA	Degradate	1	92	1%	nd	nd	nd	nd	0.058	--	--	52,000 (f)(i)	–
Atrazine	Herbicide	83	118	70%	P (<0.05)	0.130	0.468	0.704	1.560	3.4 H; 10 T	--	na	na
Deisopropylatrazine	Degradate	5	118	4%	nd	nd	nd	nd	P (<0.2)	--	--	8,500 (f)	2,500 (n)
Desethylatrazine	Degradate	71	118	60%	P (<0.05)	0.050	0.090	0.140	0.190	--	--	–	1,000 (n)
Hydroxyatrazine	Degradate	66	67	99%	0.027	0.037	0.044	0.057	0.245	--	--	> 1,500 (f)	>10,000 (n)
Azoxystrobin	Fungicide	17	66	26%	nd	0.009	0.143	0.269	0.323	--	--	130 (i)	44 (i)
Bentazon	Herbicide	38	68	56%	0.001	0.002	0.006	0.015	0.020	--	--	> 50,000 (f)(i)	4,500 (n)
Chlorpyrifos	Insecticide	6	118	5%	nd	nd	nd	P (<0.10)	P (<0.04)	0.041 T	0.083 T	na	na
Clopyralid	Herbicide	7	68	10%	nd	nd	0.028	0.194	0.630	--	--	56,000 (i)	–
Clothianidin	Insecticide	8	29	28%	nd	0.027	0.105	0.141	0.141	--	--	>46,800 (f)	120 (i)
Dicamba	Herbicide	6	64	9%	nd	nd	nd	0.319	0.710	--	--	14,000 (f)	61 (n)
Dimethenamid	Herbicide	37	118	31%	nd	P(<0.05)	0.124	0.322	0.900	--	--	3,150 (f)	5.1 (v)6
Dimethenamid ESA	Degradate	52	92	57%	0.008	0.070	0.070	0.070	0.070	--	--	–	–
Dimethenamid OXA	Degradate	11	92	12%	nd	nd	0.014	0.026	0.074	--	--	–	–
Diuron	Herbicide	1	67	1%	nd	nd	nd	nd	0.020	--	--	80 (i)	2.4 (n)
Ethofumesate	Herbicide	3	19	16%	nd	nd	0.000	0.654	0.530	--	--	250 (f)	250 (i)

Pesticide Name[1]	Pesticide Type	Detects	Total Samples	Detection Frequency	Detection Concentration Distribution					Water Quality Standards and/or Reference Values (µg/L)			
					Median	75^{th} %-tile	90^{th} %-tile	95^{th} %-tile	Maximum	MPCA Class 2Bd[5] Chronic Standard[3]	MPCA Maximum Standard[4]	EPA Acute Value Aquatic Life BenchMark (µg/L)[2]	EPA Chronic Value Aquatic Life Benchmark (µg/L)[2]
Flumetsulam	Herbicide	1	29	3%	nd	nd	nd	0.030	0.055	--	--	125,000 (i)	3.1 (v)
Imazapyr	Herbicide	1	67	1%	nd	nd	nd	nd	0.019	--	--	50,000 (f) (i)	24 (v)
Imidacloprid	Insecticide	6	66	9%	nd	nd	nd	0.030	0.043	--	--	35 (i)	1.05 (i)
MCPA	Herbicide	24	67	36%	nd	0.011	0.104	0.232	0.705	--	--	90 (i)	20 (v)
Mesotrione	Herbicide	2	64	3%	nd	nd	nd	nd	0.188	--	--	> 60,000 (f)	9.8 (v)
Metalaxyl	Fungicide	8	67	12%	nd	nd	0.008	0.018	0.028	--	--	14,000 (i)	100 (i)
Metolachlor	Herbicide	72	118	61%	P (<0.07)	0.080	0.314	0.694	1.900	23 T	271 T	na	na
Metolachlor ESA	Degradate	82	92	89%	0.070	0.120	0.182	0.367	0.929	--	--	24,000 (f)	> 95,100 (v)
Metolachlor OXA	Degradate	55	92	60%	0.015	0.038	0.094	0.221	0.444	--	--	7,700 (i)	57,100 (n)
Metribuzin	Herbicide	12	118	10%	nd	nd	0.000	0.100	0.350	--	--	2,100 (i)	8.7 (n)
Pendimethalin	Herbicide	1	118	1%	nd	nd	nd	nd	0.140	--	--	69 (f)	5.2 (n)
Prometon	Herbicide	2	86	2%	nd	nd	nd	nd	P (<0.10)	--	--	6,000 (f)	98 (n)
Propazine	Herbicide	5	88	6%	nd	nd	nd	P (<0.10)	P (<0.10)	--	--	>2,660 (i)	24.8 (n)
Propiconazole	Fungicide	22	117	19%	nd	nd	P(<0.20)	P (<0.20)	P (<0.20)	--	--	425 (f)	21 (n)
Saflufenacil	Herbicide	5	66	8%	nd	nd	nd	0.019	0.025	--	--	> 49,000 (f)(i)	42 (n)
Tebuconazole	Fungicide	7	117	6%	nd	nd	nd	P (<0.20)	0.410	--	--	1,135 (f)	12 (f)
Terbufos	Insecticide	2	118	2%	nd	nd	nd	nd	P (<0.19)	--	--	0.1 (i)	0.03 (i)
Tetraconazole	Fungicide	27	117	23%	nd	nd	P(<0.15)	P (<0.15)	0.150	--	--	1,315 (i)	190 (i)
Thiamethoxam	Insecticide	13	39	33%	nd	0.030	0.126	0.211	0.214	--	--	17.5 (i)	20,000 (f)

Table 6. Buffalo River Watershed Lake STID Pesticide Sampling.

Pesticide Name[1]	Pesticide Type	Detects	Total Samples	Detection Frequency	Detection Concentration Distribution					Water Quality Standards and/or Reference Values (µg/L)			
					Median	75th %-tile	90th %-tile	95th %-tile	Maximum	MPCA Class 2Bd[5] Chronic Standard[3]	MPCA Maximum Standard[4]	EPA Acute Value Aquatic Life BenchMark (µg/L)[2]	EPA Chronic Value Aquatic Life Benchmark (µg/L)[2]
Acetochlor	Herbicide	1	3	33%	nd	P(<0.05)	P(<0.05)	P(<0.05)	P(<0.05)	3.6 T	--	na	na
Acetochlor ESA	Degradate	1	3	33%	nd	0.078	0.124	0.140	0.155	--	--	> 62,500 (i)	9,900 (n)
Acetochlor OXA	Degradate	1	3	33%	nd	0.070	0.112	0.126	0.140	--	--	–	–
Atrazine	Herbicide	2	3	67%	P(<0.05)	P(<0.05)	0.112	0.126	0.140	3.4 H; 10 T	--	na	na
Desethylatrazine	Degradate	1	3	33%	nd	P(<0.05)	P(<0.05)	P(<0.05)	P(<0.05)	--	--	–	1,000 (n)
Hydroxyatrazine	Degradate	1	2	50%	0.018	0.027	0.032	0.034	0.036	--	--	> 1,500 (f)	>10,000 (n)
MCPA	Herbicide	1	2	50%	0.003	0.004	0.005	0.005	0.005	--	--	90 (i)	20 (v)
Metolachlor	Herbicide	1	3	33%	nd	0.055	0.088	0.099	0.110	23 T	271 T	na	na
Metolachlor ESA	Degradate	1	3	33%	nd	0.049	0.078	0.088	0.098	--	--	24,000 (f)	> 95,100 (v)
Metolachlor OXA	Degradate	1	3	33%	nd	0.041	0.066	0.074	0.082	--	--	7,700 (i)	57,100 (n)

Key to value types and symbols in surface water reference values

– – For some analytes, reference values have not been identified or evaluated.

na – not applicable.

(f) – USEPA/OPP benchmark value for fish.

(i) – USEPA/OPP benchmark value for macroinvertebrates.

(n) – USEPA/OPP benchmark value for nonvascular plants.

(v) – USEPA/OPP benchmark value for vascular plants.

H – "H" Chronic Standard values are human health-based and protective for an exposure duration of 30 days.

T – "T" Chronic Standard values are toxicity-based for aquatic organisms and protective for an exposure duration of 4 days.

[1] Reference Values are given for all detected target and non-target analytes. They are also given for non-detected target analytes when a reference value is available. Other non-detected analytes do not have an available reference value from the sources listed below.

2 Aquatic Life Benchmarks based on toxicity values derived from data available to the USEPA OPP supporting registration of the pesticide are provided only when an MPCA value is not available. Current values posted by the USEPA's OPP may differ from those of previous MDA reports. See USEPA's web site for more detailed information and definitions.

3 Chronic Standard as defined in Minn. Rule Chap. 7050. "H" value is human health-based and is protective for an exposure duration of 30 days. Human health-based values are shown only when they are less than toxicity-based values. "T" value is toxicity-based for aquatic organisms and is protective for an exposure duration of 4 days.

4 Maximum Standard Value for Aquatic Life & Recreation as defined on MPCA's web site and Minn. Rule Chap. 7050. Values are the same for all classes of surface waters.

5 State Water Classification for aquatic life (2B – sport and commercial; 2C – non-commercial; 2D – wetlands) & recreation (2B – all types; 2C,D – limited types). Not protected as drinking water sources.

6 For the Dimethenamid Chronic Value, the MPCA has calculated a non-promulgated criterion for aquatic plants using two point estimates of toxicity to the vascular plant duckweed.

(End of section authored by David Tollefson, MDA)

Minnesota water quality standards

Since 1985, MDA and Minnesota Department of Health have been monitoring the concentrations of common pesticides in groundwater near areas of intensive agricultural land-use. In 1991, these monitoring efforts were expanded to include surface water monitoring sites on select lakes and streams. To learn more about the MDA pesticide monitoring plan and results go to the following website, http://www.mda.state.mn.us/protecting/cleanwaterfund/pesticidemonitoring.aspx.

Surface water reference values *(text from MDA, 2010)*

> *The MPCA has developed toxicity-based (for aquatic life) or human health-based enforceable chronic standards for pollutants detected in surface water. The toxicity-based standard is designed to be protective of aquatic life exposure, and is typically based on exposure duration of four days. The human health-based standard (protective for drinking water plus fish consumption) is based on exposure duration of 30 days. For the most current MPCA water quality rules see Chapter 7050: Standards for Protection of Waters of the State (www.revisor.leg.state.mn.us/rules/?id=7050). A summary of MPCA's chronic and maximum standard values for common pesticides used in Minnesota are shown in Table 7.*

Table 7. Summary of MPCA surface water standards associated with target pesticides analytes – Chronic 1 and Maximum2 Standards (µg/L).

Pesticide Analyte	Class 2A3	Class 2B4	Maximum Standard4
Acetochlor	3.6	3.6	86
Alachlor	59	59	800
Atrazine	10	10	323
Chlorpyrifos	0.041	0.041	0.083
Metolachlor	23	23	271

Pesticides as a biological stressor in the Buffalo River Watershed

The presence and concentrations of pesticides in the Buffalo River Watershed have been presented in the above tables. The presence and detection frequency of pesticides in our surface waters is reason for concern. Although individual pesticide toxicity has been determined for many pesticides, there is concern that the biological effects of various combinations of pesticides under varying environmental conditions are less understood.

The results above indicate that at this time there are no pesticide concentrations exceeding an applicable standard for aquatic toxicity and therefor no direct evidence that concentrations are high enough to cause known impacts to sensitive aquatic life. This does not mean that pesticides aren't acting as stressors just that the existing monitoring data does not implicate a pesticide as a likely stressor.

The MPCA has not specifically designed a monitoring program to answer the questions regarding whether pesticides are having impacts to the aquatic biology. The Tier 3 MDA monitoring results presented above incorporate season-long automated base flow and time-weighted storm runoff sampling, representing the highest level of pesticide monitoring available in Minnesota today. In order to document the potential contribution of pesticides to stream biology impacts, one would have to design a site-specific study that, among other factors, simultaneously looked at pesticide application timetables while measuring pesticide concentration in adjacent water bodies, complete water chemistry (including the presence of other toxins), water temperature, and fluctuations in hydrology and biological diversity. The study would need to ascertain how the chemical is entering the water, the exposure time, and look for impacts to sensitive organisms. This work has not been performed and is not currently anticipated, and as such there is insufficient information available to determine if pesticides are acting as unique stressors within the Buffalo River Watershed.

Summary of Candidate Causes

Table 8 provides a summary of the candidate causes for the four bio-impaired reaches of the Buffalo River system. These candidate causes will be discussed and evaluated in the next section of this report (Impaired Reach Stressor Assessments) where decisions will be made regarding the stressors acting upon each of these reaches. Additional reach specific data for phosphorus and nitrogen may also be presented in this section. This data and information is offered to provide a summary of baseline data for future assessment and SID work and to provide insight into concerns with these nutrients as potential future stressors.

Table 8. Summary table of candidate causes for the biological impairment of Buffalo River stream reaches.

Reach (last three digits of AUID)	Buffalo River Stressor ID - Candidate Causes							
	Low DO	High TP	High Nitrate	High Sediment /Turbidity	Poor Habitat	Altered Hydrology	Lack of Physical Connectivity	Pesticides
Upper Buffalo River (593)	-	--	-	+	0	++	++	0
Deer Horn Creek (507)	+	-	-	+	+	++	++	0
S Branch Buffalo River (505)	++	--	-	++	++	++	++	0
Spring Creek (534)	-	--	-	-	0	+	++	0

KEY: The preliminary review of evidence ____ the case for this stressor being a candidate
++ strongly supports
+ weakly supports
0 neither supports or refutes
- weakly refutes
-- strongly refutes

Impaired Reach Stressor Assessments

Upper Buffalo River HUC 09020106010

Biology in the Upper Buffalo River Reach

The Upper Buffalo River HUC-11 is comprised of two AUIDs (593 and 594). The furthest headwaters reach (593) is impaired for fish and macroinvertebrates from Buffalo Lake to the confluence with an Unnamed Ditch. Figure 74 shows the location of the three biological monitoring stations sampled within this reach. The next downstream reach (594) has one monitoring site (09RD005) with a healthy fish community where over four times the number of individuals (1836) were collected than at the three sites (09RD012, 09RD038 and 09RD024) combined that make up reach 593 (number of individuals = 450). In addition, 26 different fish species were sampled at the lone bio site in 594 vs. 23, 12 and 7 in the 3 next upstream sites, respectively, that make up 593 (see table 9). Some of this difference may be due to sites 09RD005 and 09RD012 having two sampling runs (June and then July 2009) vs. sites 09RD024 and 09RD038 only having the late June run. The data from the sites with two runs was averaged. In both cases the July sampling run showed slightly better results (quality and quantity), however not significantly different to explain the fish density differences between the sites that are presented in Table 9.

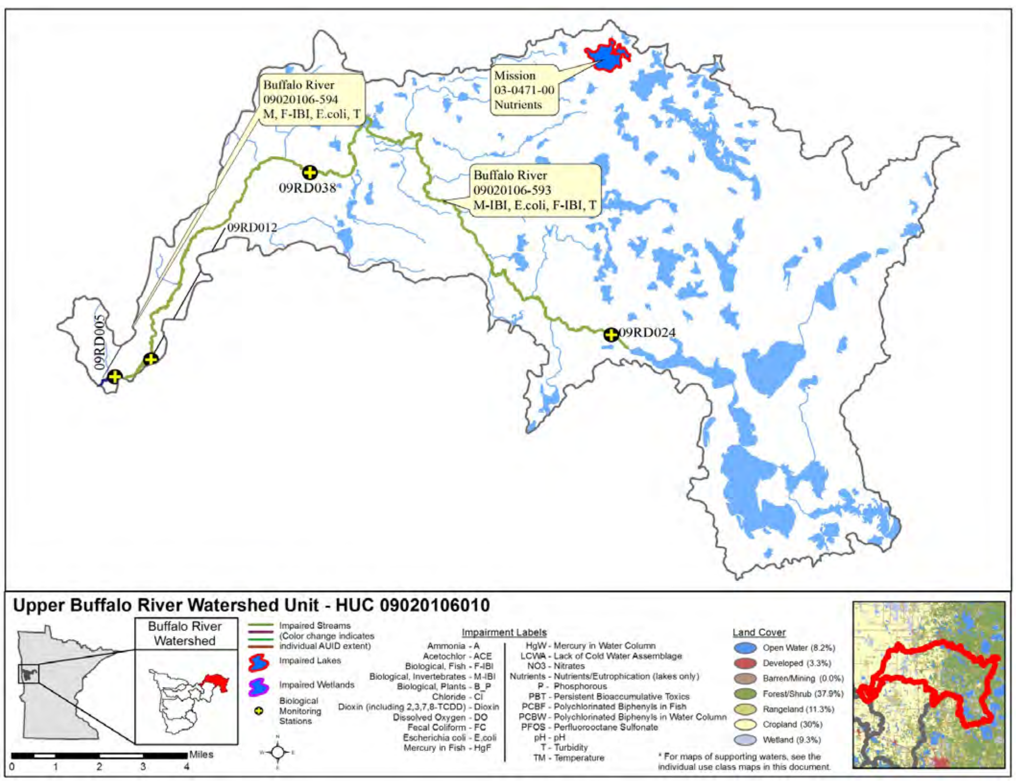


Figure 74. Upper Buffalo River Reach HUC-11 (09020106010) with sampling locations and land cover map.

Table 9. Biological data summary for Upper Buffalo River reach.

Upper Buffalo River Reach - Changes in Fish Quality & Quantity (based on 2009 bio-results - listed upstream to downstream)			
Site ID #	**Aquatic Life**	**# of Species**	**# of Individuals**
09RD024	impaired	7	161
09RD038	impaired	12	55
09RD012	impaired	23	234
09RD005	unimpaired	26	1836

The fish community of the Upper Buffalo River AUID (593) is dominated by two species, bluegills and common shiners which make up that make up 56.2 percent of the individuals sampled in 2009. A review of the fish biological metric scores found differences between the Aquatic Life Impaired Headwaters Reach (593) and the immediate downstream reach 594. The average percent sensitive taxa metric score for reach 594 was 4.3% compared to 2.9% for the impaired headwaters reach 593. In addition site 09RD005 in reach 594 has higher simple lithophilic, sensitive, intolerant and insectivore scores as shown in Figure 75.

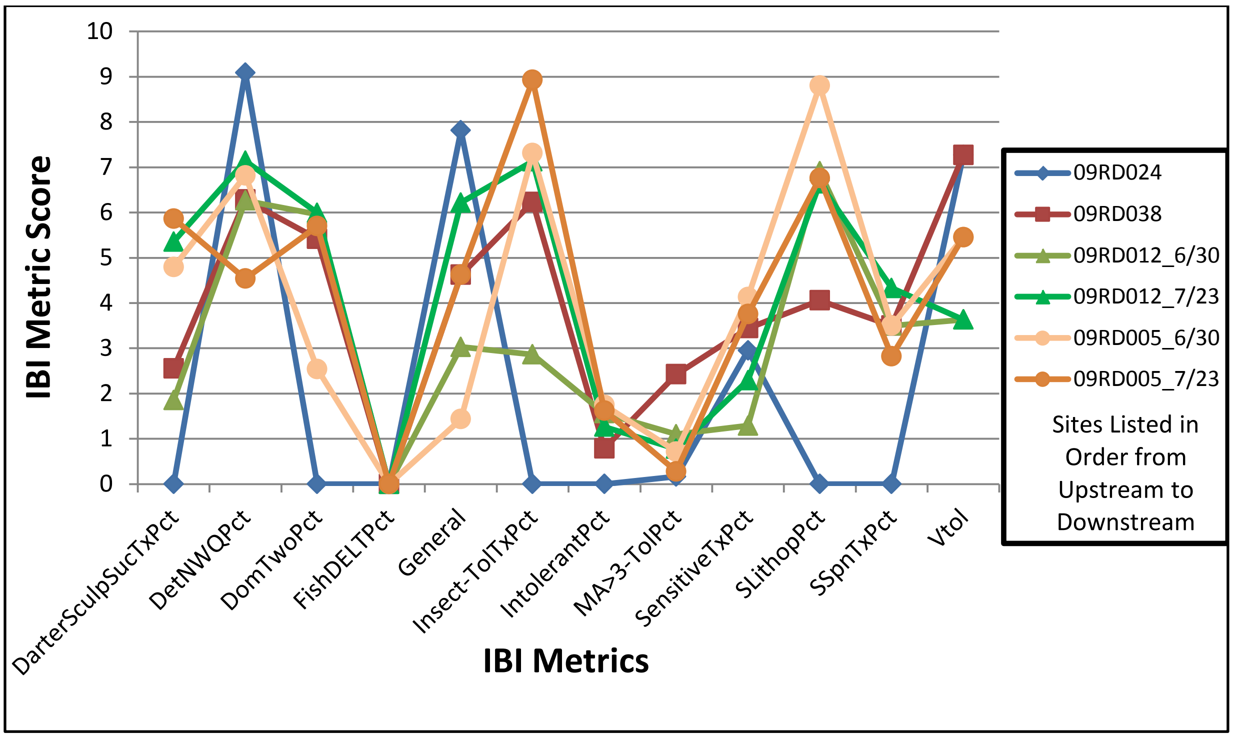


Figure 75. Comparison of Metric Scores for the Upper Buffalo Sites.

Candidate Cause: Habitat

Differences in habitat quality can often explain differences in the diversity and biomass of biological communities. Better habitat conditions should provide for higher reproductive success, more diverse and abundant food resources and improved protective cover. The significant differences in community diversity and biomass presented in Table 9 however have little relationship to the habitat scores for these sites. Figure 76 shows a comparison of the fish IBI scores vs. habitat scores for each site in the Upper Buffalo River HUC-11. The habitat score for the unimpaired reach 594 (site 09RD005) has the second highest habitat score. The three sites in the bio-impaired upstream portion of this HUC had habitat scores and IBI scores that showed a reverse correlation. The highest habitat score (at 09RD024) had the lowest IBI score and site 09RD012 with the highest IBI score had the lowest habitat score.

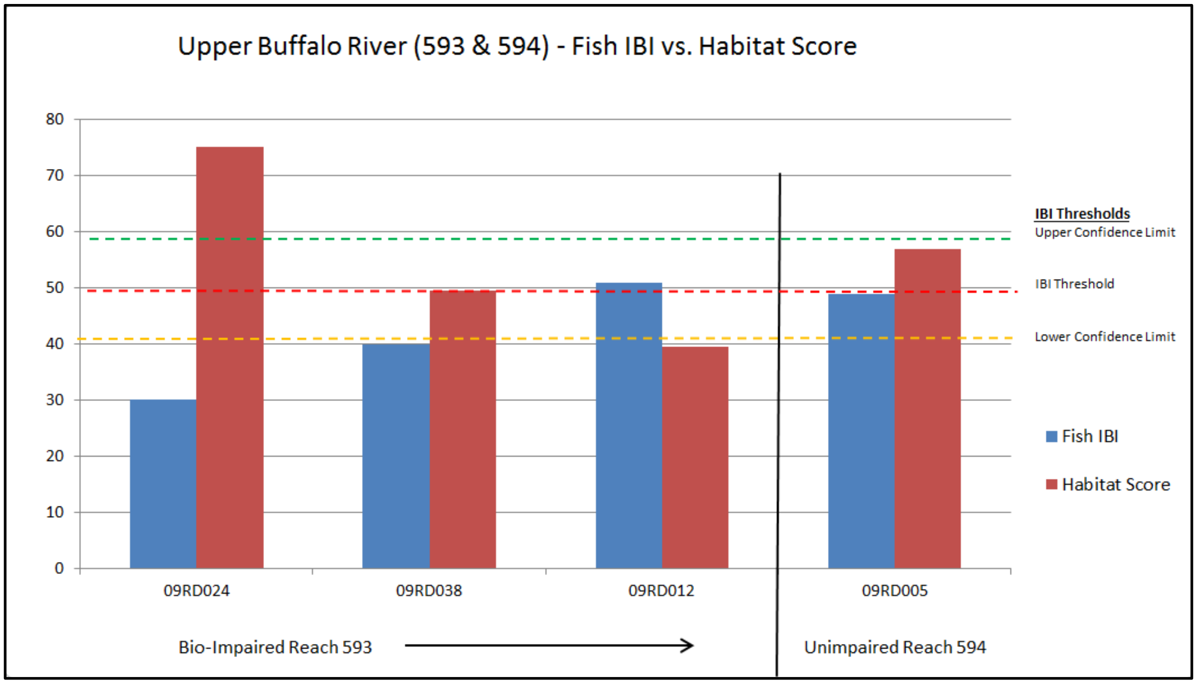


Figure 76. Upper Buffalo River reaches comparison of IBI scores vs. habitat scores.

When looking at the number of species and number of individuals moving from the upstream to downstream sites (Table 9), the numbers significantly increase, completely contrary to habitat conditions that get worse as one moves downstream in the impaired 593 reach. This inverse relationship of habitat to fish community health provides evidence that habitat is not a significant stressor in the Upper Buffalo River HUC-11.

A Google Earth "flyover" of this HUC finds that the riparian buffers are in fairly good condition in the upper portion of the watershed where a forested riparian zone is generally intact (bio site 09RD024). This corresponds with the "good" rating of the habitat score at this site. As one moves downstream west of State Hwy 59 (bio sites 09RD038 and 09RD012), the forest gives way to more row-crop agriculture and the riparian condition becomes less stable. The stream width nearly doubles as it flows through a cattle pasture and the sediment from agricultural ditch systems and channelization is seen deposited in large point bars and center bars in several locations. The relatively intact forested riparian corridor along with the better stream habitat scores in the area east of State Hwy 59 should support a healthy biology if habitat was playing an important role as a biological stressor. In this case the more degraded condition west of Hwy 59 supports a healthier IBI score.

It has been suggested by a reviewer that a more detailed look at habitat metrics might help explain the relationship between the IBI score, IBI metrics and the habitat metrics. Due to time constraints this analysis will not be performed. It is recommended that this work be done during future stressor ID studies to help differentiate the cause effect relationship, if any, between habitat and IBI.

Habitat doesn't appear to be a primary stressor in the Upper Buffalo River HUC-11 even though there are clear indications of habitat problems west of State Hwy 59. The inconsistency in the relationship between habitat score and IBI score in this reach indicates that there are other more significant stressors responsible for the poor biology.

Candidate Cause: Sediment/Turbidity

Turbidity

Each of the Upper Buffalo HUC-11's (593 and 594) is currently on the 303d list as impaired for turbidity. Monitoring at the Upper Buffalo River outlet station located at Becker County Hwy 9 (during 2008 and 2009) found that 26.3% of the turbidity results exceeded the 25 NTU standard (number of samples = 19). The mean turbidity was 22.5, median 13.7 and maximum 69.2. These results are fairly typical of the Red River Basin headwater streams in the glacial moraine landscape that have been impacted by intensive agricultural land use.

TSS

TSS results are used as an indicator of potential effects of suspended solids and turbidity on fish and macroinvertebrate populations. TSS concentrations at the Becker County Hwy 9 site from 2006 through 2012 ranged from 3 mg/L to 316 mg/L with a mean of 35.3 mg/L (n = 50). These results had 9 values or 18% exceeding the proposed TSS standard of 60mg/L. This water quality station at County Hwy 9 is co-located with the bio site number 09RD005 that is not impaired for both fish and macroinvertebrates (downstream of the impaired 593 reach). Although the lack of a bio-impairment at this location indicates that the community is in relatively good condition, these TSS results and the aerial photo evidence (Figure 80) show significant sediment depositional bars indicating that excessive erosion and sedimentation is playing a role in habitat quality and the aquatic ecology in this portion of the stream system.

Bank erosion from livestock access, riparian vegetation change, and excessive high flows caused from ditching, wetland loss and altered hydrology are causing excess sediment to be delivered to the stream. Buffers of inadequate width to protect stream bank integrity and aquatic habitat were observed throughout the two Upper Buffalo River HUC-11s. Some of this sediment input is deposited, filling pools, causing excessive bar formation and smothering riffles, resulting in the loss of important fish and macroinvertebrate habitat. The geomorphic reconnaissance work at Becker County Hwy 9 found a bimodal distribution of sediment with gravel and an excess of fine sediment indicating the excess of fine sediment supply. The TSS results indicate that sediment is a problem in this reach of the river, although not likely sufficient to stress the biological communities to levels below the IBI thresholds.

The fish samples were analyzed to determine the sensitivity to suspended sediment using Meador and Carlisle sediment tolerance indicator values (TIV) (Meador & Carlisle, 2007). Quartile 1 has the least tolerance to increases in suspended sediments while quartile 4 has the most tolerance to increased suspended sediment. Figure 77 displays the distribution of individual fish based on the ranking system from Meador and Carlisle. Based on the result of the graph, it doesn't appear that sediment is a significant stressor in the Upper Buffalo River HUC-11 as the first and second quartiles (those that are more sensitive to increases in TSS) are well represented in the population.

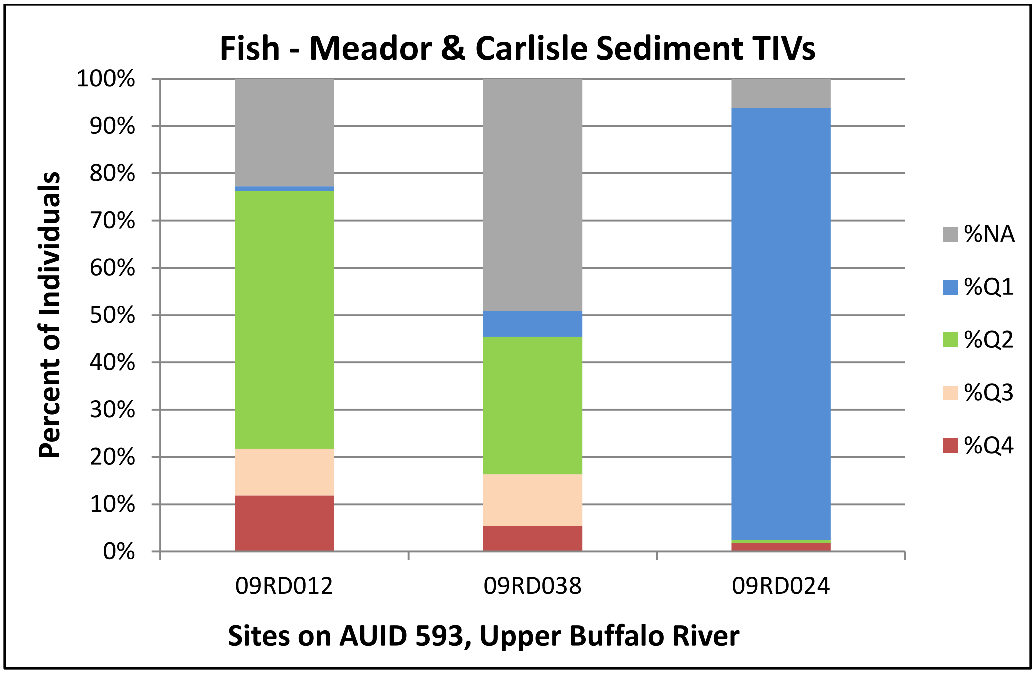


Figure 77. Percent individuals by biological site sampled in Upper Buffalo River Reach, for each quartile based on suspended sediment weighted averages (Meador and Carlisle, 2007).

The evidence for turbidity/sediment as a stressor in the Upper Buffalo River is mixed. The AUID is listed for turbidity and there is evidence of excessive sedimentation present in the stream with center bars and significant point bar formation. The Meador & Carlisle TIVs for fish however indicate that species sensitive to increased sediment are represented as a relatively high percent of the population. Based on the inconsistency of these results turbidity/sediment will be considered a secondary stressor. Additional work will be needed during the next assessment cycle in order to better define the impacts of sediment to the biology in the Upper Buffalo HUC-11.

Candidate Cause: Dissolved Oxygen

Dissolved oxygen data for the Upper Buffalo reach 593 found no significant issues that would indicate that the biology is being stressed from low DO. Site S004-105 is located at Becker CSAH 14 about two miles NE of Callaway. Data from 2006 through 2012 includes 63 DO readings. The lowest of these readings was 6.61 mg/L on 9/16/08 and only a few others fall below 8 mg/L.

Dissolved oxygen data for the Becker CSAH 9 site also found relatively good levels. There were a total of 68 DO readings at this site from 2006 through 2012. Of these results only two readings fell below 7.0 mg/L (6.83 and 6.85 mg/L) with only eight others falling below 8.0 mg/L.

Although most of these 131 data points are presumed to be after 9:00 am (they don't represent the daily low DO), they fail to indicate low DO conditions and did not warrant further assessment through the use of deployed sondes. Based on these results, DO is not being considered a stressor at this time. Future studies of the Buffalo River should include the use of deployed sondes during the low flow, summer peak temperature period to further assess DO conditions in this watershed.

Candidate Cause: Connectivity

The lack of connectivity in a stream system can have a significant impact to the health of a fish community. The evidence presented regarding habitat and the biological data showing the incremental reduction of species and individuals as one move upstream indicates that there may be connectivity issues that are preventing the migration of some fish species. In working on this part of the watershed, I have observed several beaver dams that are present on the Upper Buffalo River (Figure 78).

Figure 78. Beaver dam across the inlet of a box culvert found in the Upper Buffalo River.

The flow station previously located at Becker CSAH 14 was impacted by a beaver dam in 2010 and 2011 and was relocated upstream to another location that was subsequently impacted by a beaver dam. A Google Earth flyover of the Upper Buffalo Reach found what appear to be as many as 12 beaver dams across the stream. This number is only an estimate as a large portion of the riparian area is forested and is not very visible via Google Earth. One example that appears to be either a beaver dam or some type of diversion dam is located 2.32 miles NW of where the Buffalo River crosses Minnesota Hwy 59 (Figure 79).

Figure 79. Apparent beaver dam located in the Upper Buffalo watershed. This photo is from Google Earth and was taken on September 5, 2011.

This dam was erected sometime between the Google Earth photos of April 25, 2011 (dam not present) and September 5, 2011. The biological data for this study was collected during 2009 so this particular dam was not a factor in restricting fish movement during 2009 but it shows a representative example of the types of dams present throughout the Upper Buffalo watershed. The photo shows the flooding above the dam as well as the severe low water condition below the dam that would make it very difficult for fish migration.

Connectivity issues are not limited to beaver dams. There are two stream crossings east (upstream) of the beaver dam in Figure 79 (about four miles NW of Callaway) that appear to be perched culverts that are barriers to fish migration. The first is a railroad (RR) crossing located about one third of a mile west of State Hwy 59 and the second is a private field crossing located another 2/3 of a mile downstream (NW) of the RR crossing (Figure 80). The perched private culverts shown below appear to be the result of a head cut that worked its way upstream following some channelization work that had taken place.

Figure 80. Google Earth photo 9/5/11 showing a pair of culverts on a private stream crossing located about 4 miles NW of Callaway that appear to be perched creating a fish passage barrier.

Conclusions

The primary stressor to the biotic community in the Upper Buffalo appears to be connectivity. The significant change in both quality and quantity of fish between reaches 593 and 594 appears to be primarily attributable to a lack of connectivity between the two reaches. The increase in species diversity as one moves downstream (Table 9) lends support to the concept that the stressor is the result of the incremental and cumulative impact of the series of migration barriers that are both human and naturally (beaver) created.

Secondary stressors in the Upper Buffalo watershed appear to be habitat, sediment and altered hydrology. It is believed that if the connectivity problems are resolved in this HUC, these other secondary stressors will begin to exhibit more influence on the biology than they currently show. The impact of the lack of stream connectivity is significant enough at this time that the impact from what appear to be the secondary stressors is not evident in the biology. The habitat and TSS data show no strong correlation to the fish IBI scores even though these conditions are poor within the impaired reach. Macroinvertebrate communities may be impacted from excessive sedimentation at this time but a detailed assessment of this was not pursued.

South Branch Buffalo River HUC 09020106050

The Deerhorn-Buffalo River (South Branch Buffalo River) watershed unit consists of 12 AUIDs, of which six were assessed for aquatic life and recreation (table 19 of Buffalo River Watershed Report). The South

Branch Buffalo River (from Deerhorn Creek to Whisky Creek) has a Macroinvertebrate IBI score that fails to meet the threshold and is impaired for aquatic life. In addition, the Fish and Macroinvertebrate IBIs on Deerhorn Creek (a tributary to the South Branch) also fail to meet thresholds established for the use class of 2C for this stream. These are separate subwatersheds within this HUC-11 and represent different scales and they will each have their own section of this report where stressors will be identified for each subwatershed. In organizing and writing the assessment of the candidate causes of stressors affecting these reaches it made the most sense to look at the entire HUC-11 when discussing the biology, and the candidate causes of connectivity, habitat and altered hydrology as it helped to compare and contrast the different subwatersheds in teasing out possible stressor/biology cause/effect relationships.

Biology in the South Branch Buffalo River

Biological communities in this HUC-11 showed great variability depending on site location with Fish IBI scores ranging from 2 to 81 and Macroinvertebrate IBI scores ranging from 9 to 70 (Appendix 6 of Buffalo River Watershed Report). Relationships between biological communities and habitat were not evident; however, a possible relationship between Fish IBI and flow may exist. Although moderate to high Fish IBI scores were randomly found in the small tributaries (see site locations in Figure 81), the average score on the main stem of the South Branch Buffalo River was 52 versus 33 on the tributaries. This may indicate that the larger contributing watershed and more consistent perennial flow on the South Branch main stem are more suitable for fish survival. In a well-drained/flashy watershed such as the South Branch Buffalo River, this flow component is likely a key ingredient to the health of the stream biological communities. In addition, AUID 531 (Lawndale Creek aka State Ditch 14) is the only AUID to not be impaired for turbidity and is also the only to be fully supporting of aquatic life. The low turbidity in this tributary may help explain why the site (09RD048) had the second highest F-IBI and M-IBI scores found in the watershed.

Water quality data was available on several reaches of the South Branch Buffalo River, Deerhorn Creek, and a number of state and county ditch systems. The entire South Branch Buffalo River from its headwaters to the Buffalo River main stem and the entire reach of Deerhorn Creek (AUID 09020106-507) are impaired for aquatic recreation use (excess bacteria) and aquatic life use (excess turbidity). A DO impairment is also present on the South Branch Buffalo River upstream of Deerhorn Creek and also identified as a possible stressor on the downstream reaches (table 22 of Buffalo River Watershed Report). Excessive bacteria and turbidity are found throughout the watershed, in addition to sporadic low oxygen levels.

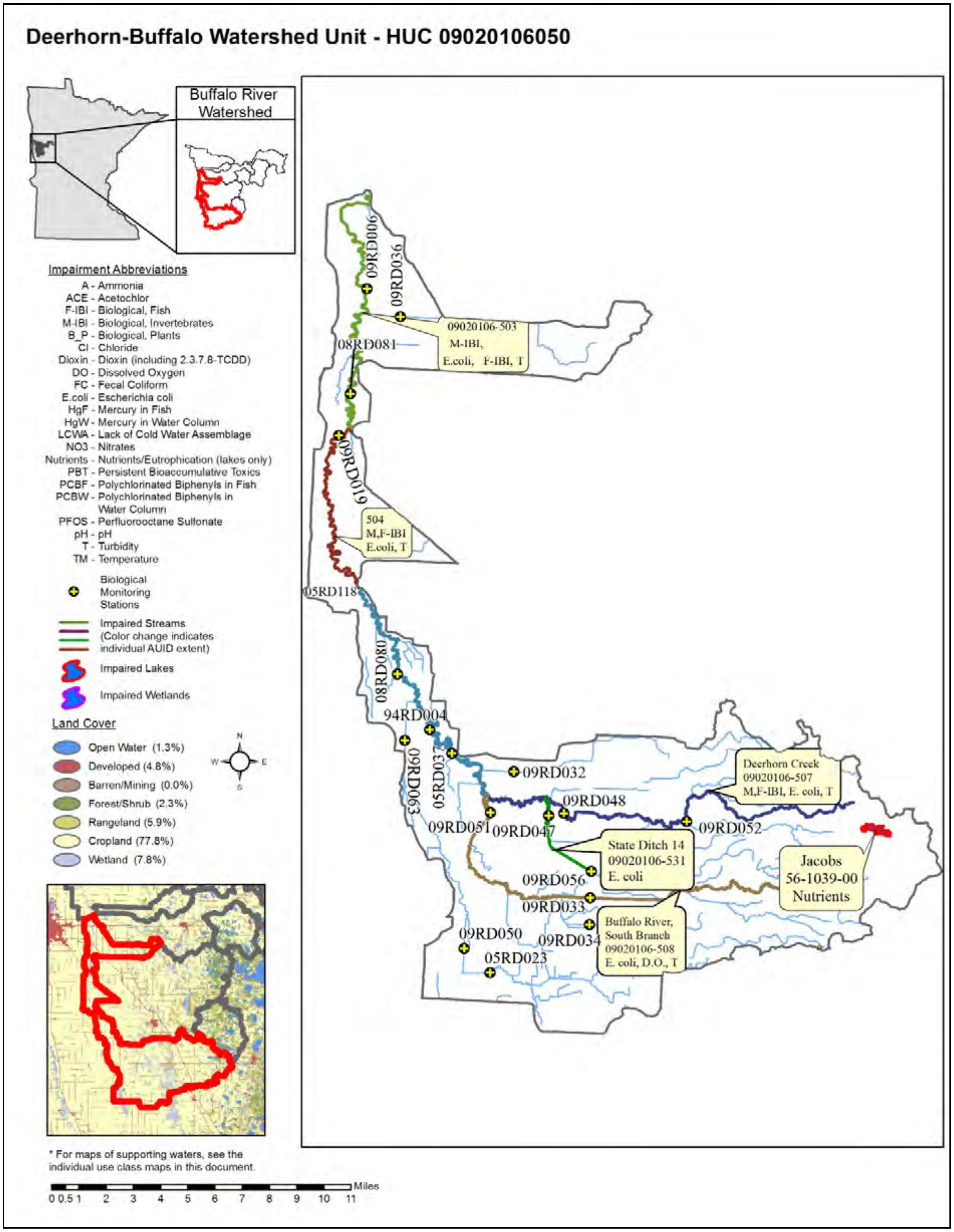


Figure 81. Bio-monitoring locations in the Deerhorn - South Branch Buffalo River HUC-11.

Candidate Cause: Habitat

Quality stream habitat within this subwatershed is severely lacking with no sites receiving a good score and an overall average habitat score of poor. The MSHA score for all nine Buffalo River, South Branch bio stations sites rated poor for habitat (Table 10). Several tributary sites rated fair for habitat in this subwatershed including the Deerhorn Creek stations, various ditches and Lawndale Creek (State Ditch 14). The Lawndale Creek station was the only site that barely missed the good habitat score as it scored 65.3, just short of the 66 points needed for the good rating.

Table 10. Habitat Scores for the Deerhorn Buffalo River, South Branch Buffalo River HUC-11.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph (0-36)	MSHA Score (0-100)	MSHA Rating
1	94RD004	Buffalo River, South Branch	0	8	9	11	6	34	Poor
1	05RD037	Buffalo River, South Branch	0	9	8	7	14	38	Poor
2	05RD118	Buffalo River, South Branch	1.75	9	9.5	5.5	13.5	39.25	Poor
1	08RD080	Buffalo River, South Branch	0	9.5	10	8	14	41.5	Poor
1	08RD081	Buffalo River, South Branch	0	8.5	7	5	15	35.5	Poor
1	09RD006	Buffalo River, South Branch	0	5	9.1	12	8	34.1	Poor
1	09RD019	Buffalo River, South Branch	0	8.5	7	7	11	33.5	Poor
1	09RD032	Judicial Ditch 3-1	2.5	9	12.3	12	10	45.8	Fair
1	09RD033	Buffalo River, South Branch	2.5	12	9	13	7	43.5	Poor
2	09RD034	Judicial Ditch 3-2	1.88	13	16.1	13	10	53.98	Fair
1	09RD036	County Ditch 12	0	7	15.7	11	16	49.7	Fair
1	09RD047	Deerhorn Creek	0	11	12	13	13	49	Fair
1	09RD048	State Ditch 14	0	9	12	10	11	42	Poor
1	09RD050	State Ditch 15	3.75	9	4	11	10	37.75	Poor
1	09RD051	Buffalo River, South Branch	0	6.5	8	11	10	35.5	Poor
1	09RD052	Deerhorn Creek	2	11	18.8	16	12	59.8	Fair
1	09RD056	Unnamed Creek (Lawndale Creek)	5	14	12.3	11	23	65.3	Fair
1	09RD063	Unnamed Creek	0	6.5	9.7	12	11	39.2	Poor
Average Habitat Results: *Deerhorn-Buffalo HUC-11*			**1.08**	**9.19**	**10.53**	**10.47**	**11.92**	**43.19**	**Poor**

Qualitative habitat ratings:

- **Good: MSHA score above the median of the least-disturbed sites (≥66)**
- **Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)**
- **Poor: MSHA score below the median of the most-disturbed sites (≤44)**

There is no strong pattern between the Fish IBI Scores and MSHA Habitat Score. A review of the subparts of the habitat score in Table 10 finds the land use and channel morphology portions are very poor throughout the subwatershed. The mean landuse score was 1.08 out of a possible score of 5 and the channel morphology was 11.92 out of a possible score of 36. A review of the raw habitat field data found a good relationship between percent of riparian landuse undisturbed within 30 meters of the bank and macroinvertebrate IBI scores (Figure 82).

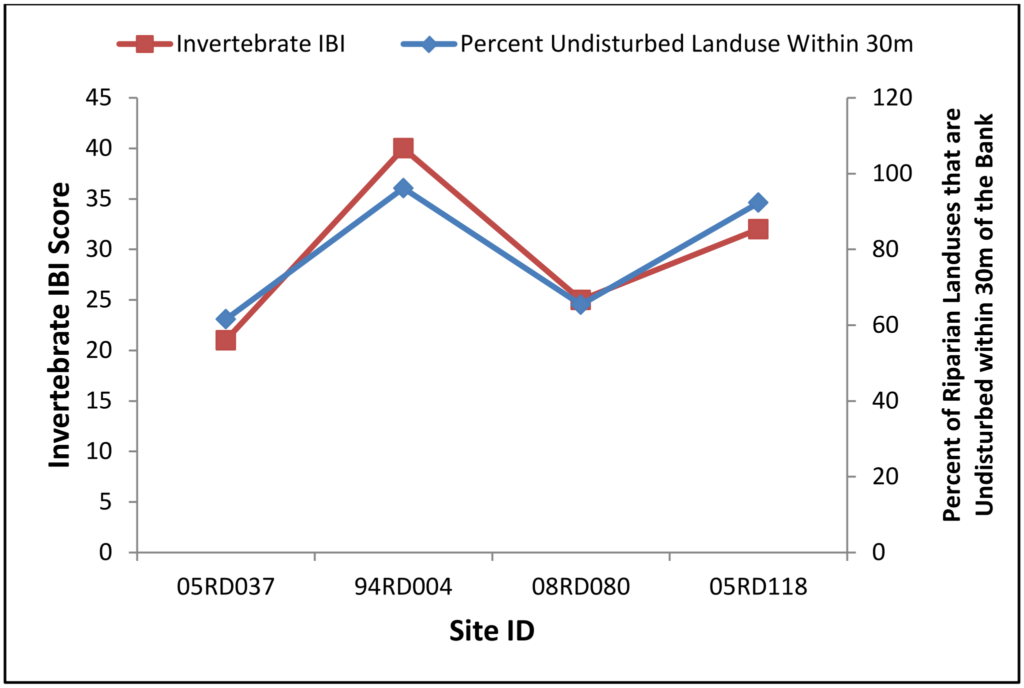


Figure 82. Relationship between Macroinvertebrate IBI Score and percent of riparian landuse undisturbed within 30 meters of the bank.

One of the largest cause and effect relationships is that those streams that have been channelized tend to have poor IBI scores. There are exceptions to this rule but even when habitat scores are fair, channelized reaches tend to have lower IBI scores. The four non-channelized assessable reaches in Figure 83 have F-IBI scores well above the impairment threshold however when looking at their habitat scores, they all rank poor, and in many cases significantly worse than some of the channelized non-assessable reaches. The higher IBI scores for these non-channelized reaches appear to be due to the position in the watershed or size of contributing watershed. These reaches are all below the confluence with Deerhorn Creek and as such have a greater chance of maintaining year round flow than the lower order streams reaches in the Deerhorn subwatershed and the Upper South Branch subwatershed. In addition, the stream segments that are further downstream have a greater likelihood of providing good overwintering habitat and are in a better location for recruitment from the Red River and Buffalo mainstem than reaches further upstream.

The drainage of wetlands and groundwater that would normally provide base flow to these upper reaches has in effect dewatered these reaches and this compounds the effects that periods of drought and winter (freezing) have on the biology of the lower order stream reaches. Although it is natural to have biological die offs in lower order streams associated with periods of no flow, dry down and complete winter freezing; the frequency, duration and spatial extent of these events will increase relative to the extent of artificial drainage within the watershed. This habitat loss is directly attributable to the stressor - altered hydrology that will be discussed in the next section.

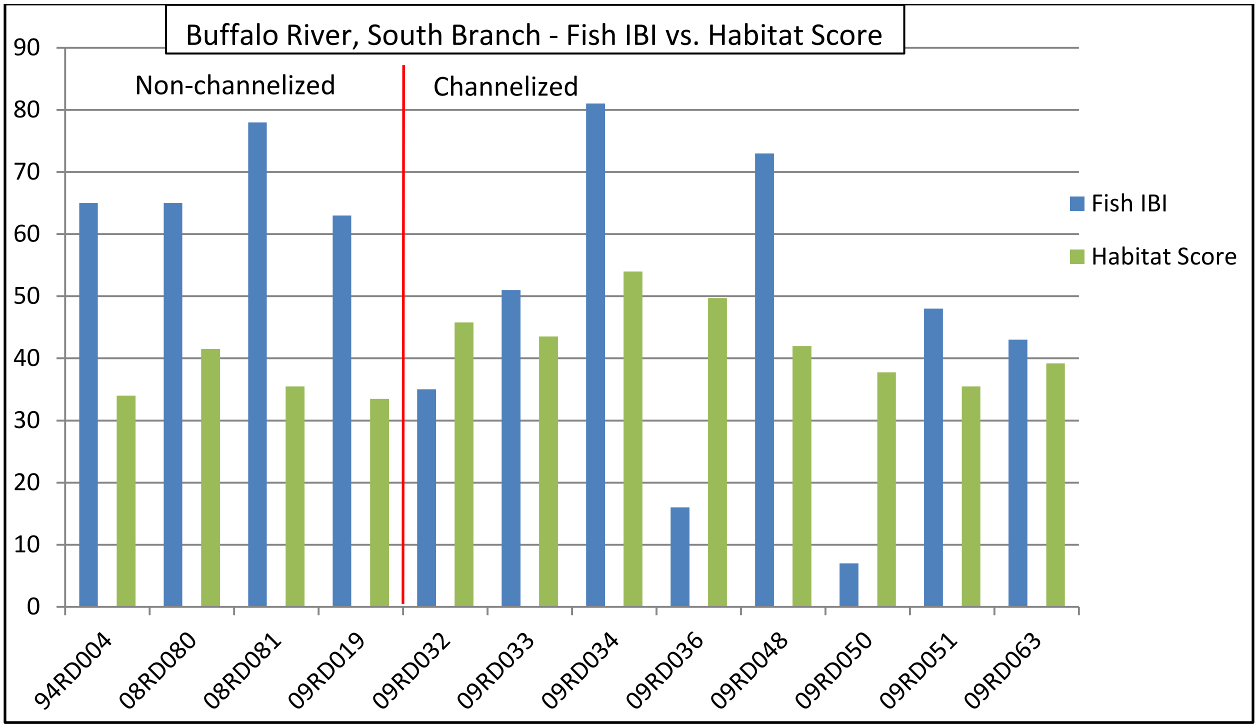


Figure 83. South Branch Buffalo River relationship of fish IBI score to MSHA score for assessable bio-monitoring sites.

The loss of "pre-development" first and second order (headwater) streams to agriculture is perhaps the most significant habitat loss stressor on these stream systems and a primary cause of altered hydrology in the Red River Basin. These smaller intermittent streams serve as the capillary system that connect the uplands and riparian areas to the stream much like the capillaries in the human connect the body tissue, muscle and organs to the rest of the circulatory system. These streams are graded for drainage and farmed through in most cases and typically only visible as swales in the landscape until after a precipitation event erodes a new channel (gully) in the cultivated soil. This gully erosion has been identified as the primary source of sediment to streams in the Red River Valley (Emmons and Olivier, 2009). These headwater streams typically make up about two-thirds of the total stream length of a river system (Leopold et al., 1964), and when intact, provide vital services to the biological communities that inhabit the system. The channelization and dewatering of these headwater streams through agricultural tiling exacerbates the changes in base flow from alterations of landuse and wetland drainage as found by Schottler, et.al. (2013) and Vandegrift and Stefan (2010).

Since the loss of these streams to cultivation may have occurred prior to the Clean Water Act (1972) they may be considered legacy impacts and will be grandfathered-in through the tiered aquatic life standards development. In essence, the expectation for the biological community health of streams affected by such impacts will be less due to their pre-1972 degraded condition. An assessment of the percentage of headwater streams farmed through pre and post 1972 would be interesting because the shift to larger equipment and the corresponding reduction of grassed waterways and stream buffers appears to have occurred over a period starting in the 1960's and into the 1990's.

The poor habitat scores within the South Branch Buffalo River subwatershed point to significant issues with habitat and suggest that poor habitat is a stressor. This stream, in the intensively farmed lake plain zone, is the most complex in the Buffalo River system due to the combination of stressors acting on the stream biology. The impacts from the different stressors in this portion of the stream can mask each other making it difficult to sort out the primary cause of the impairment.

Candidate Cause: Altered Hydrology

The impacts from altered hydrology within a stream system often appear as habitat issues that express themselves on the biology of the system. Impacts that are common in the well-drained agricultural dominated watershed of the South Branch Buffalo River include a change in the hydrograph that results in higher peak discharge rates and lower base flow rates. This change can cause increased frequency and intensity of flooding, channel instability with excessive bank and or bed scour, increased TSS load/turbidity and sedimentation and the loss of pool and riffle habitat (embeddedness). These changes in the stream condition appear in the form of reduced habitat quality as discussed in the previous section.

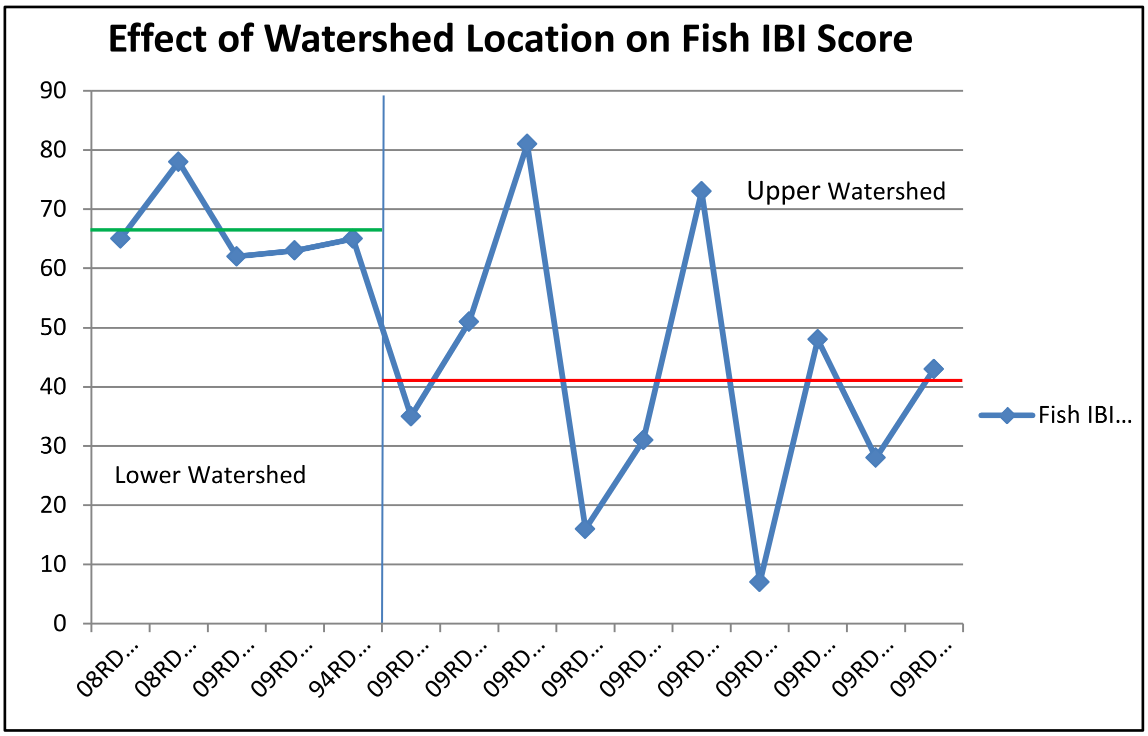


Figure 84. Effect of watershed location on Fish IBI score.

Altered hydrology and the resultant impacts appear to be a stressor to the fish community in the South Branch Buffalo and Deerhorn Creek subwatersheds. Based on the F-IBI results, the lower reaches of the system (that have a more consistent year-round flow regime) have better fish communities. The data shows that this relationship is present throughout the mainstem Buffalo River as well as the South Branch Buffalo River where the lower river reaches tend to have better IBI scores. Figure 84 shows a watershed comparison of F-IBI scores for the sites within the South Branch Buffalo River HUC-11. The lower sites are located on the left with an average IBI Score of 66.6 (indicated with green line). These sites have an average watershed size of 312 square miles (minimum watershed size of 126.74 to maximum of 506.32 sq. mi). The upper watershed sites are on the right with an average F-IBI score of 41.3 (indicated with red line) and these sites have an average watershed size of 23 square miles (minimum of 4.09 to maximum of 38.64 sq. mi). It is difficult to determine whether the differences in F-

IBI are attributable to channelization, changes in hydrologic conditions or related to the distance from more diverse populations associated with the mainstem and the Red River because each of these factors would be expected to have a similar response in the figures provided.

There exist two sites in the upper watershed side of the figure with F-IBI scores above 70. These sites on Judicial Ditch No 32 (09RD034) and Lawndale Creek (a.k.a. State Ditch 14) (09RD048) have extensive wetland and prairie habitat located upstream that contribute base flow to their flow regime. Both sites have the Rothsay State Wildlife Management Area (WMA) contributing good water quality and base flow and Lawndale Creek (Figure 85) has the Atherton WMA natural area and at least two large springs that contribute more than two cubic feet per second (cfs) of groundwater to the stream year-round. These natural areas provide high quality water and consistent flow to these streams and this continual input of flow sustains these streams during dry periods. It is the base flow that sustains these streams during dry periods that is generally missing from most of the other upper watershed sites that have poor F-IBI scores. It should be noted that the site (09RD033) with the third highest ranking IBI score on the upper watershed side of Figure 84 is also connected to the Rothsay WMA and derives base flow benefit and good water quality from it. If these three sites were removed from the chart, the mean F-IBI score for the upper watershed sites would be 11.4 points lower or 29.9.

Figure 85. Lawndale Creek with relatively good riparian cover. State WMAs in the watershed along with groundwater springs supply water of good quality and base flow that supports healthy stream biology.

The impacts on base flow from flow alteration were discussed in the habitat section due to the direct habitat impacts associated with the loss of stream flow. These impacts in the intensively farmed areas of the South Branch Buffalo watershed are related to channelization and drainage (both surface and subsurface). Removing the surface and groundwater out through the stream system early in the growing season through artificial drainage networks that support agriculture is not compatible with healthy stream ecology. The loss of base flow that is needed to provide critical habitat during low flow stress periods appears to be a major driver in limiting the biological integrity within this impaired reach. Based on the information available it appears that altered flow is a primary stressor on the South Branch Buffalo biology.

Candidate Cause: Connectivity

Connectivity is a fishery stressor for the entire South Branch Buffalo River and its tributaries due to the sheet pile dam that was discussed in earlier sections of this report. There are other more localized connectivity issues that will be discussed when addressing Deerhorn Creek and Spring Creek however the sheet pile dam, located just a few miles from the confluence with the Buffalo River mainstem is a significant barrier to fish migration and should be a priority for removal or modification to provide fish passage to the entire South Branch Buffalo River and its tributaries. The South Branch Buffalo River is only impaired for macroinvertebrates and not fish so connectivity will not be listed as a stressor. Fish hosts are used my mussels however there is no data that justifies listing it for that purpose.

The remainder of this section will address the Macroinvertebrate IBI impairment for the South Branch Buffalo River reach (AUID 09020106-505) from Deerhorn Creek to Whisky Creek. A separate section that follows will address the biological stressors for the Deerhorn Creek Subwatershed.

Candidate Cause: Sediment/Turbidity

This reach is listed for turbidity and the latest data set shows continued impairment. The water quality monitoring sites with landuse and impairments for the South Branch Buffalo River and Deerhorn Creek are provided in Figure 86. The TSS concentration data for the South Branch Buffalo is presented in Figure 87. Concentrations above 60 mg/L would violate the proposed State TSS standard for streams within this watershed. The climate data presented earlier identified 2010 as an unusually wet year and this may be the reason for the higher TSS results for that year. TSS is usually an event driven pollutant so those readings that exceed “normal” levels are most often associated with storm events or spring melt. In most years it is noted that the downstream site had the highest TSS concentrations recorded. The exception is 2012 and this was a dry year with annual precipitation two to six inches below normal.

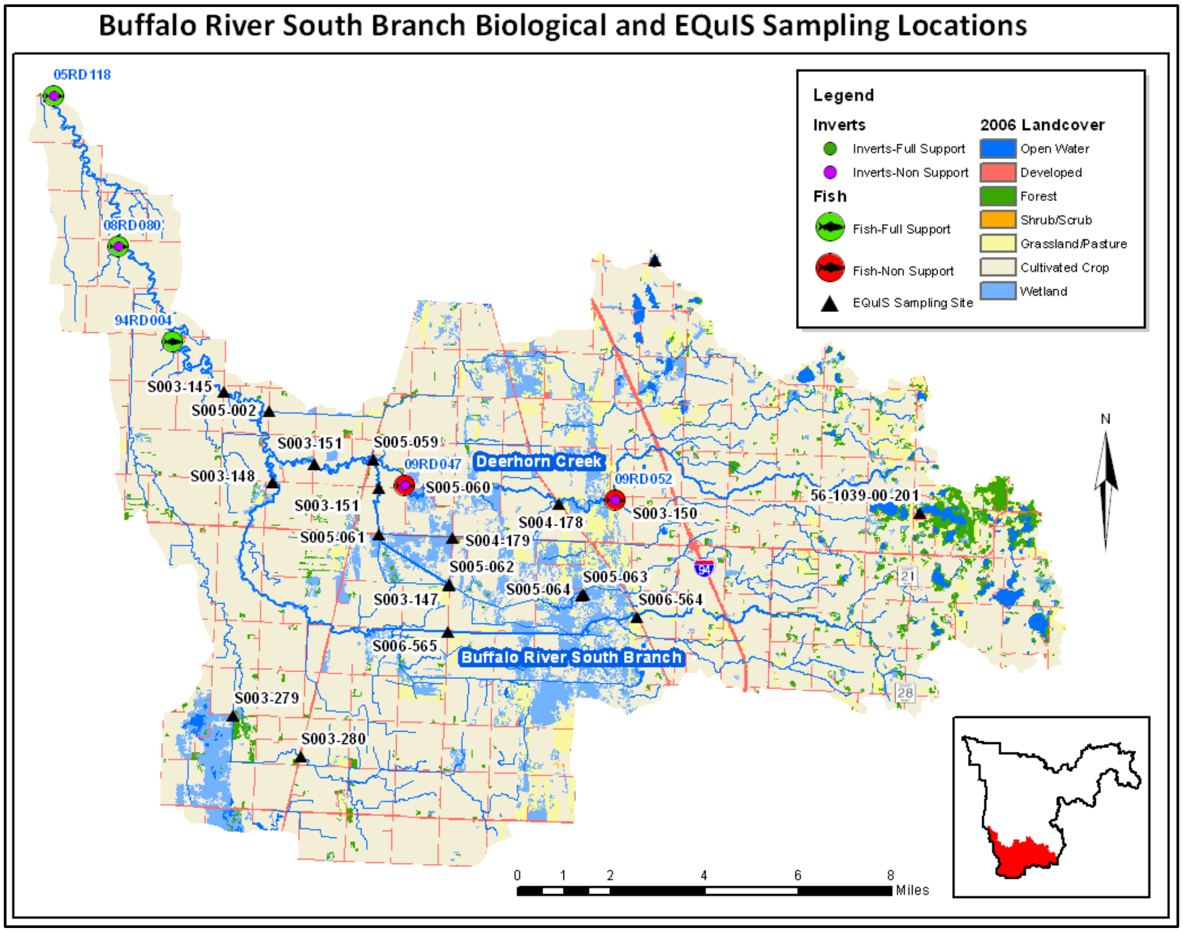


Figure 86. Water quality stations with landuse and impairments for the South Branch Buffalo River and Deerhorn Creek.

Percent embeddedness is available for two biological sites. Site 94RD004 had a 100% embeddedness score and site 08RD080 had a 0% embeddedness score. The percent fines at these sites were 98 and 96% respectively. In looking into this data, the 100% embeddedness score was due to the fact that one of the transects at this site has a gravel bottom located several inches under fine sediment. The fine sediment was present at the other site however there was no underlain gravel to result in embeddedness. This information is consistent with the geomorphic work performed on the upper end of the impaired South Branch reach just downstream from the confluence of Deerhorn Creek where sediment was identified as a problem.

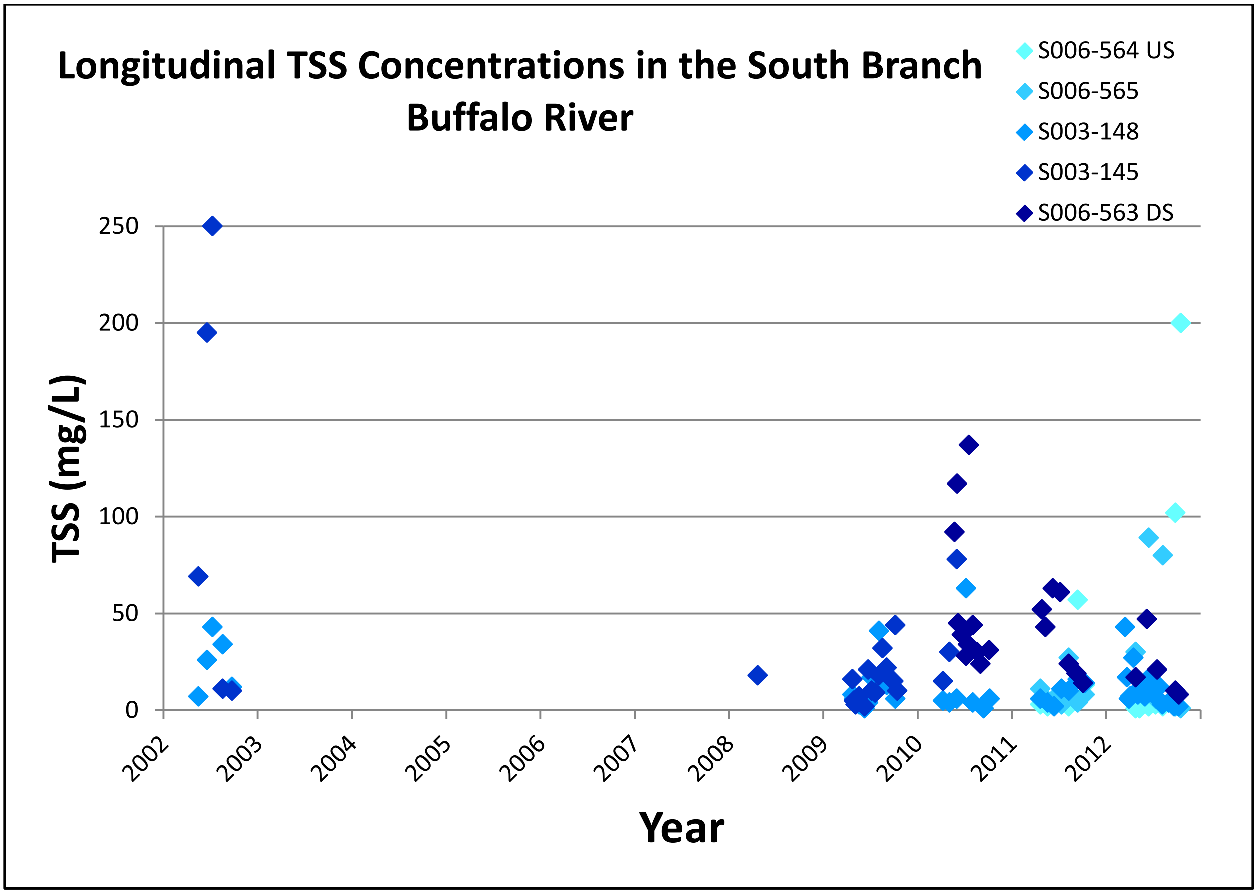


Figure 87. Longitudinal TSS Concentrations in the South Branch Buffalo River.

An assessment of the TSS vs. macroinvertebrate IBI Score relationship (Figure 88) provides evidence that TSS appears to impact IBI scores. The unimpaired Lawndale Creek sites with very low TSS range have the highest IBI score and Deerhorn Creek and the South Branch Buffalo River, with a higher range in TSS have correspondingly lower M-IBI scores. An assessment looking at the relationship of turbidity and the clinger metric score finds a similar relationship where the clinger group of organisms appears to be closely tied to turbidity readings and range in turbidity (Figure 89).

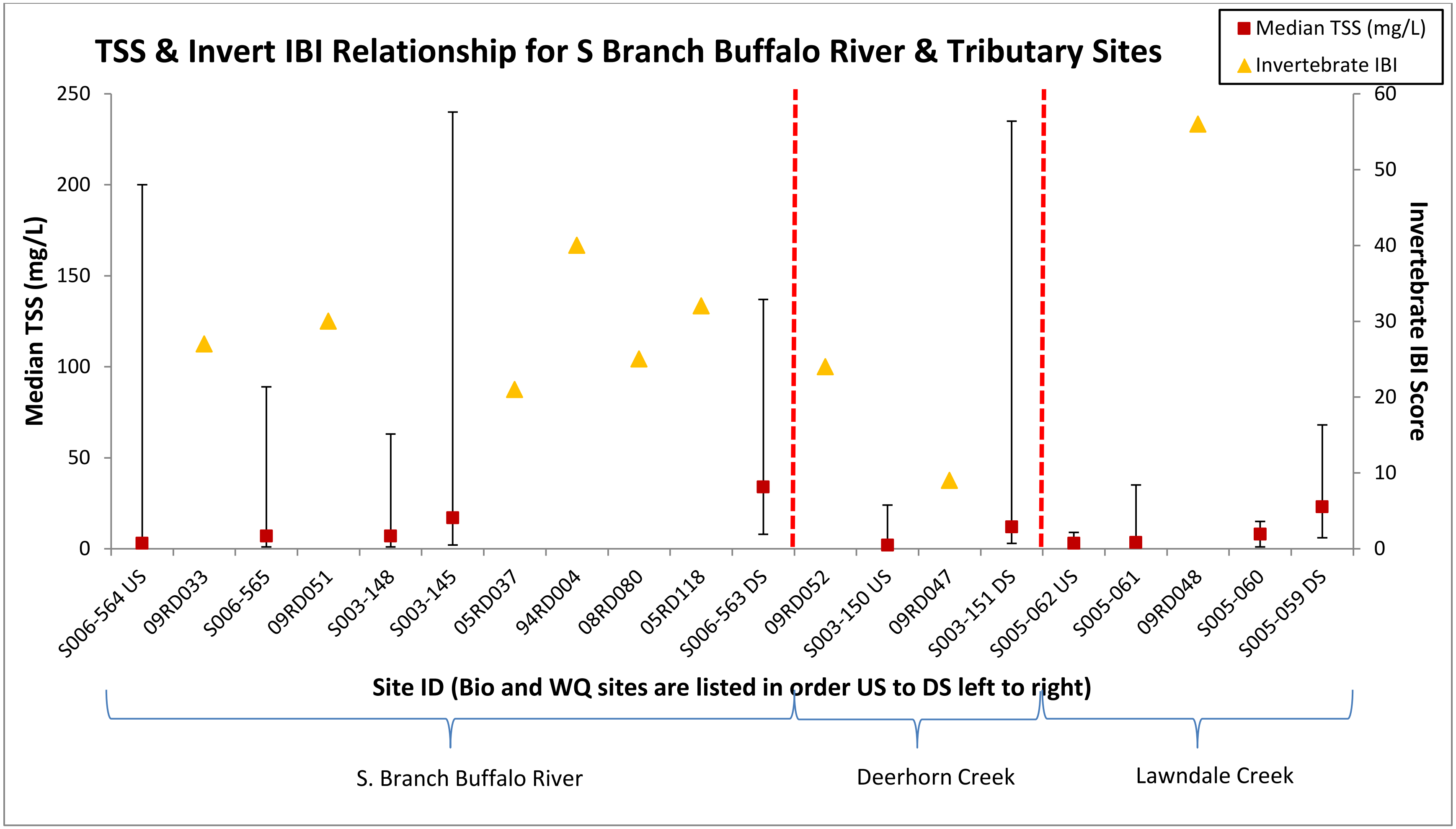


Figure 88. TSS and Macroinvertebrate IBI Relationship for South Branch Buffalo River and Tributary Sites.

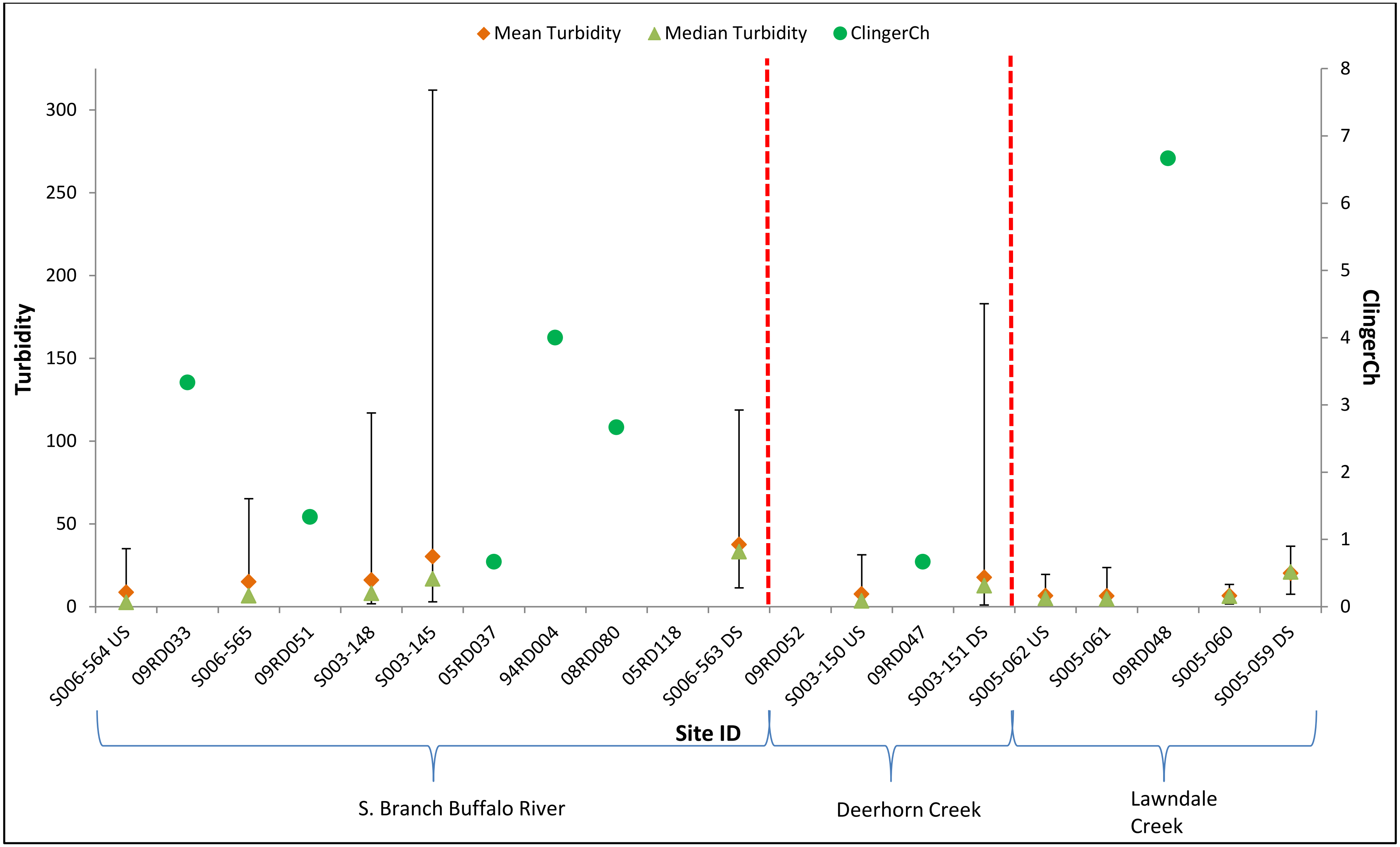


Figure 89**. Turbidity vs. clinger metric score for South Branch Buffalo River and tributaries.**

The South Branch Buffalo River has several lines of evidence that support the belief that the macroinvertebrate biology is being stressed by suspended sediment/turbidity. The turbidity impairment on this reach in combination with the embeddedness and % fines data supports this conclusion. The geomorphic investigation found high sediment levels and suggests that sediment is a cause of the macroinvertebrate impairment. The Macroinvertebrate IBI and clinger relationship to TSS and turbidity respectively also supports this conclusion. Based on this evidence, sediment/turbidity is considered a primary stressor on the macroinvertebrate biology on this reach of the South Branch Buffalo River.

Candidate Cause: Dissolved Oxygen

A low DO impairment of aquatic life was determined for the South Branch Buffalo River upstream of Deerhorn Creek and also identified as a possible stressor on the downstream reaches (Table 22 of Buffalo River Watershed Report). The assessment notes for the South Branch Buffalo River headwaters area (before confluence with Deerhorn Creek) indicate that the diurnal DO flux is likely dropping below the five mg/L standard for weeks during the warmest months (July and August) of 2009 and 2010. Early morning measurements are lacking, but a high exceedance rate still occurred at later times during the day indicating that the daily minimum was likely much lower. Stream flow records at Sabin show that 2009 was a fairly average year in terms of hydrology so it can be assumed that during dryer years the low DO conditions and related stress on the biology would be exacerbated.

This information is sufficient to consider DO a secondary stressor of the macroinvertebrate biology in the South Branch Buffalo River reach under consideration. Future monitoring within this reach should include the use of deployed water quality sondes to better characterize the DO concentrations and flux during the typical low flow, summer peak temperature period in July and August.

Candidate Cause: Nitrate

The assessment notes indicate that 21% of the small NO_2NO_3 data set is higher than the ecoregion expectation for the South Branch Buffalo River subwatershed in question. Although this indicates higher than expected data, none of the data is high enough to be considered toxic to aquatic life, including the more vulnerable early life stages. The highest nitrate level detected was .71 mg/L. The most sensitive macroinvertebrate and fish taxa and life stages are typically impacted at levels above 1 mg/L (Monson, P. and Preimesberger, 2010) and as such, nitrate is not considered a biological stressor at this time.

It should be noted however that if excessive agricultural tiling takes place in this watershed, nitrate levels can be expected to rise as they have in more heavily tiled areas in Minnesota and Iowa. It is not unreasonable to expect that nitrates could become a biological stressor in this watershed under such future conditions.

Conclusions

The macroinvertebrates within the South Branch Buffalo River between Deerhorn Creek and Whisky Creek are under stress from many of the stressors common to agriculturally dominated landscapes. The primary stressors on the macroinvertebrate community are altered hydrology, habitat and TSS/turbidity. Dissolved oxygen is considered a likely secondary stressor that requires additional data to confirm this determination. As indicated, the trend for installing agricultural tile to aid in field drainage will likely have the effect of increasing nitrate levels in the South Branch Buffalo River and this is a legitimate concern for the future of this watershed.

Deerhorn Creek HUC 09020106050-507

Biology in Deerhorn Creek

Deerhorn Creek is a tributary that flows 21.9 miles from its headwaters to the South Branch Buffalo River. The creek flows west through relatively equal portions of the three hydrogeologic landforms (the Glacial Moraines, the Lake Agassiz Beach Ridges and the Lake Plain). Lawndale Creek, a groundwater fed trout stream is the largest tributary to Deerhorn Creek. The biological and water quality monitoring stations for Deerhorn Creek are presented in Figure 90.

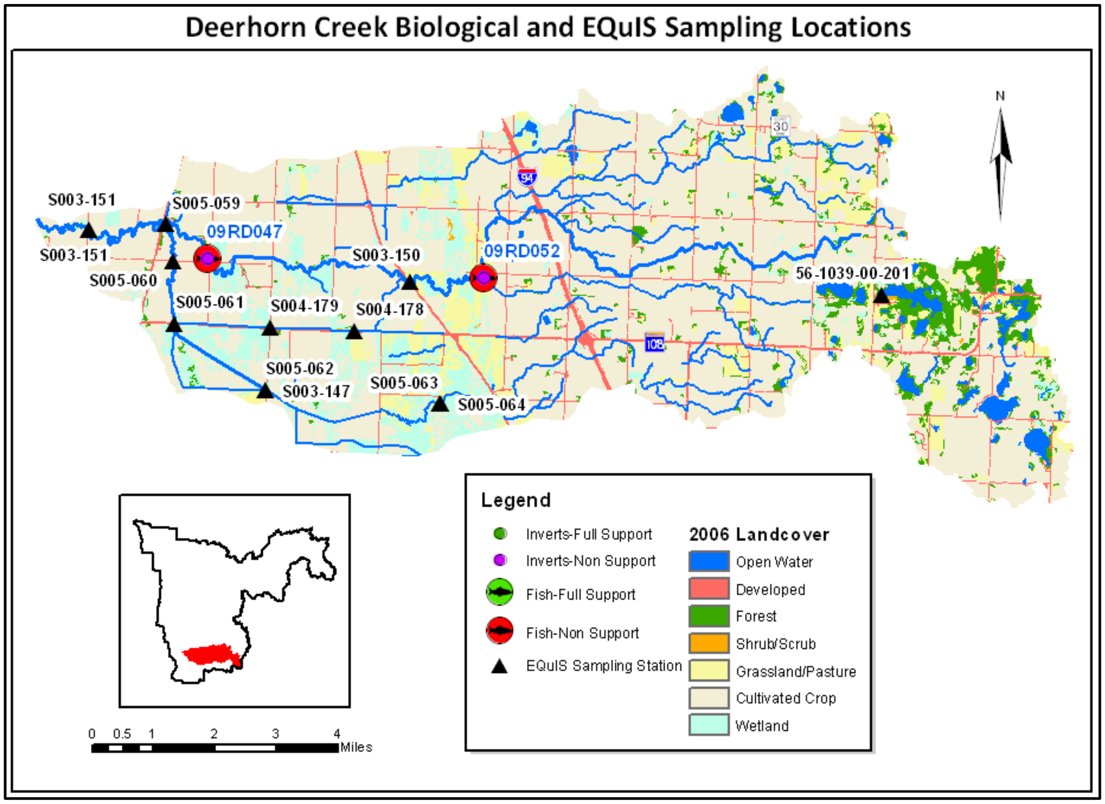


Figure 90. Deerhorn Creek water quality and biology monitoring sites.

Monitoring results from Deerhorn Creek found that it was impaired for fish and macroinvertebrates from the headwaters to the confluence with the South Branch Buffalo River. Two biological sites were located on Deerhorn Creek (09RD047 and 09RD052) and two on Lawndale Creek (09RD048 and 09RD056). Since these streams parallel each other through the same landforms and since Lawndale Creek has fish and macroinvertebrate communities that meet the IBI thresholds, they will be compared in order to help determine the stressors that are most likely causing the impairments observed in Deerhorn Creek. It must be noted that this comparison will be based on environmental conditions and not directly based on IBIs since Deerhorn Creek is a warm-water stream and Lawndale Creek a cold-water stream.

Deerhorn Creek has a very weak fish community when compared to the other class 2 streams in the Buffalo River Watershed (Figure 91). Each of the two sites (09RD047 and 09RD052) had only four species of fish present during the 2009 sampling. The most upstream site had 159 fish in the sample and they included; brook stickleback (55), central mud minnow (51), fathead minnow (52), and northern pike (1). The downstream site, located near the confluence of Lawndale Creek had 10 total fish in the sample that included; black bullhead (2), central mud minnow (1), white sucker (1), and northern pike (6).

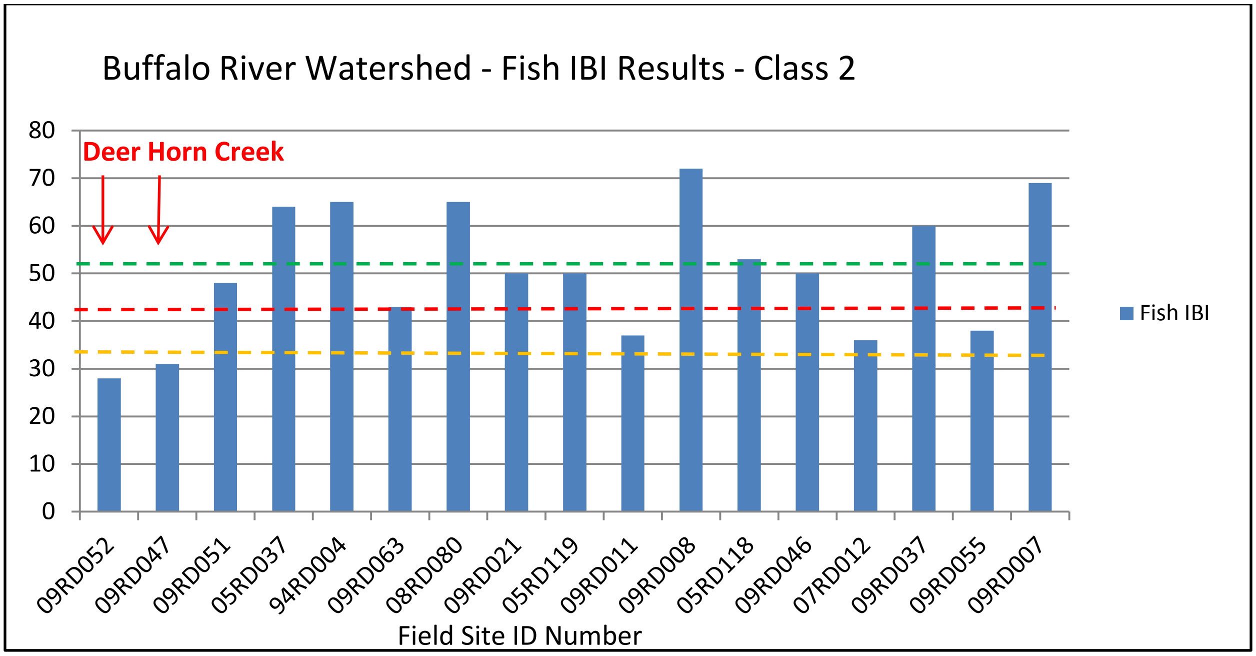


Figure 91. Comparison of Deerhorn Creek Fish IBI results to other Class 2 streams in the Buffalo River Watershed.

The macroinvertebrate community is characterized by 53.7% pollution tolerant taxa and no intolerant genera. There were 17 total genera of macroinvertebrates present in the samples however the percent of the dominant two taxa made up 63.6%. Table 11 shows a summary of the metric scores for the macroinvertebrate community and how these metrics are interpreted for determining potential stressors.

Table 11. Deerhorn Creek - 2009 Macroinvertebrate Results.

Attributes	09RD052	09RD047	Indicator of Potential Stressor
Ephemeroptera Taxa	1	2	
Plecoptera Genera	0	0	
Trichoptera Genera	2	0	
EPT Taxa	3	2	DO, P
Hilsenhoffs Biotic Index (HBI)	7.1	3.8	
Intolerant Genera	0	0	P
% Pollution Tolerant	53.7	27.6	habitat, channelization, DO, P, TSS
% Chironomidae	10.2	6.8	
% Diptera	22	6.8	
% Dominant Taxa	48.2	49.7	
% Dominant Two Taxa	63.6	73	habitat
% Filterers	13.1	0	TSS
% Gatherer	25.6	69.3	
% Hydropsychidae	1.6	0	
% Scraper	51.8	25.8	P
Total Genera	17	13	
IBI score	24	9	
Stream Position of Site	Upstream	Downstream	

Candidate Cause: Habitat

The Deerhorn Creek bio-station habitat scores each rated fair (Table 12). The scores reflect the intensive row crop land use in the watershed although the riparian sub score was 11 for each site, indicating that the stream was given some space for riparian cover/buffer at the sites. The two substrate sub scores average 15.4 of a total score possible of 27. The channel morphology sub scores were very low at these sites with scores of 12 and 13 out of a total possible of 36 points in this heavily weighted category. The fish cover and riparian sub-scores were good for each of the sites.

Table 12. Deerhorn Creek Biological Station Habitat Scores.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	09RD047	Deerhorn Creek	0	11	12	13	13	49	Fair
1	09RD052	Deerhorn Creek	2	11	18.8	16	12	59.8	Fair
Mean Subscores			1	11	15.4	14.5	12.5		

A review of the macroinvertebrate metrics for Deerhorn Creek finds that the percent clingers were low at both sites. Since the clinger taxa (EPT plus odonata) tend to be the most pollutant intolerant taxa in general, the relative absence of clingers isn't necessarily related to the lack of structural habitat but may be more related to water quality "habitat" conditions in terms of DO and or turbidity/TSS. The substrate subscore is about average at 12 and 18.8 so that isn't conclusive in terms of lack of suitable substrate being a cause of the low % clinger taxa. There are no embeddedness scores for the Deerhorn Creek to look at and this should be studied in the future to help determine whether this is a factor in the macroinvertebrate IBI scores. More information is needed to make the determination regarding this candidate cause on the macroinvertebrate community.

Figure 92 shows a comparison of the Fish IBI scores with confidence limits compared to the habitat scores. Based on the scores and the relationships there is no strong indication that habitat is the limiting factor for the biology in this stream however the habitat scores are only fair and the downstream site (09RD047) score is very close to the poor habitat threshold. For these reasons habitat can't be ruled out and can be considered a secondary stressor until additional information determines otherwise.

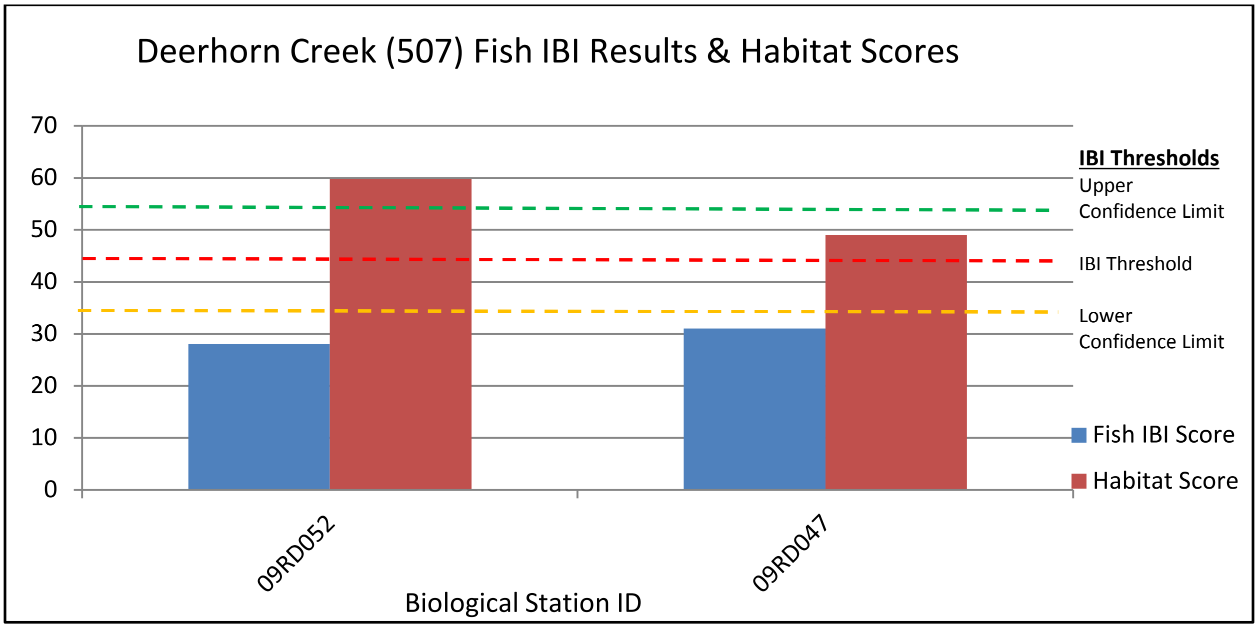


Figure 92. Deerhorn Creek Fish IBI results with confidence limits vs. habitat scores.

Candidate Cause: Altered Hydrology

Altered hydrology is a common product of intensive agriculture in watersheds that exceed about 75% agricultural landuse, such as Deerhorn Creek. The loss of headwater streams to grading and row crop production, channelization, wetland loss and tiling are the primary vehicles for altered hydrology. These landscape changes, inherent with modern agriculture, significantly change the runoff and infiltration rates on the land. Drainage and the loss of storage in intensively farmed areas are often such that the hydrologic changes both in terms of peak discharge and loss of base flow have a significant impact on the fish and macroinvertebrate communities. Stream bank instability/erosion, high sediment loads and sedimentation are symptoms of intensive drainage and the resulting flashy hydrograph (Schottler et.al. 2013) and a significant stressor/contributor to the bio- impairment of streams. Altered hydrology is a primary stressor in Deerhorn Creek.

Candidate Cause: Phosphorus

Summary statistics for the water quality data for Deerhorn Creek are provided in Table 13. Total phosphorus (TP) data was collected in 2002 for the upstream site S003-150, and in 2002, 2008, 2009, 2010, 2011 and 2012 for the downstream site S003-151. Total phosphorus was elevated above the draft standard (0.150 mg/L) in 2 of the 3 samples at site S00-150 and 4 out of 35 samples at site S003-151. Each of these sites would exceed the 10% threshold of impairment for the proposed phosphorus standard for "southern" streams.

Table 13. Deerhorn Creek water quality summary statistics table for sites S003-150 (upstream site) and S003-151 (downstream site) (N = number of samples).

Deerhorn Creek WQ Summary Statistics (data includes 2002 to 2012)								
Site ID	**Statistic**	**DO**	**TP**	**TKN**	**NO_2NO_3**	**TSS**	**Turbidity**	**T-Tube**
S003-150	Min	4.55	0.053	na	0.03	1	0.75	9
	Max	14.73	.342	na	0.11	24	31.3	114.75
	Mean	10.8	0.195	na	0.067	9	7.6	78.1
	Median	10.81	0.191	na	0.06	2	3.44	100
	N	37	3	na	3	3	37	34
S003-151	Min	5.99	0.011	0.03	0.02	3	1.1	13.3
	Max	15.41	0.635	0.876	0.56	232	183	100
	Mean	10.5	0.088	0.384	0.178	21.9	17.6	45
	Median	10.46	0.066	0.372	0.16	12	12.7	43.5
	N	91	35	14	35	36	92	71

Statewide river chlorophyll studies by Heiskary and Markus (2003) found high turbidity levels in the Red River Basin and the resultant poor light penetration tends to keep algal production low. Field observation of Deerhorn Creek confirms this with relatively little filamentous algae present. Concern for high phosphorus and potential DO issues due to decomposition of excessive algae growth doesn't appear to be warranted in this case. DO concentrations at each of the Deerhorn sites found only two of the 128 combined readings for the two sites fell below 5 mg/L. There doesn't appear to be ample evidence to indicate that phosphorus is a concern in this regard. The analysis of diurnal DO flux by using deployed sondes equipped with DO probes was not pursued in this watershed. Future studies should utilize this technique to better assess the DO flux within Deerhorn Creek.

Phosphorus can also be a stressor if it smothers the rock or wood substrate required for some of the more pollution intolerant macroinvertebrate genera (ex. Ephemeroptera, Plecoptera and Trichoptera). Based on the evidence and observations this does not appear to be an issue in Deerhorn Creek. It doesn't appear that excessive algae growth (either planktonic or attached) is limiting habitat quality in Deerhorn Creek.

Phosphorus levels should be reduced in Deerhorn Creek as they exceed levels that are preferred for healthy stream ecology, however phosphorus does not appear to be a stressor to the biology based on the evidence reviewed. The high Deerhorn Creek phosphorus levels are however a problem downstream in Lake Winnipeg where excessive Red River phosphorus levels are the major cause of the degradation of Lake Winnipeg. Efforts to reduce suspended sediment concentrations should have a similar effect on phosphorus concentrations as much of the phosphorus is tied to sediment and as such phosphorus levels are fairly well correlated with turbidity and TSS in the Red River Basin (Paakh, Goeken and Halvorson, 2006).

Candidate Cause: Nitrate

Nitrate levels in Deerhorn Creek are summarized in Table 13. There exists only three data points for the upstream site S003-150. The three results fall below the ecoregion norm of 0.2 mg/L. Site S003-151 has 35 nitrate sample results with the mean of 0.176 mg/L and maximum of 0.56 mg/L. Twelve of the 35 data points fall at or above the ecoregion norm. A review of the research by Monson and Preimesberger (2010) found that levels in excess of 1 mg/L are typically needed to affect the more sensitive stream macroinvertebrate and fish species. The caddis flies (Trichoptera) are one of the macroinvertebrate families considered more sensitive to high nitrate levels. The upstream bio site 09RD052 had two Trichoptera present in the sample where the downstream site (09RD047) had none.

The nitrate levels found in Deerhorn Creek do not appear to reach the levels needed to create significant stress on the aquatic community. Based on the existing nitrate data for this stream, nitrates are not considered a stressor in the Deerhorn Creek watershed at this time. It is important to note that the increase of agricultural groundwater tiling within the watershed is reason for concern (Figure 93). The discharge of subsurface drainage from tiling is known to significantly increase stream nitrate levels (MPCA, 2013). It is recommended that future monitoring of stream water quality include the analysis for nitrates as levels are likely to increase throughout the Buffalo River Watershed.

Figure 93. Agricultural tiling has resulted in elevated nitrate levels where it is prevalent in Minnesota and Iowa.

Candidate Cause: Sediment/Turbidity

The Deerhorn Creek HUC-11 is currently listed on the 303d list as impaired for turbidity. Seventeen of the 129 (13.2%) Deerhorn Creek turbidity readings from 2002 through 2012 meet or exceed the 25 NTU turbidity standard. The mean turbidity reading in the upstream site was 7.6 and for the downstream site 17.6. The difference between the mean turbidity for these sites may be due to the smaller data set for the upstream site and less data during the spring peak discharge period at the upstream site vs. the downstream site. TSS and turbidity levels in the Buffalo River are usually correlated with discharge although not as well correlated as most streams due to the clay sized soil particles that tend to stay in suspension. The TSS values are highest during the rising limb of the hydrograph as shown in Figure 94 below. Once the hydrograph peaks and flow begins to subside, TSS levels in the stream decrease with the reduced shear stress of the discharge.

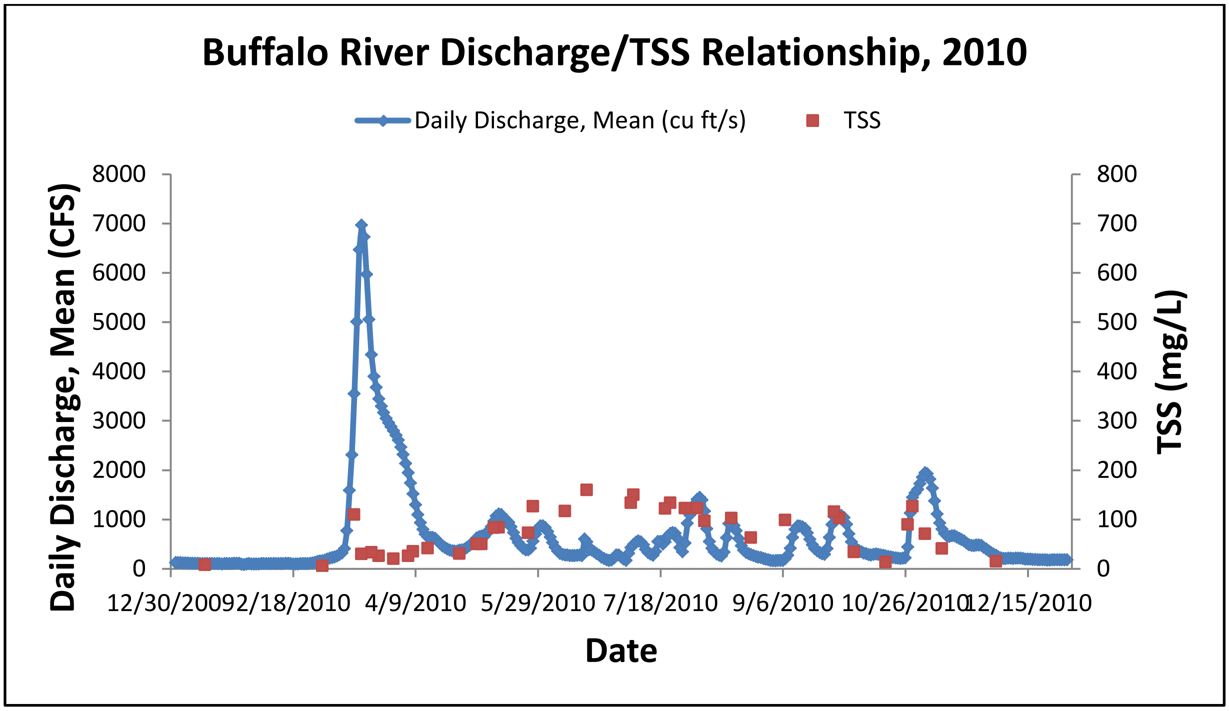


Figure 94. Buffalo River at Georgetown, Minnesota 2010 hydrograph with TSS results. Note the elevated TSS levels on the rising limb of the hydrograph compared to falling limb and base flow conditions.

Longitudinal sonde surveys were conducted on Deerhorn Creek with the YSI Water Quality Sonde equipped to measure water temperature, DO, conductivity, pH and turbidity. The survey collected YSI sonde data at each road crossings on Deerhorn Creek as well as each major tributary before the confluence with Deerhorn Creek. It should be noted that the YSI sonde uses a turbidity method that generates turbidity in FNU units. The State of Minnesota turbidity standard is 25 NTUs. The difference in FNUs and NTUs at levels near the standard is relatively insignificant for our purposes.

A longitudinal survey was conducted during base flow conditions (on May 30, 2012) as well as during an intense storm event (on June 19, 2012). The storm event put 1.35" (State of Minnesota Office of Climatology data) of rain over the watershed on June 19, 2012. The longitudinal survey took place during the afternoon while the event was still occurring and the data showed that the water quality impacts from the storm event were not across the entire watershed at the time of sampling but more centered in the upper portion of the Deerhorn Creek subwatershed.

Figure 95 shows the turbidity results of the surveys conducted in the Deerhorn Creek subwatershed. The results show that during base flow conditions all of the turbidity results fall below the 25 NTU State Standard with only two sites having the highest readings between 15 and 25 FNUs. During the storm event of June 19, 2012, turbidity levels increased significantly in the upper half of the watershed. Field notes indicate that the impact of the storm was significant from the headwaters to site Deerhorn Creek (DHC) 6 where turbidity readings ranged from 8.9 to 749 with a mean of 188 for the first seven upstream sites. Field runoff with high sediment concentrations were observed during the June 19, 2012 sample run. A sample in the headwaters of a major Deerhorn Creek tributary (upstream of DHT3) found high turbidity (920 FNUs) and low transparency (2.5 cm) as the storm runoff flowed out of an agricultural field and over a minimum maintenance road. This site is not included on Figure 95 as only the outlet sites of tributaries are included.

The survey found that from site DHC 7 through the remaining downstream sites the turbidity and transparency tube readings were at levels similar to base flow. This was due to the fact that the event was centered higher in the watershed and that impacts from the storm had not moved downstream past DHC 6 at the time of the survey.

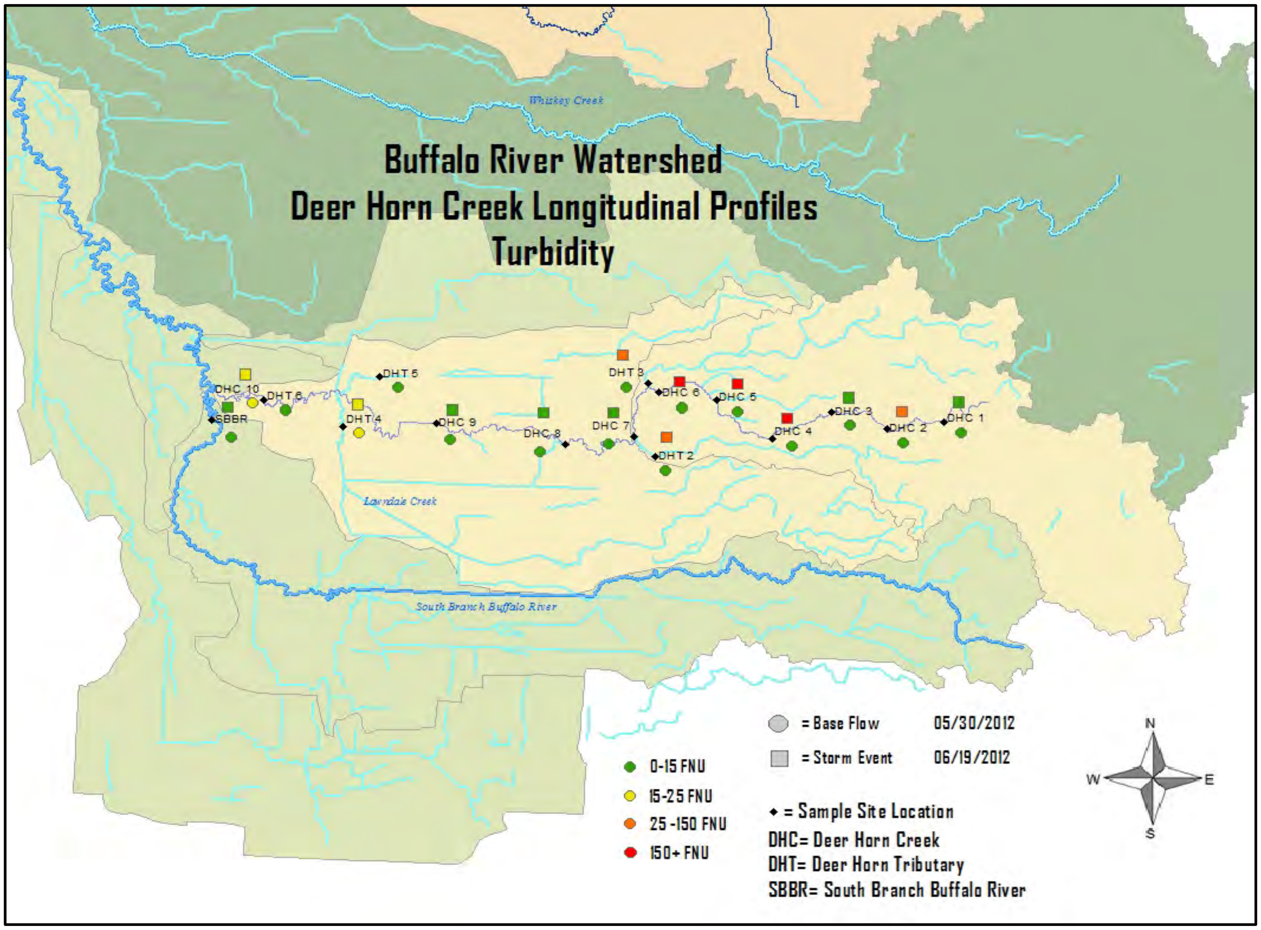


Figure 95. Longitudinal Survey results for turbidity in Deerhorn Creek.

Field reconnaissance surveys found that field sediment sources were a significant cause of turbidity and TSS in the headwater streams including Deerhorn Creek and the Upper South Branch Buffalo River. Stream Power Index ground truthing in these watersheds found numerous instances where gully erosion sent hundreds of cubic yards of soil into the receiving stream. These gullies were typically located where 1^{st} or 2^{nd} order streams were being farmed- through. These farmed-through headwater streams are prone to severe erosion as any storm event with the proper combination of intensity and duration will send a flush of water through the location of the prior stream bed and carve out a new channel in the cultivated soil. These findings tie in well to the results of the longitudinal survey turbidity results that found over a ten-fold increase in turbidity levels in some locations during storm events vs. base flow conditions.

Another source of stream sediment was discovered on a 2013 field visit. A headcut in Deerhorn Creek appears to be advancing upstream of the CSAH 52 crossing. The headcut in the channel is the result of the cleanout of sediment upstream of the Hwy 52 box culverts and this cleanout appears to have destabilized the E channel by deepening the channel and creating a nick point. This headcut has worked upstream and is causing the collapse of the channel banks immediately upstream of CSAH 52.

The TSS and macroinvertebrate relationship shown previously in Figure 88 provides data on Deerhorn Creek. The data show that the upstream bio site (09RD052) had an M-IBI score of 24 and the closest water quality station (S003-150) had a median TSS of 2 mg/L and a range of 1 to 24 mg/L TSS. The downstream bio site (09RD047) had a MIBI score of nine and the corresponding (nearest) water quality station with a median TSS of 12 mg/L and a range from 3 to 232 mg/L. This relationship, although not conclusive in and of itself, indicates that the macroinvertebrates appear to be negatively responding to higher TSS levels, as expected. This relationship also appears on this figure for the South Branch Buffalo River and Lawndale Creek.

The evidence available indicates that the Deerhorn Creek biology is being stressed by high sediment levels (measured as TSS and turbidity). TSS is considered a primary stressor on the Deerhorn Creek fish and macroinvertebrates.

Candidate Cause: Dissolved Oxygen

The assessment notes for the Deerhorn Creek DO data found that the data “exceeds criteria, potential severe impairment.” The data shows two of the 59 readings exceeded the 5.0 mg/L standard. The assessment notes indicate, *the dissolved oxygen data set is sizable but includes only one early morning measurement during summer months. Two exceedances at S003-150 are in 2002 and 2009, and are within 0.50 mg/L of the standard. Low DO conditions can't be ruled out as a stressor, especially in very low flow periods, until more early morning measurements are made during the summer months* (MPCA, 2012).

In 2012 two longitudinal sonde surveys were conducted throughout the Deerhorn Creek subwatershed. The first survey on May 30, 2012 represented base flow conditions and the second survey on June 19, 2012 was during a significant summer storm event. The event put 1.35 inches (State of Minnesota Office of Climatology data) of rain over the watershed on June 19, 2012. The longitudinal sonde survey took place during the afternoon while the event was still occurring and the data showed that the impacts from the storm event were not across the entire watershed at the time of sampling but more centered in the upper portion of the Deerhorn Creek watershed. The results of the surveys are presented in Figure 96.

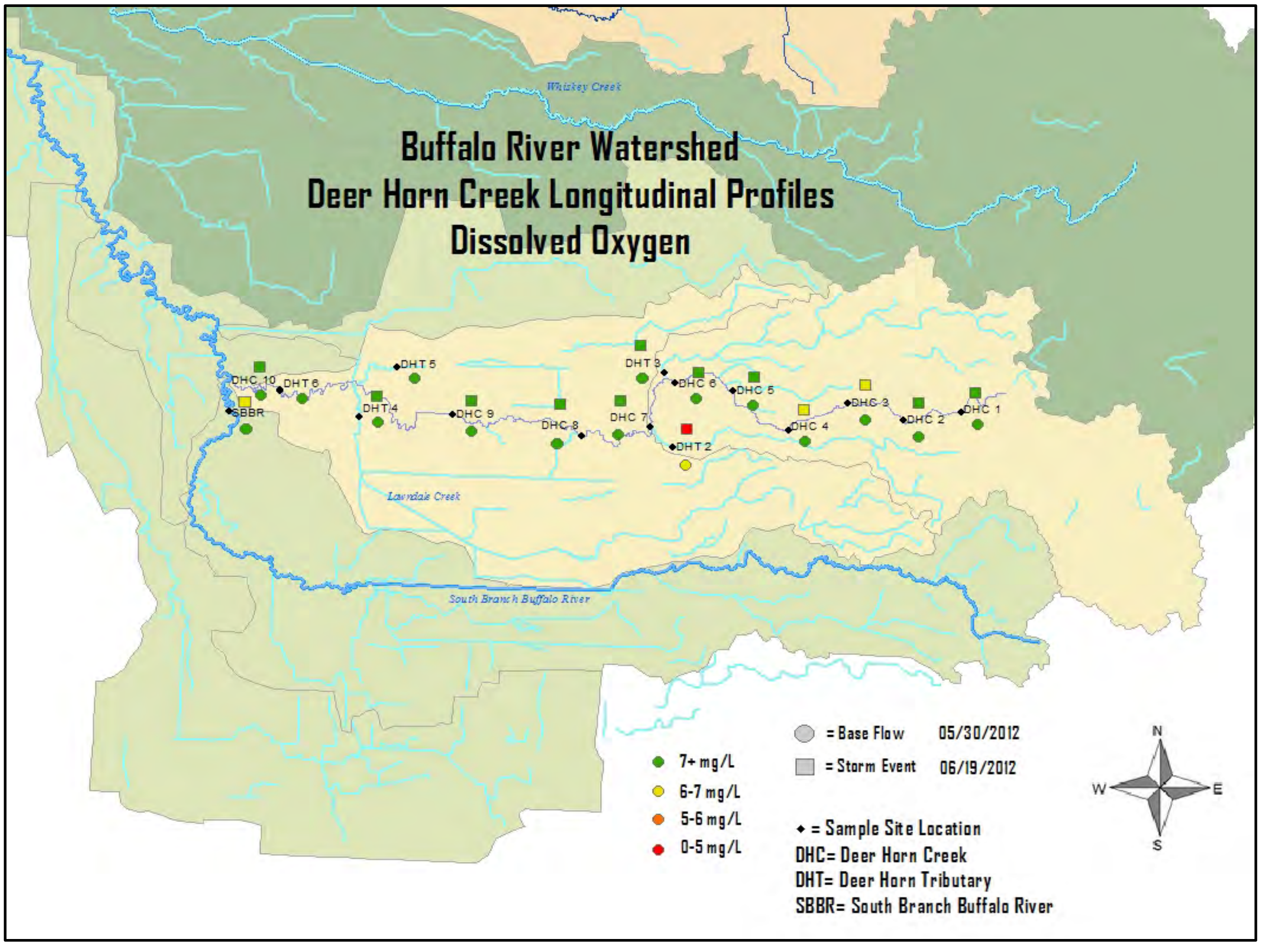


Figure 96. Deerhorn Creek longitudinal profiles dissolved oxygen results.

The results of this study found that afternoon DO levels during the base flow survey on May, 30, 2012 exceeded 7 mg/L in all but one case where the result was between 6 and 7 mg/L. Samples collected during the June 19, 2012 storm event found three of the readings between 6 and 7 mg/L DO and one below 5 mg/L. Interestingly, the site during the event that was below 5 mg/L DO was the same site during base flow conditions that was between 6 and 7 mg/L (the lowest during that sampling run). These results indicate that the runoff from the event appears to be loading the system with wastes that require oxygen for decomposition. This may be crop residue from the previous season in various stages of breakdown or dissolved organic compounds that are being flushed into the system.

The information to support DO as a primary stressor in the Deerhorn Creek subwatershed is not conclusive. Additional information such as deployed sonde data during mid to late summer would help to clarify the potential role DO levels play on the health and diversity of the aquatic biota communities. Dissolved oxygen will be listed as a secondary stressor for Deerhorn Creek at this time. Future studies should aim to better assess the role of DO as a stressor.

Candidate Cause: Connectivity

Connectivity issues exist for Deerhorn Creek due to at least two fish migration barriers that have been identified. As discussed, the most notable is on the South Branch of the Buffalo River where a sheet pile dam is located 1.7 miles west of Glyndon (about ¾ mile south of Hwy 10 and immediately downstream of the Burlington Northern Rail Road tracks). This dam, according to Dave Friedl, MNDNR (personal communication) is a significant barrier to fish migration that has the capability to affect the distribution and community structure of the upstream portions of the South Branch Buffalo River and its tributaries, including Deerhorn Creek.

Connectivity problems also exist within Deerhorn Creek as shown in Figure 97. This photo was taken at the downstream end of the box culverts under Wilkin CSAH 52. It shows that the culvert is positioned about 18 inches above the bottom of the stream and about 9 inches above the downstream water level. This perched culvert is a fish migration barrier during low to moderate flows and because of its location on the downstream portion of Deerhorn Creek it affects the fishery of both Deerhorn Creek and Lawndale Creek. There may be other fish migration barriers that have not been identified but based on the two that are discussed above, connectivity is a primary biological stressor on the Deerhorn Creek fishery.

Figure 97. Photo of Deerhorn Creek at the downstream end of box culverts under Wilkin County Hwy 52.

Conclusions

There are three biological stressors that have been identified for Deerhorn Creek. They are altered hydrology, sediment and connectivity. Dissolved oxygen cannot be ruled out and is listed as a secondary stressor as is habitat.

Spring Creek HUC 09020106534

The Spring Creek HUC-11 lies in the central portion of the Buffalo River Watershed. Spring Creek is a very small tributary of Hay Creek that flows into Stony Creek and eventually the South Branch Buffalo River. Spring Creek flows from east to west and is located about five miles north of Barnesville. The small 8.5 square mile watershed is comprised primarily of cultivated cropland with some grassland/pasture (Figure 98).

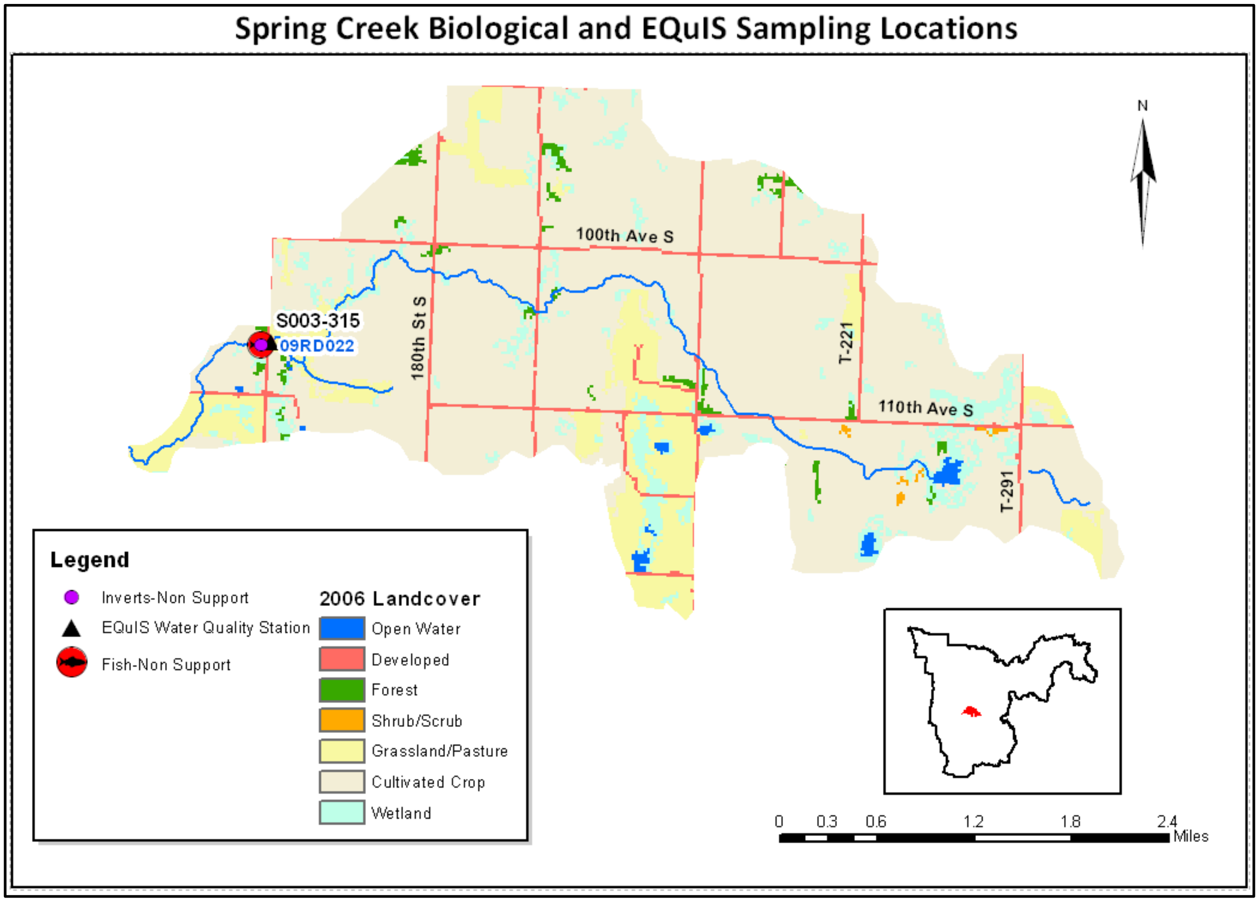


Figure 98. Landuse and site location map of Spring Creek.

Biology in Spring Creek

An assessment of the data for Spring Creek found that the data sets are generally weak and tend to leave more questions than providing answers. The Spring Creek AUID is listed for fish and macroinvertebrate impairments however each of these impairments are based on one site and one visit so the strength of the listing is supported by limited data. In addition, the monitoring site for both biology and chemistry is located only about 1/4 mile downstream of the Buffalo Red River Watershed District Project 5, Flood Water Detention Project that effects the stream hydrology during event flows and likely has an impact on the biology and chemistry of the downstream monitoring site. The assessment notes question how well the monitoring location that is positioned below this on channel, dry impoundment can represent the remaining 90% of the watershed that is situated upstream of the impoundment. The notes state “that turbidity and DO datasets do not provide indication of stressful conditions, however there are questions about how well this station location represents the entire AUID due to structural modifications upstream (Buffalo-Red Project #5)”. In addition, the assessment notes mentions, "the dissolved oxygen data set contains only one early morning summer measurement, which is inadequate for assessing oxygen conditions during low flow warm temperatures. The small NO_2NO_3 data set contains a high rate of exceedances of the ecoregion expectation". Regarding turbidity, the notes state, "the turbidity data set shows consistently good transparency conditions over most of the assessment period and the transparency tube data set reinforces this. There appears to be an artificial structure of some sort about 1/4 mile upstream that may be helping to drop out suspended sediments at the monitoring point" (MPCA, 2012).

This information indicates that there is a high likelihood that the monitoring data for chemistry and biology are impacted from the floodwater impoundment project located immediately upstream of the monitoring site. Due to the likely bias of these results, it is decided that a full assessment of stressors for Spring Creek is not warranted until additional data gathered from above this impoundment is collected and assessed during the next cycle of monitoring. An assessment of connectivity as a stressor is provided below.

Candidate Cause: Connectivity

Connectivity has been identified as a stressor for Spring Creek based on at least two fish migration barriers that have been identified. The most notable is on the South Branch Buffalo River where a sheet pile dam is located 1.7 miles west of Glyndon (about ¾ mile south of Hwy 10 and immediately downstream of the Burlington Northern Rail Road tracks). In addition, a control structure on Spring Creek that is part of Buffalo - Red Project No. 5 (a.k.a. the Henry Detention) likely acts as a migration barrier for fish during some water levels according to Erik Jones of Houston Engineering. This project (Figure 99) is an active flood management impoundment and drains through an un-gated pipe. Based on this information, the quality of the Spring Creek fishery is being limited by connectivity issues.

Figure 99. Aerial photo of the Buffalo Red River Watershed District Project 5, Flood Water Detention Project.

Conclusions

Spring Creek is being impacted from a loss of connectivity by at least two artificial dam structures that act to restrict fish migration. The remainder of the assessment for stressors has been delayed until additional data is generated that avoids bias from the on-channel flood water detention project and better reflects the condition of the stream that is primarily located upstream of this detention basin. Although the fish data above this structure may likely be impacted from the effects of the loss of connectivity of the dam, the data will better reflect the conditions of the fishery and represent the vast majority of the watershed that is upstream of the impoundment.

The majority of the stream (82%) was found to be natural without the modified habitat characteristics that are consistent with channelization. An aerial assessment of the watershed (2010 and 2011 aerial photos) found that to a large extent the stream was relatively well buffered from adjacent row crop agriculture. The stream appears to have remnant natural storage in the upper watershed that could be augmented with the restoration of many partially drained wetland basins. It is recommended that the areas with good riparian buffers be protected and that future efforts to add to this riparian buffer protection be considered along with the restoration of watershed wetlands.

Conclusions and General Recommendations

The Buffalo River Watershed has been studied to determine the factors that are affecting the four biologically impaired reaches. The stressors that were identified as candidate causes include: altered hydrology, habitat, sediment, connectivity, DO, phosphorus, nitrate nitrogen and pesticides. Nitrate and phosphorus, although elevated above ecoregion expectations, were not found to be stressing the biology within the Buffalo River Watershed, although concern has been expressed that the continuation of agricultural tiling will very likely result in increased nitrate levels above the 1 mg/L level where impacts to the more sensitive organisms are likely to begin. Pesticide levels in the Buffalo River Watershed, especially levels of Chlorpyrifos are also a concern. Impacts from this highly toxic pesticide may be taking place within this watershed due to its broad scale use, an apparent need for additional user education, and toxicity at very low levels, however no work has been done to specifically look for these impacts.

The stressors found to be affecting the biology are summarized in Table 14. Primary stressors are those that are determined to be most directly impacting the health and diversity of the biota. Secondary stressors are those that are having an impact but those impacts are at least partially overshadowed by the impact of the primary stressor. In terms of implementation, addressing the primary stressors has more relative importance to the recovery of the biology, based on the interpretation of the data.

Table 14. Summary of Stressors to the biological community.

Reach	Reach Name	Biotic Impairments	Primary (X) and Secondary (*) Stressors to the Biological Community				
			Dissolved Oxygen	Turbidity/ Sediment	Connectivity	Altered Hydrology	Habitat
09020106-593	Upper Buffalo River	F-IBI & M-IBI		*	X	*	*
09020106-505	South Branch Buffalo River	M-IBI	*	X		X	X
09020106-507	Deerhorn Creek	F-IBI & M-IBI	*	X	X	X	*
09020106-534	Spring Creek	F-IBI & M-IBI			X	X	

The evidence indicates **altered hydrology** is a stressor to the biotic communities throughout the impaired areas of the Buffalo River Watershed. Hydrology is foundational to the streams and rivers well-being and when it is perturbed many other stream characteristics which are influenced or reliant on hydrology; such as habitat and sediment, will also be affected. The landuse in the Buffalo River Watershed is dominated by agriculture and the drainage inherent with agriculture is the single most influential factor contributing to altered hydrology. The increase in peak discharge and corresponding decrease in base flow is not conducive to healthy stream biology and is a major factor in the destabilization of stream channels, loss of habitat, and increased turbidity and sedimentation. This single stressor can be considered the major driver causing the impaired biological health within this system.

Flow information is relatively weak within this watershed with only a few long-term stations. Flow stations developed during the past five years on the major tributaries and further upstream on the mainstem and South Branch Buffalo River will provide better hydrologic definition for future studies, especially if these sites can remain funded and operated.

The riparian corridor is a pathway for stressors or a buffer from stressors depending on its condition. Healthy vegetated corridors are able to resist changes in channel stability more easily than those areas without vegetation protection, due to the “roughness” that healthy riparian vegetation provides both in terms of above ground plant biomass as well as deep and dense root systems. Restoration is needed in areas of limited riparian corridor width and protection is needed for areas with healthy riparian corridors. The stream power index field ground truthing performed in the South Branch and Whisky Creek watersheds provides strong evidence linking the importance of vegetated stream corridors to the protection of stream channels.

Dissolved oxygen can be influenced by nutrient levels, water source, altered hydrology, temperature, and habitat characteristics. Altered hydrology in the Buffalo River Watershed is perhaps the main driver of low DO as base flow rates are reduced as a result of intensive drainage. Lower summer flow rates combined with peak summer water temperatures in July and August typically produces the annual minimum DO concentrations in this system. Low DO levels along with the diurnal range in DO change (or flux) contribute to the stress on the aquatic biology. Low DO concentrations in the South Branch Buffalo River and Deerhorn Creek have resulted in DO being identified as a secondary stressor. There needs to be additional data collection in the form of continuous sonde deployment to better characterize the severity and extent of the problem in both of these reaches. Addressing altered hydrology may be the best strategy for improving DO conditions in these watersheds.

Runoff and drainage from agricultural land is the primary source of nutrients to lakes and streams in the Buffalo River Watershed. **Phosphorus** and **nitrate** levels exceed ecoregion expectations although their impact to stream aquatic biota was not significant given the severity of the impacts from other stressors, namely altered hydrology and connectivity. The modeling component of the Watershed Restoration and Protection Strategy (WRAPS) will provide further information on sources of these nutrients and guide restoration and protection actions to the best locations. It is important to note that the increase of agricultural groundwater tiling within the Buffalo River Watershed is reason for concern. The discharge of subsurface drainage from tiling is known to significantly increase stream nitrate levels (MPCA, 2013). It is recommended that future monitoring of stream water quality include the analysis for nitrates as levels are expected to increase, proportional to tiling density, throughout this watershed.

Turbidity (Sediment/TSS) is inherent to the lake plain portions of the Buffalo River Watershed due to the very fine sediment size of clays and silts. Turbidity levels and sediment loads within this watershed are in a large part tied to three primary factors. First, farming through the headwater (1^{st} and 2^{nd} order) stream channels provides for excessive gully erosion during precipitation or snowmelt events that are of an intensity to provide concentrated flow to the historic stream channels. This sediment flows downstream into the next receiving stream and contributes sediment/turbidity to the system. Secondly, field erosion contributes sediment supply and its importance in the overall sediment supply for any given reach can be estimated using the HSPF or SWAT model. Conservation tillage (where applied) can do a relatively good job of reducing overland or sheet erosion in many situations. The third source of sediment is from stream banks and beds and this is driven by altered hydrology and specifically increased peak flow rates that drive the destabilization of stream channels. Poor riparian cover is a factor that can exacerbate this problem. Bank erosion rates are provided for specific study areas in the Buffalo River Watershed as outlined in the Geomorphic Study section of this report.

Turbidity/sediment was found to be a primary stressor in the Deerhorn Creek and South Branch Buffalo River and a secondary stressor in the Buffalo River - Headwaters Reach. Basin and watershed efforts to reduce peak flow rates through adding off-channel storage should have a positive impact on reducing stream channel erosion rates.

Lack of connectivity was determined to be a primary stressor in the Upper Buffalo, Deerhorn Creek and Spring Creek subwatersheds. The removal of barriers to fish migration can result in immediate positive changes to the diversity and biomass and can improve the overall health of a fishery by providing access to needed habitat types.

The priority dam for removal in the watershed is the sheet pile dam located on the South Branch Buffalo River 1.7 miles west of Glyndon on the south side of U.S. Highway 10. Removal of this structure is perhaps the single most important action in this watershed for improving the biological health of the system. As previously discussed, this dam affects three of the four biologically impaired reaches in the Buffalo River Watershed and its removal would provide access for fish from the Red River into roughly 50% of the Buffalo River that is currently obstructed by this dam. Local MDNR expertise and experience in the field of dam removal should help to insure a cost-effective and successful outcome.

Habitat scores were generally fair to poor throughout the Buffalo River Watershed although the only impaired reach that had habitat as a primary stressor was the South Branch Buffalo River. It is considered a secondary stressor in the Upper Buffalo River and Deerhorn Creek. Habitat metric scores within the impaired reaches were generally low in landuse, substrate, and channel morphology and average in riparian and fish cover. Stream hydrology is a critical component and driver of habitat. Habitat quality is, in part, a response to the hydrology acting upon the channel and the sediment yield from the watershed and stream channel. Altered hydrology is in effect a habitat issue as aquatic organisms have developed their life cycles based on a natural hydrograph vs. the flashy hydrograph that results from intensive drainage.

Transitioning From Stressor ID to Implementation - Considerations for Protection and Restoration

This section is provided to assist in the transition from the stressor identification process to the implementation process. It offers information and suggestions to those who are charged with developing the implementation plan in order to support the promotion of effective strategies for restoring biological health to the river system. Information gained through the research, field investigation and data crunching aspects of stressor identification can provide useful insight into the relationships between land use and stream ecology. This information can help the project to focus on the types of protection and restoration work that is necessary as well as help direct the appropriate implementation activities to the correct locations in order to generate the best environmental results for the dollar invested in the resource.

Figure 100. Maintaining adequate riparian buffers on streams and wetlands is critical to the health of the aquatic biology.

Setting Realistic Goals and Expectations

It is important to note that the conclusions within this report resulting from the study of this watershed were based on the conditions present when the biological surveys and watershed data were collected. If these conditions were unchanging, one could expect to restore the health of the biological communities through a concerted effort to implement effective practices that are targeted on priority management areas. One of the primary concerns is that the condition of this watershed is in a state of continued ongoing hydrologic, physical, chemical, climatic and biological change. The factors contributing to this change include; the accelerated rate of tile drainage, the continued loss of wetlands and watershed storage, more intensive agricultural landuse with the resultant loss of conservation practices and set-side lands, an increasing threat from invasive species, and changing climatic conditions that are predicted to result in higher intensity and more frequent large precipitation events. These factors point toward a river system under increasing physical, biological and chemical stress.

The loss of set a side (CRP, CCRP, etc.) land to cultivation is of primary concern. Land enrolled in CRP is typically the more sensitive land within the watershed. Steep slopes, highly erodible soil, wetland, stream and lake riparian fringe and floodplain are the types of land that were preferred for enrollment. Many landowners enrolled into these programs in order to protect surface water from sedimentation, keep hill slopes from further erosion, and to generate steady income from marginal land that produced crops on an inconsistent basis (often unable to plant in the spring due to moisture or summer flooding of crops). High commodity prices, the aggressive use of tile, along with high land rental rates has resulted in many of these sensitive areas being worked up for crop production. The desire to farm as much as possible is demonstrated by Figure 101 that shows cultivation and crop production within the gravel on the shoulder of a township road within the Buffalo River Watershed.

Figure 101. Example of row crop planted within the gravel shoulder of a township road.

These factors suggest that rather than to realistically restore the biological communities in these impaired reaches at this time it may be more realistic to maintain the existing condition of the resource. This isn't meant to discourage the aggressive implementation of practices for the better but rather to understand the consequences of the intensification of agriculture, spread of invasive species and climate change and to set realistic goals and expectations for the protection and restoration work. It's also is a heads-up to those who will be charged with designing and implementing restoration and protection that protection of those critical, sensitive areas has never been more important.

SWCD Knowledge, Experience, and Perspectives

A brief survey was conducted of the four SWCD offices that have jurisdiction within the Buffalo River Watershed (Figure 102). These offices house the resource managers that have the best on-the-ground knowledge and experience regarding the condition of the resource, BMP effectiveness and acceptance, and landowner attitudes toward conservation. An eight question survey was provided to each office that asked questions that were designed to gather a snapshot of office perspectives in regards to resource condition, BMP effectiveness and use, and landowner attitudes (Table 15). This information can be used to look for general trends as well as differences that may be due to geophysical region or local priorities.

Figure 102. Location of SWCD/County boundaries as related to survey responses.

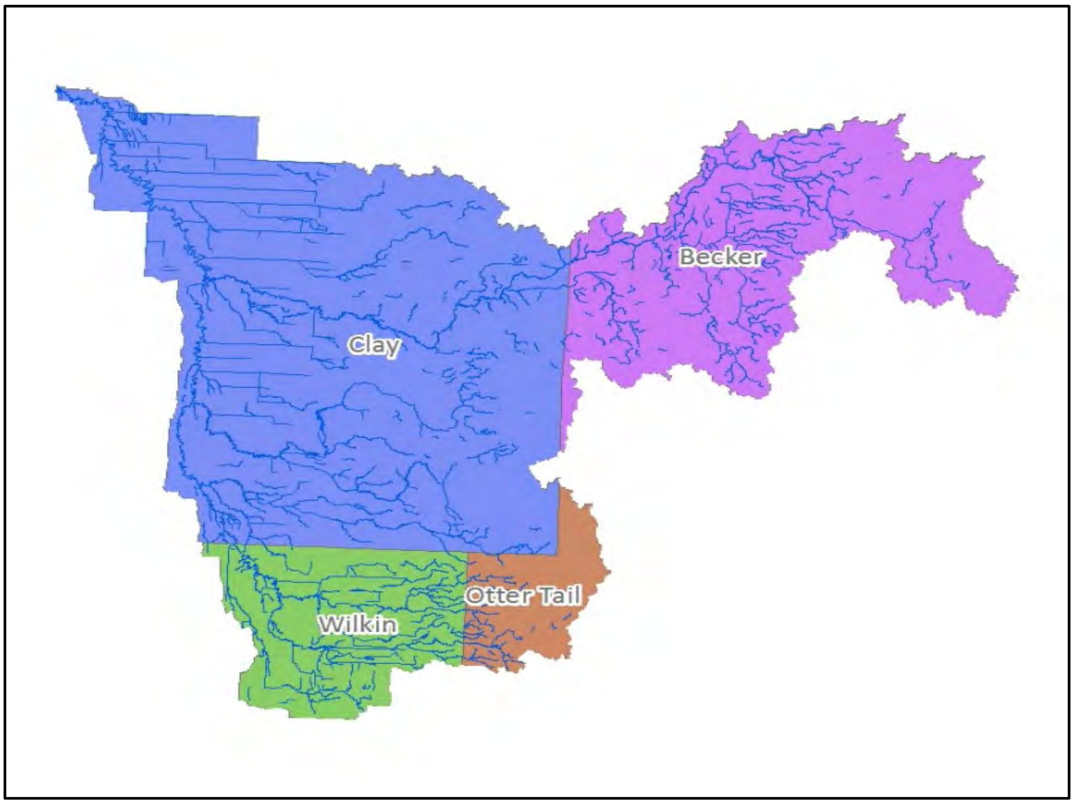


Table 15. Results of SWCD Office perspectives in regards to resource condition, BMP effectiveness and use, and landowner attitudes.

Question	Clay County	Wilkin County	Becker County	Otter Tail County
1. What are the most common problems you see in the field that result in degraded water quality? Are these problems broad across the watershed or localized?	Farming close to watercourses; wind erosion (after spring tillage); water (sheet) erosion from flood events causing turbidity issues; the loss of CRP acres. The problems are found throughout the watershed.	NPS broad scale across county. Outlets of tiled fields and field ditch outlets. Wind erosion more significant than water. Sediment washes out of low spots with storm events. Not a lot of livestock – less significant. Controlled outlets for tile line lines helps with nitrates. BWSR grant to install tile outlets.	The primary problem is soil erosion & sediment deposition. Field observations in the Becker County portion of the watershed would indicate the problem area is in the transition area west of U.S. Highway 59.	Water erosion i.e. gullies due to lack of residue management. Loss of conservation acres i.e. CRP. The problems are found throughout the watershed
2. What geographical areas within the Buffalo River Watershed do you feel are in the worst ecological condition? This could be answered as part of a township or a reach of a stream.	Stream bank slumping occurs from east (Hawley area) to west (Kragnes area). Whiskey Creek is a focal point at the present. The eastern edge of the county (area of highest elevation) has a need for water and sediment control basins.	The listed systems in TMDL.	Again we would refer to the transition area, which tends to have a rolling topography that is intensely farmed.	Areas with steeper highly erodible slopes & larger sub-watersheds throughout the entire watershed.
3. What areas do you feel are currently in great condition & that should be protected? These are either pristine areas or areas that would cause major problems if they were allowed to be developed more intensely.	Virgin ground in the Beach Ridge areas of the county. This area is home to numerous threatened/endangered/special concern species. The region is rich in gravel resources which raises concerns when it comes to “preserving” these areas. The light soils in this area are generally good candidates for conservation program (i.e. CRP) enrollment. Present farm commodity prices are enticing	Lawndale is very good. Manston Slough area where there are concentrations of wetland & prairie. Headwater areas are in better shape.	For broad discussion the watershed areas east of U.S. Highway 59 are in fairly good condition & have less impact’s from agricultural practices. More pasture areas are present & these should be maintained.	Areas enrolled in conservation programs immediately adjacent to the water bodies.

Question	Clay County	Wilkin County	Becker County	Otter Tail County
	landowners to cancel contracts or break-up sensitive lands.			
4. What BMPs do you feel are benefitting or would most benefit water quality & stream biology?	Streambank Restorations, Riparian Buffer Strips, Filter Strips, Water and Sediment Control Basins, Side Inlets, Bio-Filters (on new & existing drain tile systems).	Side inlets, water control structure, weirs/jetties, buffers and cover crops – barley in sugar beets 1/3 bushel per acre. Sprayed after it gets up - prevents wind erosion. Reduced tillage & windbreaks.	Buffers, more pastures, reduced tillage, installation of grassed waterways, sediment & erosion control basins.	Water & sediment control basins, reduced tillage, filter strips, stream bank stabilization.
5. Which BMPs do you see as least useful in protecting stream water quality/biology in your area & why?	None (terraces were mentioned due to the fact (as a rule) they are not very applicable to Clay County's landscape).	Low areas?	Nutrient & pest management; it's our opinion that they are not being over applied. If proper land treatments are applied (i.e. buffers, grassed waterways, etc.) the risk of nutrient loading is reduced even more.	None
6. What are the barriers to implementing practices on the land for both protection & restoration?	Permanency of some programs; lack of program funding; bureaucracy; major landowner investment to become eligible; non-competitive rental rates.	If a landowner is committed to doing BMPs we have the programs to do it. Some need to be approached more than once to keep them up to date with the new funding numbers. Once the farmers see that BMPs are most everywhere except in their field, they can have a change of heart.	Unwillingness of operators to install conservation measures on land they do not own. High commodity prices.	High commodity prices.
7. What do you perceive as the prevailing landowner attitudes toward conservation at this time?	Too many rules! Not competitive!	Low areas that they can't get crops off, they are putting buffers in – can't tile wetland areas so they are buffers.	Fairly good when a conservation practice will benefit the farming operation. If a landowner can eliminate a gully and be able to farm through it he is more likely to install a water	Not good, commodity prices outweigh conservation value.

Question	Clay County	Wilkin County	Becker County	Otter Tail County
			and sediment control basin. It is more difficult to sell practices that take cropland out of production (i.e. installing a buffer next to a lake or watercourse).	
8. What are your current strategies to address the issues?		Water control structure, dike, into ditch systems to help drop out sediment and prevent head cuts. Line of rock across ditch, level about 1 foot of elevation. Worked with Luther on the Wolverton Creek Comstock coulee to install rock weirs, jetties. Flap gates on side inlets to drop sediment & nutrients. FDR benefit because of large system scale work. Comstock Coulee is about 75% buffered. Lawndale is about 80% protected.	Providing additional incentive payments for the life of the practice in high priority areas (as funding allows). When landowners in priority areas are willing to adopt all of the applicable or recommended BMPs at little to no cost, & receive additional incentives - adoption increases.	Work with our partners and watershed district to seek funding for promotion & installation of conservation programs in the watershed. Increased cost share on construction projects & incentive payments on CRP.

Implementation Discussion

This section is provided to give the SWCD technicians and engineers some "food for thought" as they begin to look for protection and restoration opportunities within the impaired watersheds they decide to focus on. It provides some ideas and is not meant to be a prescription to cure the biology of the impaired watersheds. The various sections list out some concepts, ideas and provide some tools for consideration during the early project planning stage, through design and grant writing phases. These concepts, ideas and tools are focused on the goal of reducing the impact of the identified stressors.

Protection

Protection of existing natural resource assets should be a high priority in any resource enhancement project. When comparing the time, energy and money required to protect a key feature vs. restoring it, there is no doubt that protection represents the most efficient use of public funding. In theory, for every piece of buffer or wetland lost, an equal amount of buffer or wetland must be restored just to keep even. So without a strong protection effort (during a time when pressure on the resource is high) we could be simply replacing the loss we are experiencing and just staying even. In this age of "plant it all" one shouldn't assume that anything is safe. When a plan is being prepared for a landowner some time could be spent identifying the riparian area buffers, wetlands, steep slopes, etc. that are currently in a vegetated condition (grass, shrub or trees) and make sure they are labeled for protection. That done, one can focus on those same types of areas that may be candidates for restoration.

Altered hydrology is the driver of two major stressors in the Buffalo River Watershed, sediment and habitat. In order to address this stressor there are efforts needed at the large and small scale. Watershed districts throughout the Red River Basin are planning and building flood water storage projects and these projects will help with the volume aspect needed to reduce peak flows on the HUC-8 mainstem streams and in the Red River. For the impaired reaches of this study, smaller scale storage will need consideration. In regards to protection of the existing hydrology, this means trying to save the wetlands that remain and the groundwater storage that remains. In addition, protecting stable streams and stable ditches from disturbance is important.

Protection of the existing vegetated riparian areas, floodplains, grassed waterways, erodible slopes, wetlands, shrub and forested areas are important as the pressure is high to convert land that can support crop production. Of primary importance are those areas adjacent to and connected to the stream system – the riparian zone. As discussed in the Stream Power Index (SPI) portion of this report, the presence of perennial vegetation on areas with the high potential for erosion is of utmost importance. The SPI ground truthing showed a strong positive correlation between the lack of well vegetated ditch and stream corridors to the presence of head cuts and the more advanced erosion of gullies. Maintaining ample buffer widths on these features is crucial to the hydrology, sediment and habitat concerns and can assist with nutrient removal as well.

The SPI field ground truthing results for the South Branch Buffalo River and Whisky Creek provide a great starting point in those subwatersheds for protection and restoration. A detailed list of the results of this work which point to specific areas that need protection to avoid significant gully erosion as well as areas where various cases of erosion were discovered can be obtained by contacting the author and via the MPCA website (the chart is too large to print in this document). The table is titled, "SPI Reconn Results Table Whisky and S Br Buffalo 011714.xlsx, wq-ws5-09020106a". It is designed to locate the area of the observation, describe the environmental conditions present, identify the biotic stressors observed and provide suggestions for BMPs that should reduce the stress on the stream biology. The information is directly applicable to restoration and protection activities, and for applying for clean water funds for best management practices, especially when coupled with appropriate prioritization systems (as they are developed) for the Buffalo River Watershed.

The importance of riparian buffers in areas with sloped topography cannot be overstated. While conducting the SPI field work on the Whisky Creek subwatershed upstream of Barnesville it became very clear that the land management decisions that each landowner makes is of great importance to the health of the stream. Sites with high SPI scores that were not adequately protected had erosion present in the form of headcuts, channel incision and gullies. Sites with similar erosion potential (high SPI scores) that had adequate riparian protection were stable and without erosion. The SPI tool is useful for gauging the potential for erosion and can be used as a guide to inform landowners about the potential for erosion on land they manage and to help prioritize sites for cost-share assistance.

Restoration

Restoring critical natural landscape features/assets are an important component to restoring the biological integrity of an impaired stream reach. It is recommended that efforts to restore hydrology be considered a high priority due to its importance in impacting the health of the system. Reducing peak flow rates will help reduce in-stream erosion and allow for the recovery of bank stabilizing riparian vegetation, as long as riparian buffer widths are sufficient. Consideration must be given to whether efforts will be focused on treating the symptoms of altered hydrology (eroded stream bank channels) verses treating the cause of the channel instability, the loss of watershed storage and increased peak flow rates. Problem erosion sites that threaten buildings or road infrastructure typically get the bulk of attention because they are visible and represent a need for action however spending too much time, energy and money on stream bank repair can be a never ending struggle if the root cause of altered hydrology isn’t addressed.

Wetland restoration or water impoundments (off-channel) that add storage are an important strategy to reduce peak flow rates for the purposes of restoring hydrology to the system. Any wetland, large or small that discharges to the stream system should contribute to reducing peak flows in most years when restored, although wetlands can vary in the functions they provide in relation to surface and ground water. In general, larger wetlands tend to provide more storage however restoring smaller basins or a complex of smaller wetlands should not be overlooked. In addition, headwater wetlands fed by intermittent stream flow may tend to provide more storage than wetlands farther downstream with larger contributing watersheds. The goal of reducing peak flow rates will require the cumulative effect of the protection of existing storage with the addition of wetland restorations in the subwatershed of focus. It is suggested that a “start upstream and work downstream” approach be considered rather than “shot-gunning” storage throughout a larger area. By starting upstream the project can build success, and gain the benefits and practical experience in a smaller area that can be used to work downstream in a strategic manner. The cumulative impact of these watershed changes can be simulated through the use of the HSPF and or SWAT models and this can help one understand the predicted outcome of implementation efforts on the ground.

The fish and macroinvertebrate IBI results in some headwater streams within the South Branch Buffalo River provide evidence that it is possible to have ditch systems that support good habitat and strong biological communities. An important feature of these healthy ditches is the base flow that keeps the ditches supplied with flow during the low flow seasons of mid to late summer and through the winter. Restoring water storage back into the watershed can help build back shallow groundwater reserves that are needed to provide base flow during periods of low-flow. Base flow provides important habitat that is often lost with intensive drainage and mitigating it will be important for restoring the affected/stressed aquatic biota in this system. Water storage impoundments that have a slow release (trickle tube) for a portion of the storage can be designed to augment base-flow where and when needed.

Building water storage back into the watershed is a process that can include many strategies. Although capturing and holding precipitation runoff on the land within wetlands or other water retention is needed, many of the other BMPs can contribute by slowing runoff rates that allow for evaporation, plant uptake and groundwater infiltration. Landowners who don't have a practical wetland restoration on the land they manage can help to restore hydrology with other BMPs that influence altered hydrology in a positive way. These BMPs include but aren't limited to upland buffers, grassed waterways, sediment basins, restoring floodplain function, controlled tile outlets and expanding or restoring riparian buffers. The alternatives for restoring hydrology as well as treating the other stressors are presented in Table 16.

A guidance tool (Table 16) has been developed for this project to assist in the selection of BMPs based on the specific stressors that have been identified. The Biological Stressor and BMP Relationship Guide provide a list of the BMPs that act to reduce the impact of the stressor on the biology. This table is developed to assist resource managers and landowners working on watershed projects to identify the specific BMPs that are known to positively affect the identified stressor(s). The table is intended for use following the completion of the stressor identification process so that implementation aimed at addressing a stressor can be focused on the BMP or combination of BMPs that are best suited to reduce the impacts from the known stressor.

This chart is for general guidance purposes and should always be used in conjunction with a good understanding of the onsite conditions (soils, slopes, landuse, hydrology, etc.). The selection of BMPs for implementation on a specific parcel must work in conjunction with how the land is operated and meet landowner approval. A comprehensive list of BMP alternatives can expand the options from which to choose and allow the resource manager and landowner to select the best alternatives for the given situation. BMPs must be properly located, designed, implemented/constructed and maintained in order to be effective. Note: At the time of this report printing, Table 16 is still in draft form. Please contact the author to get the most current version for use.

Table 16. Biological Stressor and BMP Relationships Guide.

<table>
<tr><th colspan="18">AQUATIC BIOLOGICAL STRESSOR & BMP RELATIONSHIP GUIDE</th></tr>
<tr><th rowspan="4">Land Use Type</th><th rowspan="4">Treatment Group</th><th rowspan="4">BMPs</th><th colspan="15">AQUATIC BIOLOGICAL STRESSORS</th></tr>
<tr><th colspan="6">Physical</th><th colspan="6">Chemical</th><th colspan="3">Toxic</th></tr>
<tr><th rowspan="2">Altered Hydrology</th><th rowspan="2">Habitat</th><th rowspan="2">Turbidity/ Sediment</th><th rowspan="2">Connectivity</th><th rowspan="2">Thermal Loading</th><th rowspan="2">Conductivity</th><th colspan="4">Nutrients</th><th rowspan="2">Chloride</th><th rowspan="2">Dissolved Oxygen</th><th rowspan="2">Pesticides</th><th rowspan="2">Metals</th><th rowspan="2">Oil & Grease</th></tr>
<tr><th>Phosphorus</th><th>Soluble Phosphorus</th><th>Nitrogen Nitrates</th><th>Nitrogen Ammonia</th></tr>
<tr><td rowspan="18">Agricultural</td><td rowspan="3">Training & Regulation</td><td>Ditch Set-back Ordinance</td><td></td><td></td><td>|</td><td></td><td></td><td></td><td>|</td><td></td><td></td><td></td><td></td><td>|</td><td></td><td></td><td></td></tr>
<tr><td>Restricted Use Pesticide Training</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>Controlled Tile Ordinance</td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="13">Pollution Prevention - Source Controls</td><td>Conservation Cover</td><td></td><td>|</td><td>| [1]</td><td></td><td></td><td></td><td>| [1]</td><td></td><td>| [1]</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Conservation Crop Rotation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>| [1]</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Contour Farming</td><td></td><td></td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>Cover Crops</td><td></td><td></td><td>|</td><td></td><td></td><td></td><td>|</td><td></td><td>| [1]</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Grade Stabilization</td><td>|</td><td></td><td>|</td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Terrace</td><td></td><td></td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>Grassed Waterways</td><td>|</td><td></td><td>| [1]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>| [1]</td><td></td><td></td></tr>
<tr><td>Grade Stabilization @ Side Inlets</td><td></td><td></td><td>|</td><td></td><td></td><td></td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Two Stage Ditch Design</td><td>|</td><td>|</td><td>| [1]</td><td></td><td>|</td><td></td><td>|</td><td></td><td>| [1]</td><td></td><td></td><td>|</td><td></td><td></td><td></td></tr>
<tr><td>Contour Strip-cropping</td><td></td><td></td><td>|</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Conservation Tillage</td><td></td><td></td><td>| [1]</td><td></td><td></td><td></td><td>| [1]</td><td>| [1]</td><td>| [1]</td><td></td><td></td><td></td><td>|</td><td></td><td></td></tr>
<tr><td>Nutrient Management</td><td></td><td></td><td>| [1]</td><td></td><td></td><td></td><td>| [1]</td><td>| [1]</td><td>| [1]</td><td>| [1]</td><td></td><td>|</td><td></td><td></td><td></td></tr>
<tr><td>Pest Management</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>| [1]</td><td></td><td></td></tr>
<tr><td rowspan="2">Filtration</td><td>Filter Strips & Field Borders</td><td></td><td>|</td><td>| [1]</td><td></td><td>|</td><td></td><td>| [1]</td><td>| [1]</td><td>| [1]</td><td>| [1]</td><td></td><td></td><td>| [1]</td><td></td><td></td></tr>
<tr><td>Contour Buffer Strips</td><td></td><td>|</td><td>| [1]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>| [1]</td><td></td><td></td></tr>
</table>

	Infiltration	Alternative Tile Intakes	✓		✓[1]			✓	✓[1]	✓[1]							
		Tile System Design	✓					✓			✓[1]						
		Controlled Drainage	✓			✓		✓	✓[1]	✓[1]	✓[1]						
		Irrigation Management			✓				✓		✓				✓		
	Settling	Water and Sediment Control Basin	✓		✓					✓							
		Culvert Sizing/Road Retention/Culvert Downsizing	✓		✓												
		Sediment Basin			✓				✓		✓	✓			✓		
	Nutrient Removal	Constructed (Treatment) Wetlands	✓	✓	✓[1]				✓[1]		✓	✓[7]		✓[1]		✓[7]	
		Wetland Restoration	✓	✓	✓[1]				✓[1]		✓[1]	✓[7]			✓	✓[7]	
		Woodchip Bioreactor (Denitrification Beds)							✓[1]	✓[1]	✓[1]				✓[1]		
	Livestock Management	Feedlot Wastewater Filter Strip			✓[1]			✓	✓[1]	✓[1]	✓[1]						
		Feedlot Clean Water Diversion	✓		✓[1]			✓	✓[1]	✓[1]	✓[1]						
		Rotational Grazing			✓				✓	✓	✓	✓					
		Livestock Exclusion/Fencing		✓	✓				✓	✓	✓	✓					
		Waste Storage Facility							✓		✓[1]	✓					
Riverine	Vegetative Cover	Streambank Protection	✓	✓	✓												
		Streambank Stabilization with Vegetation	✓[7]	✓[7]	✓[6,7]		✓[7]		✓[6]	✓[6]	✓[6]	✓[7]		✓[7]			
		Re-establish Riparian Trees & Brush	✓[7]	✓[7]	✓[7]		✓[7]					✓[7]		✓[7]		✓[7]	
		Riparian & Channel Vegetation		✓	✓				✓		✓						
	In - Channel Restoration	Retrofit Dams with Multilevel Intakes					✓[7]										
		Grade Control / Drop Structures	✓[7]	✓[7]	✓[7]							✓[7]		✓[7]			
		Dam Removal	✓[5]		✓[7]	✓[5]	✓							✓[5]			
		Restore Riffle Substrate		✓[7]	✓[7]							✓[7]		✓[7]			
		Restore Natural Stream Meander and Complexity	✓[7]											✓[7]			
		Alter Dam Operation to Mimic Natural Conditions	✓[7]	✓[7]													
		Two Stage Ditch	✓	✓	✓[1]		✓		✓		✓[1]						
		Proper Culvert Sizing or Replace with Bridge	✓	✓	✓	✓											
		Reset Culverts @ Proper Elevation	✓			✓[1]											

Urban	Training & Regulation	Erosion & Sediment Control Training		•	• 2				• 2	• 2	• 2	• 2		• 2			
		Storm Drain Stenciling							• 2	• 2	• 2	• 2		• 2		• 2	• 2
		Establishing an Infiltration Standard(s)	• 2		• 2		• 2		• 2	• 2	• 2	• 2					
		Illicit-Discharge Identification & Risk Reduction							• 2	• 2	• 2	• 2		• 2			• 2
		Pet Waste Ordinance							• 2	• 2	• 2	• 2		• 2			
		Establishing a Buffer Ordinance	• 2	•	• 2		• 2		• 2	• 2	• 2	• 2					
	Pollution Prevention - Source Controls	Park & Open Space Fert/Chem Appl. Programs							• 2	• 2	• 2	• 2		• 2	•		
		Street & Parking Lot Sweeping			• 2				• 2	• 2	• 2	• 2		• 2			
		Composting Programs			• 6				• 6	• 6	• 6	• 6		•			
		Vehicle Washing			• 6				• 2	• 2	• 2	• 2		• 2		• 2	• 2
		Residential Waste Collection & Clean-up Programs		•					• 2	• 2	• 2	• 2		• 2		• 2	
		Reducing Impervious Surfaces	• 2		• 2		• 2		• 2	• 2	• 2	• 2	• 2			• 2	• 2
		Volume Control Using Compost /Soil Amendments	• 2		• 2				• 2	• 2	• 2	• 2					
		Open Space Design	• 2	•	• 2		• 2		• 2	• 2	• 2	• 2					
		Fertilizer Management							•	•	•	•					
		Winter Road Materials Management			• 2			•	• 2	• 2	• 2	• 2	• 2			• 2	
		Urban Forestry	• 2		•		• 2		• 2	• 2	• 2	• 2				• 2	
		Hazardous Material Storage & Handling													•	• 2	• 2
		Septic System Maintenance Programs			• 2				• 2	• 2	• 2	• 2		• 2			
	Infiltration	Infiltration Basin/Trench	• 2		• 2		• 2		• 2,6	• 2,6	• 2	• 2				• 2	
		Green Roofs	• 2		• 6		• 2		• 6	• 6	• 6	• 6				• 6	
		Vegetated Swales	•		• 6				• 6	• 6	• 6	• 6				• 6	• 6
		Improved Turf			• 6				• 6	• 6	• 6	• 6					
		Pervious Pavements	• 2		• 2		• 2		• 2	• 2	• 2	• 2	• 2			• 6	• 6
	Filtration	Bio retention							• 6	• 6	• 6	• 6		•		• 6	• 6
		Tree Trenches/Boxes	•				•		•	•	•	•	•				•
		Wet Swales	• 6		• 6				• 6	• 6	• 6	• 6				• 6	• 6
		Dry Swales	• 2		• 2		• 2		• 6	• 6	• 6	• 6				• 6	• 6
		Permeable Pavement with Underdrains	•		•		•										

		Sand Filters							❘ [6]								
		Filter Strips/Buffers	❘ [2]		❘ [2]		❘ [2]		❘ [2]	❘ [2]	❘ [2]	❘ [2]					
	Reuse	Underground Storage Systems	❘														
		Rainwater Harvest/Reuse & Rain Barrel Programs	❘ [2]		❘ [2]				❘ [6]	❘ [6]	❘ [6]	❘ [6]	❘ [6]		❘ [6]	❘ [2]	❘ [6]
	Settling	Stormwater Ponds	❘		❘		❘ [6]		❘ [6]	❘ [6]	❘	❘				❘ [6]	❘ [6]
		Hydrodynamic Devices			❘												
		Constructed Wetlands	❘		❘ [6]				❘ [6]	❘ [6]	❘ [6]	❘ [6,7]				❘ [6]	❘ [6]
	Chemical Treatment	Iron & Aluminum Enhanced BMPs			❘ [6]				❘ [6]	❘ [6]	❘ [6]	❘ [6]				❘ [6]	
Forestry	**Pollution Prevention - Source Controls**	Site Reconnaissance/Protect Sensitive Areas	❘ [3,4]	❘ [3,4]	❘ [3,4]	❘ [3,4]	❘ [3,4]		❘ [3,4]	❘ [3,4]	❘ [3,4]	❘ [3,4]		❘ [3,4]	❘ [3,4]		
		Wetland Protection	❘	❘ [3]		❘ [3]											
		Avoidance of Logging Residue into Waterbodies		❘ [3,4]	❘ [3,4]		❘		❘	❘				❘			
		Water Diversion Structures	❘ [3,4]		❘ [3,4]			❘					❘				
		Properly Clearing Debris in Rights-of-Way			❘ [3,4]	❘ [3,4]											
		Minimization of Soil Disturbance			❘ [3,4]				❘	❘							
		Erosion Control (water bars, silt fence, etc.)			❘				❘								
		Proper Use of Mechanical Site Prep Techniques			❘ [3,4]												
		Soil Protection/Seeding			❘ [3,4]				❘	❘							
		Integrated Pest Management													❘ [3,4]		
		Careful Pesticide Selection													❘ [3,4]		
		Precautions During Pesticide Use Cycle													❘ [3,4]		
	Infrastructure Management	Appropriate Wetland Road Construction	❘ [3]	❘	❘ [3,4]				❘	❘							
		Proper Water Crossings	❘ [3,4]		❘ [3,4]	❘ [3,4]											
		Forest Road Cross-Drainage			❘ [3,4]												
		Maintaining Active Forest Roads			❘ [3,4]	❘ [3,4]											
		Proper Alignment of Forest Roads	❘		❘ [3,4]	❘											
		Appropriate Winter Road Construction			❘ [3,4]												

		Closure of Inactive Roads & Post-Harvest	yellow 3,4	green	yellow 3,4												
		Road Construction, Excavation, & Surfacing			yellow 3,4				green	green							
		Location & Sizing of Landings			yellow 3,4				green	green							green
	Vegetative Cover/ Structure	Riparian Management Zone Widths		blue 8	blue 8	blue 8	blue 8		blue 8	blue 8	blue 8	blue 8		blue 8			
		Minimization of Young Forest/Open Area Cover	blue 9	blue 9	blue 9												
		Improving Tree Longevity & Diversity of Composition		blue 8		blue 8											
		Shade Strips Along Lakes, Streams & Wetlands		yellow 3,8			yellow 3,8							green	blue 8		blue 8
		Prescribed Burning		yellow 3,4,8	yellow 3,4,8	blue 8											
	Infiltration	Proper Timing of Harvest (minimize compaction) or of Vegetative Treatments	blue 8,10	blue 8,10	blue 8,10				blue 8,10	blue 8,10	blue 8,10	blue 8,10					
	Filtration	Filter Strips Adjacent to Lakes, Streams & Wetlands		yellow 3,4,8	yellow 3,4,8				yellow 3,4,8	yellow 3,4,8	yellow 3,4,8	yellow 3,4,8			yellow 3,4,8		

Key: A dot in a cell (with the exception of red) indicates the BMP should have a positive effect on the stressor.

- Well Documented/Stressor is primary target of BMP
- Some Study/Stressor is secondary target of BMP
- Assumed/Stressor potentially affected by BMP
- BMP has potential to aggravate the stressor

1,2,3 Literature Cited Supporting the BMP-Stressor Relationship

Notes:

1. *BMPs for Altered Hydology may be included for their impact to reduce the effects of either low and/or high flow.
2. BMP's must be properly located, designed, installed and maintained to be effective.
3. This is a working document. Please contact Bruce Paakh, MPCA (bruce.paakh@state.mn.us) or Joe Hadash (joseph.hadash@state.mn.us) for the most current version. July 14, 2014 version.

About Ditches:

Ditch design for reduced maintenance and biological health

The adverse impact of traditional agricultural drainage and channelization on stream biology was presented in the discussion of Figure 83. New approaches to ditch design are providing effective drainage while providing favorable habitat for stream biota and a reduction in the need for maintenance and repair. The two-stage ditch design achieves these benefits and provides a more sustainable drainage system that moves water and sediment efficiently. Building sinuosity into the design will add storage into the system, reduce the ditch gradient and erosive energy and can allow for additional habitat features to develop. Figure 103 provides a cross-sectional comparison between the traditional trapezoidal ditch design in red vs. the two-stage design in blue.

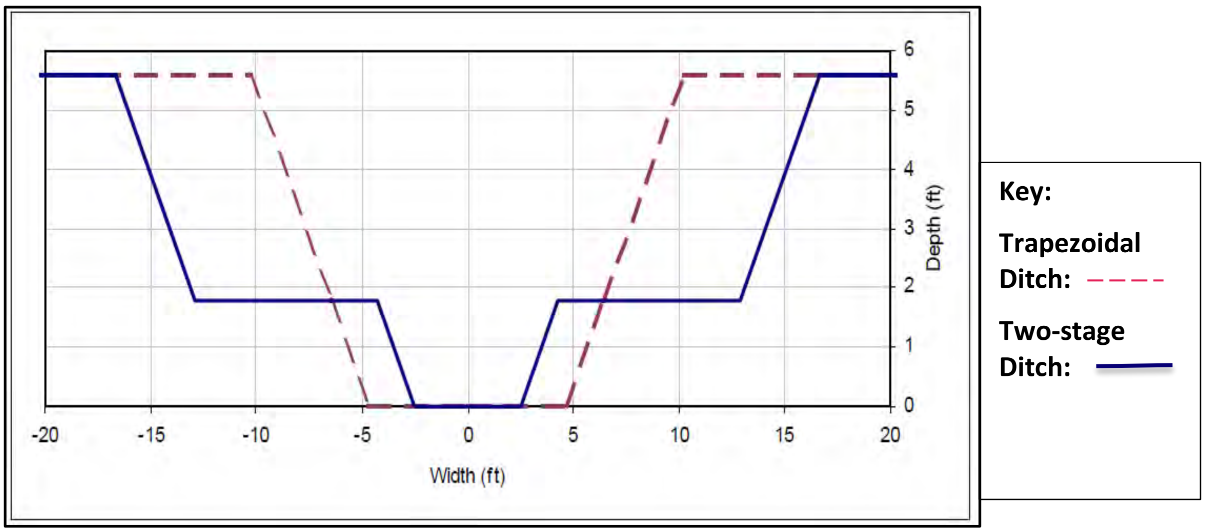


Figure 103. A comparison of the trapezoidal and two-stage ditch design cross sectional view. Note the vertical and horizontal scales are not uniform.

The larger cross sectional area of the two-stage design handles flood flows more effectively and the smaller low flow channel provides for base flow discharge while transporting sediment more efficiently than the traditional ditch design. Designed and constructed properly, the two stage system reduces bank slumping/erosion typical of traditional ditches eliminating the need for costly repairs and cleanouts.

Protection of stable self-maintaining biologically healthy ditches

There are biologically healthy ditches in the Buffalo River Watershed that are in need of protection. The healthy ditches that were observed were generally stable E channels based on the Rosgen Stream Classification System (Rosgen, 1996). Protection of these stable E channel ditches is needed in order to prevent the loss of the many benefits to stream biota as well as the efficient flow and sediment transport they provide. In instances where the headwaters area of a subwatershed is intensively farmed (typically streams originating in the lake plain), these ditches can provide some of the only stable healthy headwater “stream” habitat for biota. These “evolved ditches” can provide important pool-riffle habitat for aquatic biota and the low width/depth ratio with overhanging vegetation (Figures 49-51) can provide cooler water temperatures with higher DO levels.

Healthy ditches typically have a low-flow channel that has developed over time, often carved into the bed at an elevation below the original ditch grade. This low flow channel and the adjacent flood plain tend to mimic a natural stream in the ecological function they provide, similar in form and function to the two-stage ditch discussed above. The sinuous channel that evolves, if not cleaned out or "maintained," increases storage and reduces stream velocities (Figure 52 and Figure 54). The low-flow channel with its low width/depth ratio efficiently moves sediment downstream and is considered "self-maintaining" (a ditch that will allow for the passage of sediment downstream and that doesn't require cleanout to remove sediment buildup).

Adding flow capacity to existing ditch systems

The reduction of peak flow rates in the Red River is needed for a host of reasons and remains a relatively universal water management goal throughout the Red River basin. Contrary to this goal, the need to increase ditch capacity is a reality that continues to be addressed as drainage improvements and tiling continue to increase flow rates and flooding remains an issue in some portions of the watershed. Increased flow capacity within ditches can be accomplished by increasing the flood flow capacity of the ditch rather than enlarging the entire ditch channel. Adding flood plain either through the use of set-back levees that have been successfully employed in Deerhorn Creek or though excavating a wider ditch top to accommodate peak flows are two solutions. Each of these options can be accomplished without disturbing the lower ditch banks/vegetation and low flow channel where developed. These options can maintain a low flow channel configuration needed by fish and macroinvertebrates and for sediment transport.

Ditches that require periodic cleaning from field sources can be considered for watershed BMP's that will help to keep soil on the fields. Sediment basins, conservation tillage, grass waterways and buffer strips, as an example, can be used singly or in aggregate to help reduce sediment loss to the ditch system. In many cases it is the headwater streams that are farmed-through that are the sources of sediment. These intermittent "streams" are good candidates for sediment basins when restoring the stream channel is not desirable. Sediment basins allow the farmer to farm the swale as in the past and the sediment basins trap the soil that would otherwise wash downstream.

Additional Implementation Resources

There are two sources of additional stream resource management suggestions that are provided here. The first was developed by Henry Van Offelen (MNDNR) and edited by Dave Friedl (MNDNR) and is provided in Appendix 6. This document is written with specific recommendations for implementation and restoration and is considered too specific for this section of this report.

The second list of management recommendations were found in the Buffalo River Fisheries Report (Groshens, 2003). This report provides a well-developed page of recommendations for improving the fishery and managing the resource. These suggestions are listed out below and are provided for consideration when planning and applying for strategies to improve the biological integrity of the system. The full report titled, “Red River Basin Stream Survey Report – Buffalo River Watershed 2001” can be accessed through the MDNR.

Buffalo River Watershed Recommendations

The rivers and streams in the Buffalo River Watershed have the capacity to provide a variety of quality habitats for fish and other animals. Hydrologic conditions and unstable channels limit most reaches of streams from achieving their potential. Activities listed below will help improve conditions in the streams in the Buffalo River Watershed. Priority areas for implementing these recommendations are:

1. South Branch Buffalo River Subwatershed, especially the Stony Creek and Whisky Creek drainages
2. Middle and lower reaches of Buffalo River
3. Other small tributary sub-watersheds

The recommended activities listed below should be implemented progressing from upstream to downstream whenever possible.

Habitat protection and enhancement

- Establish riparian corridors along all waterways, including ditches, and encourage the use of native vegetation.
- Protect existing riparian corridors along all waterways.
- Implement agricultural Best Management Practices (BMP's) to reduce sedimentation and erosion, and facilitate natural channel evolution.
- Re-establish naturally functioning, stabile stream channels wherever possible, particularly in the channelized segments in the watershed: define targets and priorities.
- Use natural channel design principles to reestablish natural channels where channel have been destabilized.
- Define areas critical for sustaining base stream flows.
- Restore wetlands in critical areas to augment base flows.
- Stop or mitigate future activities that will continue to disrupt the hydrology (e.g., drainage, tiling, etc.).
- Support incentives to implement strategies that will stabilize streams.
- Include stream protection measures during land use planning efforts to reduce impacts from urban sprawl likely to occur in association with Fargo-Moorhead expansion.
- Hire staff to work with landowners.

Data and monitoring needs

- Recommend air photo interpretation for wetlands and riparian corridors to develop strategies to prioritize.
- Monitor water quality in the basin.
- Track land use changes in the watershed, particularly the continuous sign-up CRP lands.
- Update drainage figures (e.g.: ditches vs natural channels) as more detailed data becomes available.
- Survey culverts in the watershed (dimensions and slope).
- Survey dams in the watershed (locations and types).
- Spring trap net surveys in the watershed to assess northern pike and walleye spawning runs.
- Conduct similar surveys of Buffalo River Watershed streams and their fish populations every five years.
- Pre and post monitoring of approved NRE and FDR projects.

Priority Management Areas

The bio-impaired stream reaches can be considered priority management areas in terms of protection and restoration activities. Decisions regarding where to focus implementation should include an assessment of the landowner willingness, importance of the subwatershed to the health of the impaired reach and overall likelihood of success. The advantages of starting implementation in the upper reaches of the watershed should be considered as well as whether to protect a healthy subwatershed before trying to restore one that is in poor condition. Some will argue that protecting the best should come before restoring degraded reaches as the protected areas can act as critical refugia for remnant biodiversity. These decisions should be discussed and considered at the local level when planning and prioritizing implementation efforts.

The sheet pile dam near Glyndon is considered a high priority for removal by the MNDNR and MPCA for restoring biologic integrity to this system. This dam, according to Dave Friedl, MNDNR (personal communication), is a significant barrier to fish migration that is affecting the distribution and community structure of fisheries in the upstream portions of the South Branch Buffalo River and its tributaries, including Deerhorn Creek. Based on the location of the dam it impacts three of the four biologically impaired reaches in this watershed. Removal or modification of this dam represents an ideal opportunity to reconnect these impaired reaches with the mainstem of the Buffalo River and the Red River of the North enabling fish communities to benefit from the available upstream habitat.

Data Needs – Suggestions for Future Study

This report provides the groundwork for future SID efforts within the Buffalo River Watershed that will build upon the conclusions made herein. Several areas of data need were discussed within this report and efforts to gather this data should be made prior to and during the next assessment cycle. In summary, DO monitoring with deployed sondes should be accomplished in each of the subwatersheds where DO monitoring results indicate potential problems, often during the low flow, peak temperature summer period.

The boom in agricultural drain tile installation during the past decade provides reason for concern as surface water nitrate concentrations are projected to increase with tile density. Monitoring of surface water nitrate levels is encouraged to see if annual mean and maximum nitrate levels show increases above historical data paying particular attention to the subwatershed areas where tile density has increased. Monitoring efforts at the outlet of the Buffalo River may be too diluted to pick up the changes so the continued monitoring of the established regional assessment locations is encouraged. Additional monitoring that specifically targets this issue may be warranted in specific areas of concern once better information on tile installation is determined.

Tile installation should be tracked through a permit or other process so that accurate tile data can be collected and used to access spatial and temporal trends in tile usage. The system could track whether specific systems have outlet controls and this data could be useful in temporary water storage efforts. An ordinance that requires new systems to be designed and installed with flow controls should be a priority for consideration by the Buffalo Red River Watershed District as uncontrolled tile drainage can in certain circumstances exacerbate flooding on the Buffalo River and contribute to flooding further downstream.

Ditch cleanout location, frequency and estimated volume of sediment removed should be tracked by the watershed district as an indicator of where sediment/soil loss control is needed. The frequency and extent of ditch cleaning is a relatively direct indicator of either flow rate/ditch gradient problems (where channel stability issues are present), or the need for land treatment (sediment basins, grassed waterways, riparian buffers, conservation tillage) if sediment sources are primarily from upland field sources or farmed through headwater streams. In each case, the source of the sediment could be determined and the cause addressed, thereby reducing the maintenance costs to landowners while improving ditch system stability, aquatic habitat and water quality.

References

Aadland, L. P. 2010. Reconnecting Rivers: Natural Channel Design in Dam Removals and Fish Passage. MDNR. http://files.dnr.state.mn.us/eco/streamhab/reconnecting_rivers_intro.pdf.

Allan, J. D. 1995. Stream Ecology - Structure and function of running waters. Chapman and Hall, U.K.

Annear, T., I. Chisholm, H. Beecher, A. Locke, P. Aarrestad, C. Coomer, C. Estes, J. Hunt, R. Jacobson, G. Jobsis, J. Kauffman, J. Marshall, K. Mayes, G. Smith, R. Wentworth and C. Stalnaker. 2004. Instream Flows for Riverine Resource Stewardship - Revised Edition. Instream Flow Council, Cheyenne, Wyoming, USA.

Barr Engineering, Anderson. T. 2003. Final Basin Hydrology Technical Memorandum to MPCA. From http://www.pca.state.mn.us/index.php/about-mpca/legislative-resources/legislative-reports/detailed-assessment-of-phosphorus-sources-to-minnesota-watersheds-2004-legislative-report.html.

Becker, G. C. 1983. Fishes of Wisconsin. Univ. Wisconsin Press, Madison. 1052 pp.

Blake, R. W. 1983. Fish Locomotion. London: Cambridge University Press.

Bourne, A., Armstrong, N., Jones, G. November 2002. A Preliminary Estimate of Total Nitrogen and Total Phosphorus Loading to Streams in Manitoba, Canada. Water Quality Management Section, Water Branch. Manitoba Conservation Report No. 2002-04. 49 pp.

Camargo J. and A. Alonso. 2006. Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment. Environment International 32:831-849.

Carlisle D.M., Wolock D.M. and M.R. Meador. 2010. Alteration of streamflow magnitudes and potential ecological consequences: a multiregional assessment. Front Ecol Environ 2010; doi:10.1890/100053.

Collen, P. and Gibson, R.J. 2001. The general ecology of beavers (Castor spp), as related to their influence on stream ecosystems and riparian habitats and subsequent effects on fish - a review. Reviews in Fish Biology and Fisheries 10: 439-461.

Cormier, S., Norton S., Suter G., and D. Reed-Judkins. 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency, Washington, DC, EPA/822/B-00/025, 2000.

Davis, J. 1975. Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: A Review. Journal of the Fisheries Research Board of Canada, p 2295-2331.

Deeproot.com.

Dave Friedl. 2013. Personal communication.

Dingmann, A., et.al. 2012. Buffalo River Watershed Monitoring and Assessment Report. MPCA. http://www.pca.state.mn.us/index.php/view-document.html?gid=16300.

Doudoroff, P. and C. E. Warren. 1965. Dissolved oxygen requirements of fishes. Biological Problems in Water Pollution: Transactions of the 1962 seminar. Cincinatti, Ohio. Robert A. Taft Sanitary Engineering Center, U.S. Public Health Service, Health Service Publication, 999-WP-25.

EPA's CADDIS Webpage http://www.epa.gov/caddis/, EPA's CADDIS Flow Alteration webpage.

http://www.epa.gov/caddis/ssr_flow4s.html.

Freeman, Mary C., Catherine M. Pringle, and C. Rhett Jackson, 2007. Hydrologic Connectivity and the Contribution of Stream Headwaters to Ecological Integrity at Regional Scales. Journal of the American Water Resources Association (JAWRA) 43(1):5-14. DOI: 10.1111/j.1752-1688.2007.00002.x.

Grabda, E., Einszporn-Orecka, T., Felinska, C. and R. Zbanysek. 1974. Experimental methemoglobinemia in trout. Acta Ichthyol. Piscat., 4, 43.

Griffith, M.B., B. Rashleigh, and K. Schofield. 2010. Physical Habitat. In USEPA, Causal Analysis/Diagnosis Decision Information System (CADDIS). http://www.epa.gov/caddis/ssr_phab_int.html.

Groshens, T., B. Evarts, H. Van Offelen, M. Johnson. 2003. Red River Basin Stream Survey Report – Buffalo River Watershed 2001. Section of Fisheries, Minnesota Department of Natural Resources. St. Paul, Minnesota.

Hansen, E. A. 1975. Some effects of groundwater on brook trout redds. Trans. Am. Fish. Soc. 104(1):100-110.

Heiskary, S and Markus H. 2003. Establishing Relationships Among In-stream Nutrient Concentrations, Phytoplankton Abundance and Composition, Fish IBI and Biochemical Oxygen Demand in Minnesota USA Rivers. Final Report to USEPA Region V. MPCA.

Helsel, D. R. 1995. Nitrate in the Nation's Waters: A Summary of Recent Studies. Water Resources Update, 101, 12.

Leopold, L. B., Wolman, M. G., and Miller, J. B. 1964. "Fluvial Processes in Geomorphology", W. H.

Freeman, San Francisco.

Marcy, SM. 2007. Dissolved Oxygen: Detailed Conceptual Model Narrative. In USEPA, Causal Analysis/Diagnosis Decision Information System (CADDIS).

http://www.epa.gov/caddis/pdf/conceptual_model/Dissolved_oxygen_detailed_narrative_pdf.

Markus, H.D. 2010. Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity). MPCA.
http://www.pca.state.mn.us/index.php/view-document.html?gid=14922.

McCollor, S. and S. Heiskary. 1993. Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions - Addendum to: Descriptive Characteristics of the Seven Ecoregions of Minnesota. Water Quality Division, Minnesota Pollution Control Agency.

Meador, M.R.; Carlisle, D.M. 2007. Quantifying tolerance indicator values for common stream fish species of the United States. Ecological Indicators, 7, 329.

Miller, C, et al. 2001. A User's Guide to Natural Resource Efforts in the Red River Basin. Red River Flood Damage Reduction Work Group. MDNR.

Mitchell, S.C. and Cunjak, R.A. (2007). Stream flow, salmon and beaver dams: roles in the construction of stream fish communities within an anadromous salmon dominated stream. Journal of Animal Ecology 76: 1062-1074.

Minnesota Department of Agriculture. http://www.mda.state.mn.us/chemicals/pesticides/maace.aspx.

Minnesota Department of Agriculture. 2012. The Agricultural BMP Handbook for Minnesota [Online]. Available at http://www.eorinc.com/documents/AG-BMPHandbookforMN_09_2012.pdf.

MNDNR, Division of Forestry. 1995. Protecting Water Quality and Wetlands in Forest Management: Best Management Practices in Minnesota. Schroeder Communications, Delano, Minnesota.

MNDNR, Division of Forestry. 1990. Water Quality in Forest Management: Best Management Practices in Minnesota.

MNDNR. Watershed Health Assessment Tool.http://www.dnr.state.mn.us/whaf/index.html.

Monson, Phil and Preimesberger, Angela. 2010. Aquatic Life Water Quality Standards.

Technical Support Document for Nitrate Triennial Water Quality Standard Amendments to Minn. R. chs. 7050 and 7052. DRAFT For External Review, November 12, 2010.

MPCA STREAM HABITAT ASSESSMENT (MSHA) PROTOCOL FOR STREAM MONITORING SITES. Available at http://www.pca.state.mn.us/index.php/component/option,com_docman/task,doc_view/gid,6088.

MPCA. 2009. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. Minnesota Pollution Control Agency, St. Paul, Minnesota.

MPCA. 2011. Pollution Prevention and the MS4 Program: A Guide on Utilizing Pollution Prevention to Meet MS4 General Permit Requirements. http://www.pca.state.mn.us/index.php/view-document.html?gid=11849.

MPCA. 2012. 2012 Clean Water Act Reporting Cycle Stream Assessment Transparency Documentation.

MSUM, 2009.

Munawar, M., W. P. Norwood, and L. H. McCarthy. 1991. A method for evaluating the impacts of navigationally induced suspended sediments from the Upper Great Lakes connecting channels on the primary productivity. Hydrobiologia, 219: 325-332.

Murphy, M. L., C. P. Hawkins, and N. H. Anderson. 1981. Effects of canopy modification and accumulated sediment on stream communities. Trans. Am. Fish. Soc 110:469–478.

Nebeker, A., Dominguez, S., Chapman, G., Onjukka, S., & Stevens, D. (1991). Effects of low dissolved oxygen on survival, growth and reproduction of Daphnia, Hyalella and Gammarus. *Environmental Toxicology and Chemistry* , Pages 373 - 379.

Office of State Climatology, DNR. http://climate.umn.edu/HIDradius/radius.asp

Paakh, B., Goeken, W. & Halvorson, D. 2006. State of the Red River of the North – Assessment of the 2003 and 2004 Water Quality Data for the Red River and its Major Minnesota Tributaries. MPCA.

Poff N. L., Allan D. J., Bain M. B., Karr J. R. , Prestegaard K. L., et al. 1997. The natural flow regime: a paradigm for conservation and restoration of riverine ecosystems. *Bio-Science* 47:769–84

Pringle, C.M., 2003. What is Hydrologic Connectivity and Why is it Ecologically Important? Hydrological Processes 17:2685-2689.

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: brown trout. Biological Report 82 (10.124). U.S. Fish and Wildlife Service. 65 pp.

Rosgen, D. 1996. *Applied River Morphology. Wildlands Hydrology*. Pagosa Springs, Colorado.

Rosgen, D. 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Ft. Collins, Colo.: Wildland Hydrology.

Rosgen, David L. 2001. A Practical Method of Computing Streambank Erosion Rate, 7th Federal Inter - agency Sediment Conference, March 24-29, Reno, Nevada.

Rosgen, D. 2008. River Stability Field Guide. Ft. Collins, Colo.: Wildland Hydrology

Schottler, S.P. 1*, Ulrich, J. 2, Belmont, P. 3, Moore, R. 4, Lauer, J. W. 5 Engstrom, D. R. 1, and Almendinger, J. E. 1. 2013. Twentieth century agricultural drainage creates more erosive rivers. HYDROLOGICAL PROCESSES. Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/hyp.9738.

Tomasek, M. 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Prepared by Barr Engineering for the Minnesota Pollution Control Agency.

U. S. EPA. 2003. National Water Quality Report to Congress (305(b) report). http://www.epa.gov/OWOW/305b/.

USGS Website http://mn.water.usgs.gov/flood/duration/index.html.

Vandegrift, T.R. and H.G. Stefan. 2010. Annual Stream Flow and Climate Changes in Minnesota's River Basins. St. Anthony Falls Laboratory Project Report 543. 42 pp.

Wall, D., Mulla, D., Weiss, S., Wasley, D., Pearson, T., Henningsgaard, B., Lorenz, D., Gervino, N., Lazarus, W., Fabrizzi, K., Galzki, J., Christopherson, D., Baskfield, P., Martin, G., and Kim, K. 2013. "Nitrogen in Minnesota Surface Waters - Conditions, trends, sources, and reductions." Minnesota Pollution Control Agency, University of Minnesota, and U.S. Geological Survey. 401 pp.

Waters, T. 1995. *Sediment in Streams: Sources, Biological Effects, and Control.* Bethesda, Maryland: American Fisheries Society.

Appendix 1. Biological sampled sites and F-IBI scores in the Buffalo River Watershed.

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Fish Class	Threshold	F-IBI	Visit Date
HUC-11: 09020106-010 (Upper Buffalo River)							
09020106-593	09RD012	Buffalo River	127.75	5	50	51	23-Jul-09
09020106-593	09RD012	Buffalo River	127.75	5	50	38	30-Jun-09
09020106-593	09RD024	Buffalo River	54.28	5	50	27	29-Jun-09
09020106-593	09RD038	Buffalo River	110.68	5	50	42	29-Jun-09
09020106-594	09RD005	Buffalo River	215.91	5	50	50	23-Jul-09
09020106-594	09RD005	Buffalo River	215.91	5	50	47	30-Jun-09
HUC-11: 09020106-020 (County Ditch #15)							
09020106-514*	09RD057	Unnamed creek	5.74	6	-	29	08-Jun-09
09020106-515*	05RD072	Unnamed ditch	54.78	5	-	36	09-Jun-09
09020106-515*	05RD072	Unnamed ditch	54.78	5	-	58	28-Jun-05
09020106-515*	07RD029	Unnamed ditch	48.67	6	-	71	20-Aug-07
09020106-515*	07RD029	Unnamed ditch	48.67	6	-	64	07-Aug-07
09020106-515*	09RD004	Trib. to Buffalo River	86.39	5	-	50	29-Jun-09
09020106-515*	09RD026	Unnamed ditch	38.90	6	-	36	08-Jun-09
09020106-516*	09RD058	Unnamed ditch	19.26	6	-	24	10-Jun-09
09020106-518*	05RD045	Trib. to Buffalo River	25.94	6	-	67	09-Jun-09
09020106-518*	05RD045	Trib. to Buffalo River	25.94	6	-	25	20-Jul-05
09020106-527*	09RD059	Unnamed ditch	14.03	6	-	72	10-Jun-09
09020106-577*	09RD027	Trib. to unnamed ditch	7.28	7	-	37	09-Jun-09
09020106-578*	09RD025	Unnamed Ditch	1.51	6	-	29	08-Jun-09
HUC-11: 09020106-030 (Lake Park)							
09020106-511*	05RD071	Hay Creek	18.83	6	-	12	13-Jul-09
09020106-511*	05RD071	Hay Creek	18.83	6	-	19	20-Jul-05
09020106-513	09RD003	Hay Creek	6.35	6	40	67	7-Jul-09
09020106-576*	10EM069	Unnamed trib. to Hay Creek	6.30	6	-	0	09-Jun-10
HUC-11: 09020106-040 (Middle Buffalo River)							
09020106040-580*	09RD013	Trib. to Buffalo River	11.21	7	-	22	9-Jun-09
09020106040-581*	09RD028	Trib. to Buffalo River	6.47	7	-	14	10-Jun-09

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Fish Class	Threshold	F-IBI	Visit Date
09020106040-582*	09RD017	Trib. to Buffalo River	5.87	7	-	0	14Jul-09
09020106040-594	05RD116	Buffalo River	254.75	7	40	38	22-Aug-09
09020106040-594	09RD039	Buffalo River	257.24	7	40	33	30-Jun-09
09020106040-595	09RD040	Buffalo River	308.63	5	50	40	21-Jul-09
09020106040-595	09RD042	Buffalo River	360.11	5	50	58	21-Jul-09
09020106040-595	05RD110	Buffalo River	315.95	5	50	44	26-Jul-09
09020106040-595	09RD002	Buffalo River	399.47	7	40	76	20-Jul-09
HUC-11: 09020106-050 (Deerhorn-Buffalo)							
09020106050-503	08RD081	Buffalo River, South Branch	461.84	7	40	71	9-Sep-09
09020106050-503	09RD006	Buffalo River, South Branch	506.32	2	45	58	16-Jul-09
09020106050-504	09RD019	Buffalo River, South Branch	300.23	7	40	0.00	8-Sept-09
09020106050-505	05RD037	Buffalo River, South Branch	124.64	7	40	69	28-Jun-09
09020106050-505	05RD118	Buffalo River, South Branch	171.39	7	40	53	26-Jul-09
09020106050-505	08RD080	Buffalo River, South Branch	164.18	7	40	70	25-Aug-09
09020106050-505	94RD004	Buffalo River, South Branch	126.74	7	40	65	13-Aug-09
09020106050-507	09RD052	Deerhorn Creek	30.75	7	40	2	15-Jun-09
09020106050-507	09RD047	Deerhorn Creek	35.04	7	40	0	8-Jul-09
09020106050-508*	09RD051	Buffalo River, South Branch	38.64	7	-	36	16-Jun-09
09020106050-508*	09RD033	Buffalo River, South Branch	14.88	7	-	51	15-Jun-09
09020106050-530*	09RD050	State Ditch 15	23.12	7	-	7	8-Jul-09
09020106050-530*	09RD056	Unnamed Creek (Lawndale Creek)	12.71	9	-	30	15-Jun-09
09020106050-531*	09RD048	State Ditch 14	19.21	7	-	73	16-Jun-09
09020106050-550*	09RD036	County Ditch 12	11.29	7	-	16	15-Jul-09
09020106050-554*	09RD063	Unnamed creek	33.36	7	-	49	22-Jul-09
09020106050-554*	09RD032	Judicial Ditch 3-1	14.75	7	-	35	8-Jul-09
09020106050-587*	09RD034	Trib. to Buffalo River, South Branch	4.09	7	-	81	16-Jun-09

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Fish Class	Threshold	F-IBI	Visit Date
09020106050-587*	09RD034	Trib. to Buffalo River, South Branch	4.09	7	-	46	15-Jul-09
HUC-11: 09020106-060 (South of Hawley-South Buffalo)							
09020106-502	09RD007	Stony Creek	157.87	2	45	72	01-Sep-09
09020106-509*	09RD008	Whiskey Creek	113.84	2	-	69	14-Jul-09
09020106-509*	09RD011	Whiskey Creek	90.55	2	-	45	01-Jul-09
09020106-510*	09RD031	Stony Creek	25.29	3	-	68	15-Jul-09
09020106-510*	09RD031	Stony Creek	25.29	3	-	65	10-Jun-09
09020106-519*	09RD023	Hay Creek	75.17	2	-	0	09-Jul-09
09020106-520*	07RD012	Hay Creek	87.79	2	-	36	22-Aug-07
09020106-520*	07RD012	Hay Creek	87.79	2	-	30	09-Aug-07
09020106-521	09RD021	Whiskey Creek	69.13	2	45	34	12-Aug-09
09020106-521	09RD021	Whiskey Creek	69.13	2	45	58	08-Jul-09
09020106-521	05RD119	Whiskey Creek	84.45	2	45	47	25-Aug-05
09020106-523*	09RD046	Stony Creek	46.42	2	-	42	12-Aug-09
09020106-523*	09RD046	Stony Creek	46.42	2	-	41	09-Jul-09
09020106-533*	09RD020	Unnamed creek	4.85	3	-	0	08-Jul-09
09020106-534	09RD022	Spring Creek	9.22	3	51	43	09-Jul-09
09020106-551*	09RD030	County Ditch 21	5.34	3	-	0	13-Jul-09
09020106-592*	09RD045	Trib. to Buffalo River, South Branch	13.25	3	-	0	13-Jul-09
HUC-11: 09020106-070 (Olaf Groves Lakes)							
09020106-521	09RD001	Whiskey Creek	35.93	6	40	63	11-Jun-09
09020106-586	09RD053	Trib. to Whiskey Creek	14.33	6	40	60	10-Jun-09
HUC-11: 09020106-080 (County Ditch #2)							
09020106-555	09RD062	Trib. to County Ditch 2	23.34	6	40	11	13-Aug-09
09020106-555	09RD062	Trib. to County Ditch 2	23.34	6	40	13	13-Jul-09
09020106-556*	09RD037	County Ditch 2	35.97	2	-	50	22-Jul-09
HUC-11: 09020106-090 (Lower Buffalo River)							
09020106-501	05RD120	Buffalo River	987.76	1	39	78	21-Aug-06
09020106-501	09RD009	Buffalo River	1129.35	1	39	62	10-Sep-09
09020106-501	09RD043	Buffalo River	1016.92	1	39	73	10-Sep-09
09020106-501	09RD018	Buffalo River	921.71	1	39	72	09-Sep-09
09020106-538*	09RD016	County Ditch 25	15.94	7	-	0	14-Jul-09

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Fish Class	Threshold	F-IBI	Visit Date
09020106-557*	09RD044	County Ditch 3	22.10	3	-	0	07-Jul-09
09020106-559*	09RD055	County Ditch 39	42.24	2	-	68	14-Jul-09
09020106-559*	09RD055	County Ditch 39	42.24	2	-	43	17-Jun-09
09020106-560*	09RD015	County Ditch 59	8.68	3	-	0	17-Jun-09
09020106-562*	09RD014	County Ditch 10	20.35	3	-	48	17-Jun-09
09020106-563*	09RD029	County Ditch 5 (County Ditch 8)	12.95	3	-	34	17-Jun-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating scores.**

Appendix 2. Biological sampled sites and M-IBI scores for the Buffalo River Watershed.

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Invert Class	Threshold	M-IBI	Visit Date
HUC-11: 09020106-010 (Upper Buffalo River)							
09020106010-593	09RD012	Buffalo River	127.75	7	38.3	48.28	25-Aug-09
09020106010-593	09RD024	Buffalo River	54.28	6	46.8	40.86	24-Aug-09
09020106010-593	09RD038	Buffalo River	110.68	7	38.3	25.70	26-Aug-09
09020106010-594	09RD005	Buffalo River	215.91	7	38.3	54.51	25-Aug-09
HUC-11: 09020106-020 (County Ditch #15)							
09020106020-515*	05RD072	Unnamed ditch	54.78	7	-	31.51	25-Aug-05
09020106020-515*	05RD072	Unnamed ditch	54.78	7	-	12.06	25-Aug-09
09020106020-515*	05RD072	Unnamed ditch	54.78	7	-	19.52	23-Aug-05
09020106020-515*	07RD029	Unnamed ditch	48.67	7	-	30.82	15-Aug-07
09020106020-515*	09RD004	Trib. to Buffalo River	86.39	7	-	35.81	25-Aug-09
09020106020-515*	09RD004	Trib. to Buffalo River	86.39	7	-	42.87	25-Aug-09
09020106020-515*	09RD026	Unnamed ditch	38.90	7	-	37.41	24-Aug-09
09020106020-516*	09RD058	Unnamed ditch	19.26	7	-	37.70	24-Aug-09
09020106020-518*	05RD045	Trib. to Buffalo River	25.94	7	-	13.55	25-Aug-05
09020106020-518*	05RD045	Trib. to Buffalo River	25.94	7	-	11.24	22-Aug-05
09020106020-518*	05RD045	Trib. to Buffalo River	25.94	7	-	30.47	24-Aug-09
09020106020-527*	09RD059	Unnamed ditch	14.03	7	-	46.76	24-Aug-09
09020106020-578*	09RD025	Trib. to unnamed Ditch	23.25	7	-	16.17	24-Aug-09
HUC-11: 09020106-030 (Lake Park)							
09020106030-511*	05RD071	Hay Creek	18.83	6	-	25.84	25-Aug-05
09020106030-511*	05RD071	Hay Creek	18.83	6	-	18.69	22-Aug-05
09020106030-576*	10EM069	Unnamed Creek	6.3	5	-	19.39	15-Sep-10
HUC-11: 09020106-040 (Middle Buffalo River)							
09020106040-580*	09RD013	Trib. to Buffalo River	11.21	7	-	12.83	25-Aug-09
09020106040-581*	09RD028	Trib. to Buffalo River	6.47	7	-	26.01	25-Aug-09
09020106040-582*	09RD017	Trib. to Buffalo River	5.87	7	-	6.47	22-Sep-10
09020106040-594	05RD116	Buffalo River	254.75	7	38.3	65.54	25-Aug-05
09020106040-594	09RD039	Buffalo River	257.24	7	38.3	60.78	28-Sep-09
09020106040-595	09RD040	Buffalo River	308.63	5	35.9	38.91	25-Aug-09

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Invert Class	Threshold	M-IBI	Visit Date
09020106040-595	09RD042	Buffalo River	360.11	5	35.9	42.86	25-Aug-09
09020106040-595	05RD110	Buffalo River	315.95	5	35.9	52.66	25-Aug-05
09020106040-595	09RD002	Buffalo River	399.47	7	38.3	46.62	31-Aug-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating scores.**

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Invert Class	Threshold	M-IBI	Visit Date
HUC-11: 09020106-050 (Deerhorn-Buffalo)							
09020106050-503	08RD081	Buffalo River, South Branch	461.84	7	38.3	31.84	29-Sep-09
09020106050-503	09RD006	Buffalo River, South Branch	506.32	2	30.7	37.02	29-Sep-09
09020106050-504	09RD019	Buffalo River, South Branch	300.23	7	38.3	0.00	04-Aug-10
09020106050-505	05RD037	Buffalo River, South Branch	124.64	7	38.3	21.00	28-Sep-05
09020106050-505	05RD118	Buffalo River, South Branch	171.39	7	38.3	31.93	28-Sep-05
09020106050-505	08RD080	Buffalo River, South Branch	164.18	7	38.3	24.51	25-Aug-09
09020106050-505	94RD004	Buffalo River, South Branch	126.74	7	38.3	40.50	23-Sep-10
09020106050-507	09RD052	Deerhorn Creek	30.75	7	38.3	24.32	25-Aug-09
09020106050-507	09RD047	Deerhorn Creek	35.04	7	38.3	9.04	25-Aug-09
09020106050-508*	09RD051	Buffalo River, South Branch	38.64	7	-	30.07	25-Aug-09
09020106050-508*	09RD033	Buffalo River, South Branch	14.88	7	-	28.07	26-Aug-09
09020106050-530*	09RD050	State Ditch 15	23.12	7	-	12.60	25-Aug-09
09020106050-530*	09RD056	Unnamed Creek (Lawndale Creek)	12.71	9	-	69.46	25-Aug-09
09020106050-531*	09RD048	State Ditch 14	19.21	7	-	55.69	23-Sep-10
09020106050-550*	09RD036	County Ditch 12	11.29	7	-	31.20	26-Aug-09
09020106050-554*	09RD063	Unnamed creek	33.36	7	-	16.37	25-Aug-09
09020106050-554*	09RD032	Judicial Ditch 3-1	14.75	7	-	16.14	26-Aug-09
09020106050-554*	09RD032	Judicial Ditch 3-1	14.75	7	-	26.45	26-Aug-09
09020106050-587*	09RD034	Trib. to Buffalo River, South Branch	4.09	7	-	55.03	25-Aug-09
HUC-11: 09020106-060 (South of Hawley-South Buffalo)							
09020106060-509*	09RD008	Whiskey Creek	113.84	7	-	19.47	31-Aug-09
09020106060-509*	09RD011	Whiskey Creek	90.55	7	-	31.74	31-Aug-09
09020106060-510*	09RD031	Stony Creek	25.29	5	-	12.91	26-Aug-09
09020106060-519*	09RD023	Hay Creek	75.17	7	-	18.71	25-Aug-09
09020106060-520*	07RD012	Hay Creek	87.79	7	-	44.00	15-Aug-07

09020106060-521	05RD119	Whiskey Creek	84.45	7	38.3	22.00	28-Sep-05
09020106060-521	09RD021	Whiskey Creek	69.13	7	38.3	28.76	26-Aug-09
09020106060-534	09RD022	Spring Creek	9.22	5	38.3	30.92	25-Aug-09
09020106060-551*	09RD030	County Ditch 21	5.34	7	-	21.90	25-Aug-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating score.**

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi2)	Invert Class	Threshold	M-IBI	Visit Date
HUC-11: 09020106-070 (Olaf Groves Lakes)							
09020106070-521	09RD001	Whiskey Creek	35.93	7	38.3	44.49	26-Aug-09
09020106070-586	09RD053	Trib. to Whiskey Creek	14.33	7	38.3	24.24	26-Aug-09
HUC-11: 09020106-080 (County Ditch #2)							
09020106080-555	09RD062	Trib. to County Ditch 2	23.34	7	38.3	35.00	26-Aug-09
09020106080-556*	09RD037	County Ditch 2	35.97	7	-	24.85	24-Aug-09
HUC-11: 09020106-090 (Lower Buffalo River)							
09020106090-501	05RD120	Buffalo River	987.76	2	30.7	29.32	28-Sep-05
09020106090-501	05RD120	Buffalo River	987.76	2	30.7	38.82	20-Sep-05
09020106090-501	09RD018	Buffalo River	921.71	2	30.7	46.78	29-Sep-09
09020106090-501	09RD043	Buffalo River	1016.92	2	30.7	42.83	29-Sep-09
09020106090-501	09RD009	Buffalo River	1129.35	2	30.7	44.61	29-Sep-09
09020106090-562*	09RD014	County Ditch 10	20.35	7	-	9.54	24-Aug-09
09020106090-560*	09RD015	County Ditch 59	8.68	7	-	0.00	24-Aug-09
09020106090-538*	09RD016	County Ditch 25	15.94	7	-	7.61	24-Aug-09
09020106090-563*	09RD029	County Ditch 5 (County Ditch 8)	12.95	7	-	0.00	24-Aug-09
09020106090-557*	09RD044	County Ditch 3	22.10	7	-	4.83	24-Aug-09
09020106090-559*	09RD055	County Ditch 39	42.24	7	-	12.39	24-Aug-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating scores.**

Appendix 3. Fish species, site, and total number of individuals collected in the Buffalo River Watershed.

Common Name	Sites Collected At	Total Number Collected
Bigmouth Shiner	18	289
Black Bullhead	36	143
Black Crappie	4	4
Blackchin Shiner	2	3
Blacknose Dace	27	840
Blacknose Shiner	15	137
Blackside Darter	39	245
Bluegill	17	234
Brook Stickleback	49	2824
Brown Bullhead	1	2
Central Mudminnow	42	384
Channel Catfish	6	33
Chestnut Lamprey	1	1
Common Carp	15	269
Common Shiner	41	3754
Creek Chub	56	2007
Emerald Shiner	1	4
Fathead Minnow	57	6208
Finescale Dace	4	327
Freshwater Drum	2	2
Gen: Percina	1	1
Gen: Redhorses	1	1
Golden Redhorse	17	144
Golden Shiner	6	7
Goldeye	9	29
Greater Redhorse	1	1
Green Sunfish	21	205
Hornyhead Chub	19	360
Hybrid Sunfish	3	7
Iowa Darter	10	72

Common Name	Sites Collected At	Total Number Collected
Johnny Darter	43	837
Largemouth Bass	7	69
Longnose Dace	10	556
Mooneye	1	1
Northern Pike	44	185
Northern Redbelly Dace	23	991
Orangespotted Sunfish	1	3
Pearl Dace	13	151
Pumpkinseed	4	7
Quillback	3	6
Rock Bass	24	151
Sand Shiner	18	283
Sauger	5	9
Shorthead Redhorse	16	166
Silver Chub	1	1
Silver Lamprey	2	2
Silver Redhorse	7	32
Smallmouth Bass	2	3
Spotfin Shiner	27	1223
Spottail Shiner	14	171
Stonecat	9	18
Tadpole Madtom	9	39
Trout-Perch	18	93
Walleye	12	23
White Sucker	67	1553
Yellow Bullhead	1	1
Yellow Perch	13	75

Appendix 4. Minnesota statewide IBI thresholds and confidence limits, 2012

Class	Class Name	Use Class	Threshold	Confidence Limit	Upper	Lower
Fish						
1	Southern Rivers	2B	46	±11	57	35
2	Southern Streams	2B	45	±9	54	36
3	Southern Headwaters	2B	51	±7	58	44
4	Northern Rivers	2B	35	±9	44	26
5	Northern Streams	2B	50	±9	59	41
6	Northern Headwaters	2B	40	±16	56	24
7	Low Gradient	2B	40	±10	50	30
10	Southern Coldwater	2A	45	±13	58	32
11	Northern Coldwater	2A	37	±10	47	27
Macroinvertebrates						
1	Northern Forest Rivers	2B	43.0	±10.8	53.8	32.2
2	Prairie Forest Rivers	2B	30.7	±10.8	41.5	19.9
3	Northern Forest Streams RR	2B	50.3	±12.6	62.9	37.7
4	Northern Forest Streams GP	2B	52.4	±13.6	66	38.8
5	Southern Streams RR	2B	35.9	±12.6	48.5	23.3
6	Southern Forest Streams GP	2B	46.8	±13.6	60.4	33.2
7	Prairie Streams GP	2B	38.3	±13.6	51.9	24.7
8	Northern Coldwater	2A	26	±12.4	38.4	13.6
9	Southern Coldwater	2A	46.1	±13.8	59.9	32.3

Appendix 5. Good/Fair/Poor thresholds for biological monitoring stations on non-assessed channelized AUIDs, 2012.

Class	Class Name	Good	Fair	Poor
Fish				
1	Southern Rivers	>38	38-24	<24
2	Southern Streams	>44	44-30	<30
3	Southern Headwaters	>50	50-36	<36
4	Northern Rivers	>34	34-20	<20
5	Northern Streams	>49	49-35	<35
6	Northern Headwaters	>39	39-25	<25
7	Low Gradient	>39	39-25	<25
10	Southern Coldwater	>45	45-30	<30
11	Northern Coldwater	>37	37-22	<22
Macroinvertebrates				
1	Northern Forest Rivers	>51	52-36	<36
2	Prairie Forest Rivers	>31	31-16	<16
3	Northern Forest Streams RR	>50	50-35	<35
4	Northern Forest Streams GP	>52	52-37	<37
5	Southern Streams RR	>36	36-21	<21
6	Southern Forest Streams GP	>47	47-32	<32
7	Prairie Streams GP	>38	38-23	<23
8	Northern Coldwater	>26	26-11	<11
9	Southern Coldwater	>46	46-31	<31

Ratings of Good for channelized streams are based on Minnesota's general use threshold for aquatic life. Stations with IBIs that score above this general threshold would be given a rating of Good. The Fair rating is calculated as a 15 point decrease from the general use threshold. Stations with IBI scores below the general use threshold, but above the Fair threshold would be given a rating of Fair. Stations scoring below the Fair threshold would be considered Poor.

Appendix 6. Implementation and Restoration.

The following section was developed by Henry Van Offelen MNDNR) for the Tamarac River Watershed and edited by Dave Friedl (MNDNR) for use in the Buffalo River Watershed. This document is more prescriptive in nature and written more like an implementation and restoration plan. It has been included in the appendix as the Transitioning to Implementation section of this report is more general in nature.

This implementation and restoration section seeks to describe a practical approach and set of actions that can be implemented on the landscape to improve the health of the Buffalo River Watershed from a natural resource perspective by:

1. Protecting existing upland and aquatic habitats where conditions are good.
2. Improving hydrologic conditions (e.g. reduce peak flows, augment low flows, reduce runoff volume).
3. Improving stability of natural and altered natural watercourses (e.g. natural channel design restorations, grade stabilization, bank stabilization, vegetated corridors, improved hydrograph – see 2).
4. Improving aquatic habitat and biology (e.g. channel, riparian, and upland improvements as in 1 – 7.
5. Improving design and management of artificial watercourses (e.g. natural stable channel with floodplain and setback levees, two stage ditches, side-inlets and other drainage BMPs)
6. Reducing sediment and nutrient loading from upland sources (e.g. sediment basins, filter strips, floodplain restoration or reconnection, upland BMPs).
7. Improving wildlife habitat (e.g. wetland and grassland restoration, vegetation management).

Restoration activities need not be necessarily viewed as reverting watersheds and streams to pristine pre-settlement conditions, unless they already exist. Rather, finding a better balance between existing rather than historical driving variables (primarily flow and sediment regimes), and boundary conditions (valley materials, valley morphology – i.e. slope and width, riparian vegetation, and roughness elements) would improve stream stability. Improving the balance between the driving and controlling variables would help to achieve stable streams that are neither aggrading nor degrading, lower bank erosion rates, improve aquatic habitat, improve water quality, and generally improve watershed health.

An example would be a primarily gravel bed stream that is dominated by sand sediment (a symptom would be a bimodal sediment distribution in the bed of the stream – commonly found in many areas of Minnesota and the Buffalo Watershed). Once the sand sediment source is found and controlled or eliminated, and if the stream has access to the flood plain, the stream will fix itself. This will result in a host of natural resource benefits including improved aquatic habitat with gravel substrate, deeper pools, and healthy hyporheic zone with improved biological productivity, healthier biological communities, stream stability, and improved water quality.

A list of practical actions which can be taken to change the landscape and begin to achieve healthier watersheds includes:

1. Land use change
2. Land use practice change (tillage)
3. Sediment basins
4. Drainage improvements and BMPs, including effective buffers, side inlet controls, culvert sizing
5. Water retention and detention
6. Impoundments (off-channel or upper watershed areas)

7. Wetlands (including restoration of floodplains)
8. Culvert sizing (balanced with stream stability and fish passage needs)
9. Riparian buffers and filter strips
10. Channel stabilization
11. Channel rehabilitation/restoration
12. Intensive management of existing perennial vegetation
13. Regulatory approaches (i.e. shoreland ordinance, public water rules, soil loss ordinances, land use ordinances, storm water utility)

Goals and objectives for upland and wetland habitats
(wetland, grassland, woodland, and brushlands)
in the Buffalo River Watershed

Watershed-wide goals and objectives

1. Strategically protect existing habitats in the Conservation Reserve Program (CRP), and Continuous Sign-up Conservation Reserve Program (CCRP) program. They provide significant habitat, water quality, and flood damage reduction benefits and are at risk of conversion to cropland.
   - Identify and prioritize catchments in the watershed for their ability to reduce peak flows, reduce sediment loading, and provide wildlife habitat *(note: these are available for the Buffalo Watershed)*.
   - Increase awareness of the benefits of grasslands, Conservation Reserve Program and other voluntary conservation programs throughout the watershed.
   - Target marketing of CRP and Re-invest in Minnesota (RIM) to landowners in high priority areas.
2. Strategically enhance existing habitats - Conservation Reserve Program and CCRP. While these lands provide significant benefits the vegetative communities could be improved on many of them.
   - Identify and prioritize existing habitats for enhancement.
   - Work with landowners to implement activities to improve the quality of vegetation in priority areas.
   - Strategically restore wetlands to improve hydrology, water quality and wildlife habitat.
   - Identify and prioritize catchments in the watershed for their ability to reduce peak flows, reduce sediment loading and provide wildlife habitat *(note: these are available for the Buffalo Watershed)*.
   - Increase awareness of the benefits of wetland restoration and market the Wetland Reserve Program (WRP) and other voluntary conservation programs throughout the watershed.
   - Target marketing of wetland restoration programs to landowners with restorable wetland basins found in high priority areas.
   - Target restoration of at least two wetland basins in each of the 10 highest high priority area catchments by 2018.
3. Strategically restore grasslands, woodlands, and brush lands to improve hydrology, water quality and wildlife habitat.
   - Identify and prioritize catchments in the watershed for their ability to reduce peak flows, reduce sediment loading and provide wildlife habitat *(note: these are available for the Buffalo Watershed)*.
   - Increase awareness of the benefits of habitat restoration and market the CRP and other voluntary conservation program throughout the watershed.
   - Target marketing of grassland, woodland, and brushland restoration programs to landowners in high priority areas for multiple benefits.
   - Restore at least 640 acres of grasslands in the five highest high priority area catchments by 2018.

- Restore at least 640 acres of woodlands in the five highest high priority area catchments by 2018.
- Restore at least 640 acres of brushlands in the five highest high priority area catchments by 2018.

Goals and objectives for streams and watercourses in the Buffalo River Watershed

Watershed – Wide goals and objectives

1. Identify, prioritize, and install riparian buffers (grasslands, wetlands, woodlands as appropriate) and drainage BMP (e.g. side inlets) on all classes of watercourses (see Table 16 for locations of where riparian buffers are needed) to increase channel stability, reduce erosion and sediment loading, and improve wildlife habitat. Please note these objectives are consistent with many of the BMP implementation objectives found in the Watershed District's water plan but have been structured on specific water types.

Public waters

a. Achieve compliance with existing shore land buffer requirements.
   i. Identify areas where a 50 foot buffer is not currently being maintained along public waters.
   ii. Work with landowners in areas without required 50 foot buffers to ensure compliance with existing laws by 2016.
b. Identify, assess and prioritize the needs of public waters for side inlets and other erosion control best management practices.
c. Work with landowners to install BMPs on private surface drainage features which outlet to public waters.
d. Implement BMPs on highest priority public water reaches by 2018.
e. Work with landowners to develop drainage water management plans for sub-surface drainage tiles that outlet into public waters.

Legal Ditch Systems

a. Achieve compliance with existing ditch buffer requirements.
   i. Identify areas where required ditch buffers are not present.
   ii. Work with landowners in areas to ensure compliance with existing laws by 2016.
b. Identify, assess and prioritize the needs of legal ditch systems for side inlets and other erosion control best management practices.
   i. Implement BMPs on highest priority legal ditch systems by 2018.
   ii. Work with landowners to install BMPs in high priority areas where private surface drainage features outlet to legal ditch systems.
c. Work with landowners to develop and implement drainage water management plans for sub-surface drainage tiles that outlet into legal ditch systems.
d. Work with landowners to promote increases in ditch capacity, where deemed necessary, to occur in a floodplain rather than an oversize ditch channel.

All other watercourses

a. Install effective buffers along all high priority reaches of watercourses.
   i. Identify, assess and prioritize the needs of other watercourse for side inlets and other erosion control BMPs.
   ii. Work with landowners to install BMPs on private surface drainage features which outlet to other watercourses.

iii. Implement BMPs on highest priority reaches of other watercourse by 2018.

iv. Work with landowners to develop and implement drainage water management plans on sub-surface drainage tiles that outlet into all other watercourses.

2. Identify and prioritize watercourses based on need for stabilization and rehabilitation.

Natural watercourses

a. Identify, assess and prioritize natural watercourses based on their current level of stability (i.e. from relatively stable to unstable).
b. Develop a list of priority reaches of natural watercourse for grade stabilization.
c. Implement projects to stabilize the grade of two of the top five priority reaches by 2018.
d. Develop a list of priority reaches of natural watercourse for rehabilitation.
e. Implement projects to rehabilitate two of the top five priority watercourse reaches by 2018.
f. Develop a list of priority reaches of natural watercourse for protection of current conditions.
g. Work with drainage authorities to minimize the impacts of any proposed activities which would put stable functioning watercourses at risk of destabilization.

Altered natural watercourses

a. Identify, assess and prioritize modified natural watercourses based on their current level of stability (i.e. from relatively stable to unstable).
b. Develop a list of priority reaches of modified natural watercourses for grade stabilization.
c. Implement projects to stabilize the grade of two of the top-five priority reaches by 2018.
d. Develop a list of priority reaches of modified natural watercourses for rehabilitation.
e. Implement projects to rehabilitate two of the top-five priority reaches by 2018.
f. Develop a list of priority reaches of modified natural watercourse for protection of current conditions.
g. Work with drainage authorities to minimize the impacts of any proposed activities which would put stable functioning watercourses at risk of degradation.

Artificial watercourses

a. Identify, assess and prioritize artificial watercourses based on their current level of stability (i.e. relatively stable to unstable).
b. Develop a list of priority reaches of artificial watercourses for grade stabilization.
c. Implement projects to stabilize the grade of two of the top five priority reaches by 2018.
d. Develop a list of priority reaches of artificial watercourses for rehabilitation.
e. Implement projects to rehabilitate two of the top five priority reaches by 2018.
f. Develop a list of priority reaches of artificial watercourse for protection of current conditions (e.g. ditches that have become naturalized over time).
g. Work with drainage authorities to minimize the impacts of any proposed activities which would put stable functioning watercourses at risk of degradation (for example the ditched portion of the lower Tamarac River).

3. Implement activities that will improve hydrologic conditions and reduce sediment input from upland area to reduce peak flows, periods of extreme low flow and no flow, and sediment loads.

a. Increase wetland, grassland, woodland and brush land habitats in priority areas for peak flow reduction.

b. Install multipurpose water retention projects in priority areas for peak flow reduction.
c. Install sediment basins in high priority overland catchments.
d. Install or renovate shelter belts and field wind breaks in priority areas for wind erosion reduction.
e. Reduce storm water runoff in cities within the watershed through development and implementation of storm water plans when required and promoting installation of storm water structures (e.g. storm water basins, rain gardens, and bio-retention basins).
f. Work with landowners to install agricultural BMPs (e.g. conservation tillage, cover crops, etc.) in high priority overland catchments.
g. Prohibit or require mitigation for future activities that will increase peak flows, annual water yield, number of low flow or no flow days and channel erosion (e.g., new and improved drainage, tile, etc.).
h. Promote activities that result in both inter - and intra-annual flow regimes that attain critical threshold levels necessary to drive important ecological functions that sustain biological diversity and dynamic ecosystem functions (Annear et.al. 2004).

4. Systematically review the status and need for existing public drainage systems and identify and prioritize opportunities to abandon systems or portions of systems that no longer serve intended functions.