Pomme de Terre River Watershed Biotic Stressor Identification

A study of local stressors limiting the biotic communities in the Pomme de Terre River Watershed.

Minnesota Pollution Control Agency

June 2012

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Executive Summary

A Stressor Identification analysis is a step-by-step approach for identifying probable causes of impairment in a particular system. There are five stream reaches within the Pomme de Terre River watershed that were identified as impaired for aquatic life based on a lack of biological community. Further evaluation was completed to connect the biological community to the stressor(s) causing the impairment. The objective of this report is to describe 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 U.S. Environmental Protection Agency's (EPA's) Causal Analysis/Diagnosis Decision Information System (CADDIS), Minnesota Pollution Control Agency's (MPCA's) biological Total Maximum Daily Load (TMDL) protocols, and a weight of evidence analysis.

The results of the Stressor Identification analysis pointed to probable stressors in each of the impaired reaches which include:

Dry Wood Creek

- Low dissolved oxygen (DO) concentrations
- High phosphorus
- High nitrate concentrations
- High turbidity
- Lack of habitat availability
- Altered hydrologic regime

Unnamed Creek

- High nitrate concentrations
- Altered hydrologic regime

Pomme de Terre River, *Barrett Lake to North Pomme de Terre Lake* (Upper PdT)

- Low DO concentrations
- Lack of connectivity due to impoundments
- Lack of habitat availability
- Altered hydrologic regime

Pomme de Terre River, *Perkins Lake to Muddy Creek* (Middle PdT)

- Lack of habitat availability
- Altered hydrologic regime

Pomme de Terre River, *Muddy Creek to Minnesota River* (Lower PdT)

- High nitrate concentrations
- Lack of habitat availability
- Altered hydrologic regime

This process identifies areas of more research to better fully understand the impacts to the biological community. Recommendations are also developed to help direct restoration or protection efforts in this watershed.

Introduction

The Pomme de Terre River watershed was assessed in 2010 for aquatic recreation, aquatic consumption and aquatic life beneficial uses. Based on this investigation, it was determined that five stream reaches were determined to be impaired for fish and/or invertebrates, as part of the aquatic life use designation. Three of the impaired reaches are on the mainstem Pomme de Terre River beginning at the outlet of Barrett Lake and continuing to the confluence with the Minnesota River at Marsh Lake. The other two impaired reaches are tributaries to the Pomme de Terre River: Unnamed Creek and Dry Wood Creek. This report connects the biological community to the stressor(s) causing the impairments. Stressors are those factors that negatively impact the biological community. Stressors can interact with each other and can be additive to the stress on the biota. The Pomme de Terre 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 U.S. EPA's Stressor Identification process (SID), for identifying probable causes of impairment in a particular system (Figure 1). In the Pomme de Terre River watershed, stressors that were examined for possible cause of biotic impairment were low dissolved oxygen, high nitrate-nitrite, excess phosphorus, high turbidity, lack of habitat, lack of connectivity, 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 biological assessment data indicating that a biological impairment has occurred. Through a review of available data, stressor scenarios are developed that may accurately characterize the impairment, the cause, and the 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).

SID draws upon a broad variety of disciplines, such as aquatic ecology, geology, geomorphology, 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.

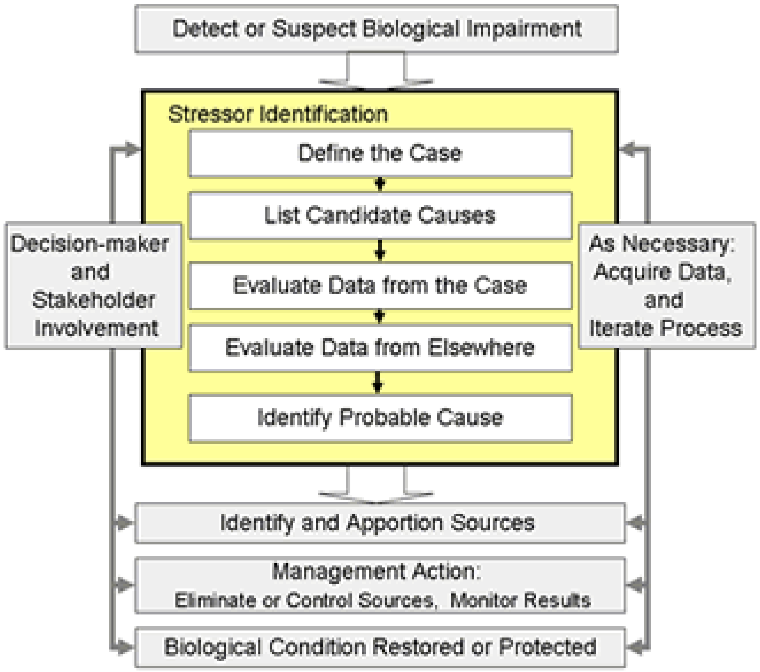

Figure 1. Conceptual model of stressor identification (SID) process

Completion of the SID process does not result in a finished Total Maximum Daily Load (TMDL) study. The product of the SID process is the identification of the stressor(s) for which the TMDL load allocation will be developed. In other words, the SID process may help investigators nail down excess fine sediment as the cause of biological impairment, but a separate effort is then required to determine the TMDL and implementation goals needed to restore the impaired condition.

Report Format

The SID report follows a format to first summarize candidate stressors. Within the summary, there is information about how the stressor relates to the Pomme de Terre River Watershed broadly, standards and ecoregion norms, effects on biology, and sources and causal pathways.

The second section is organized by watershed unit and impaired AUID.

Stations

Stations identified in Figure 2 were primarily for water chemistry collection. Figure 3 shows the biological stations and associated field codes. These locations may be co-located with the chemistry station near a road crossing and the biological station. Please see the Appendix A. Water monitoring stations in the Pomme de Terre River Watershed with nearby biological stations. For exact location of water chemistry sites and see Appendix 2 in the Pomme de Terre River Watershed Monitoring and Assessment Report for biological monitoring station locations.

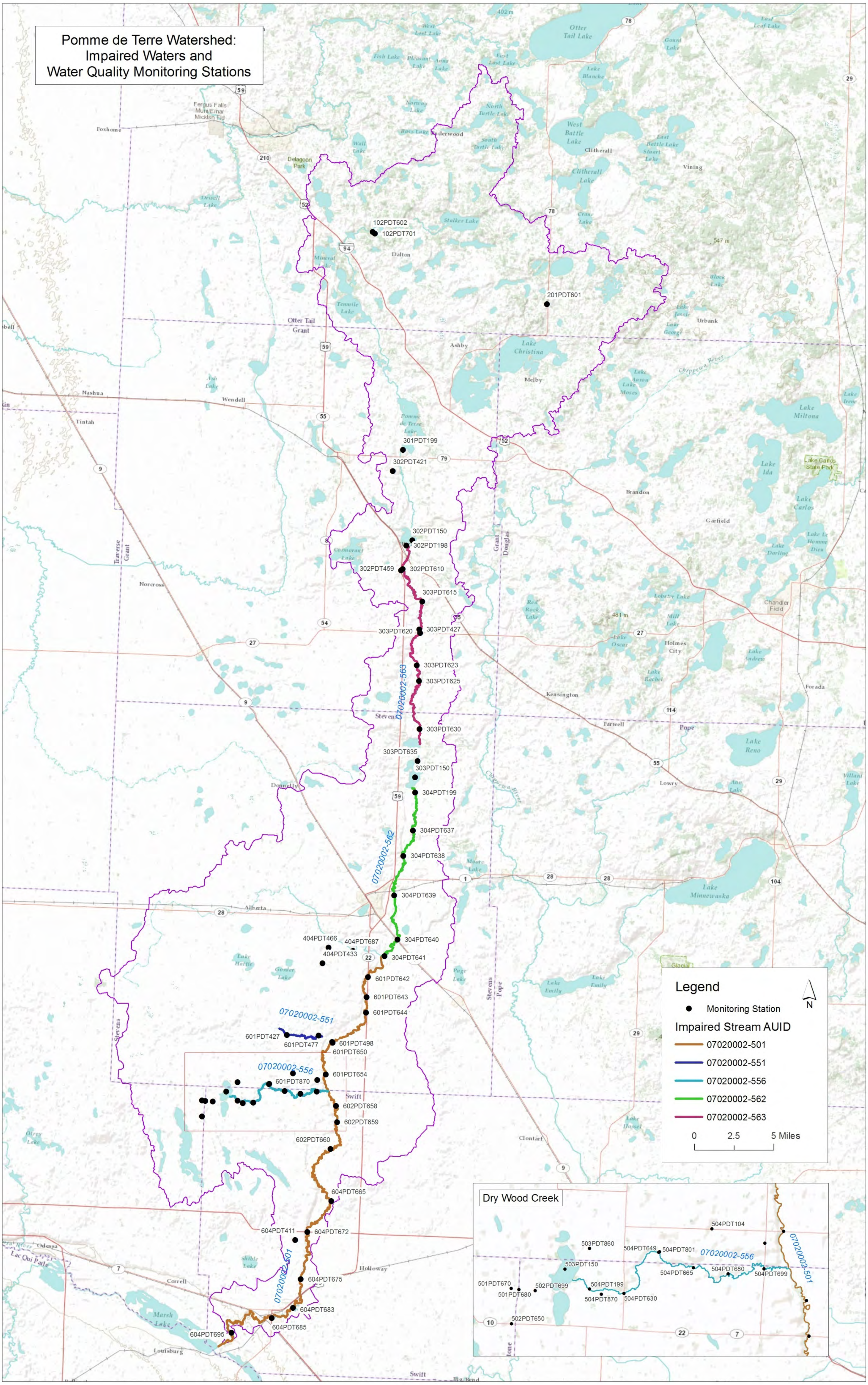

Figure 2. Map of water chemistry stations

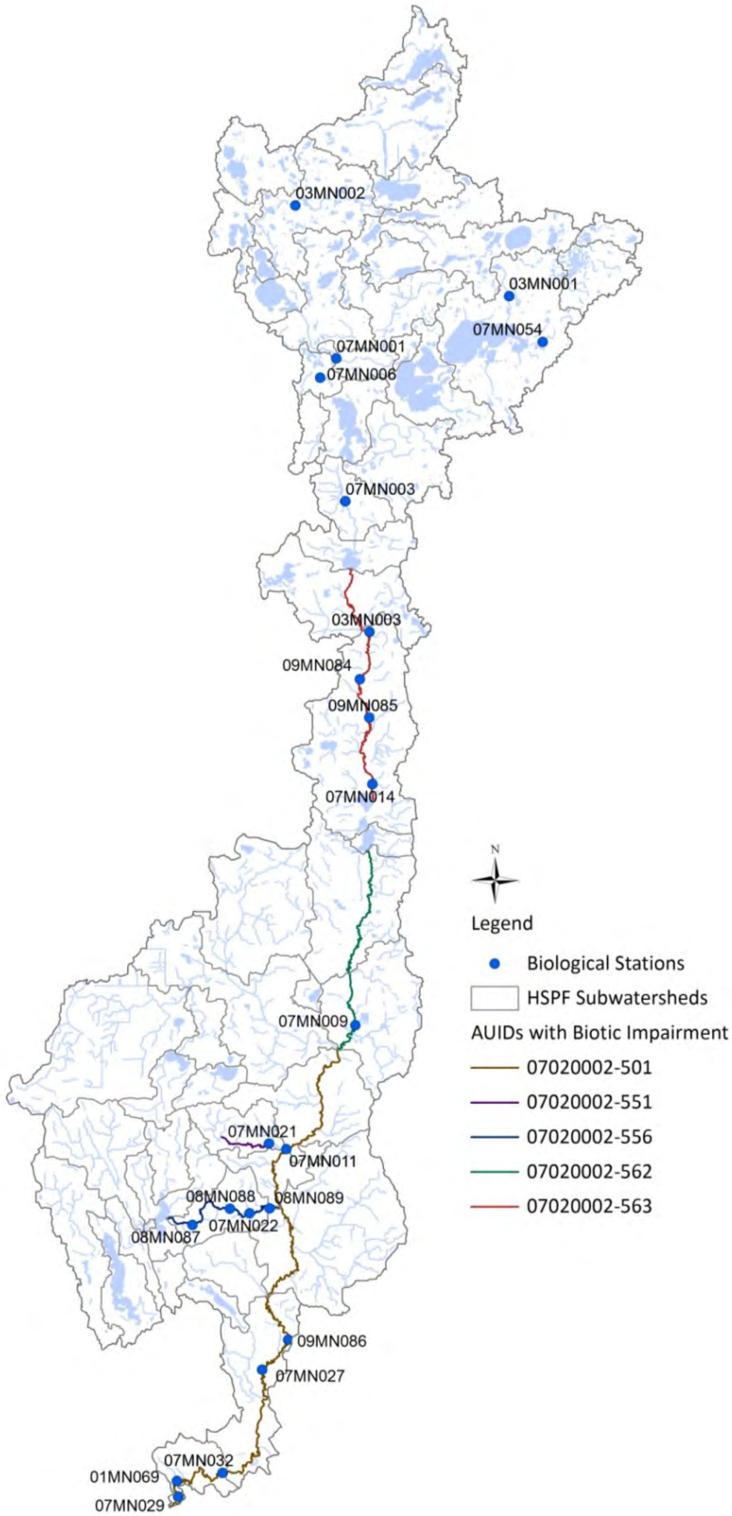

Figure 3. Map showing relevant biological stations in the Pomme de Terre River watershed with respect to the impaired AUIDs and HSPF subwatersheds

Summary of Biological Impairments

As part of the aquatic life use portion of the assessment fish and macroinvertebrates were assessed. The fish and macroinvertebrates within each Assessment Unit Identification (AUID) were compared to a regionally developed threshold and confidence interval and utilized a weight of evidence approach. Five AUIDs are currently impaired for a lack of biological assemblage (Figure 4). The data that was considered during the assessment process was collected from 1999 to 2008. Of the five listed AUIDs, two are impaired for both fish and macroinvertebrates (Dry Wood Creek and Pomme de Terre River from Muddy Creek to Minnesota River) and the other three are impaired for only fish (Unnamed tributary and two reaches of the Pomme de Terre River from Barrett Lake to Muddy Creek).

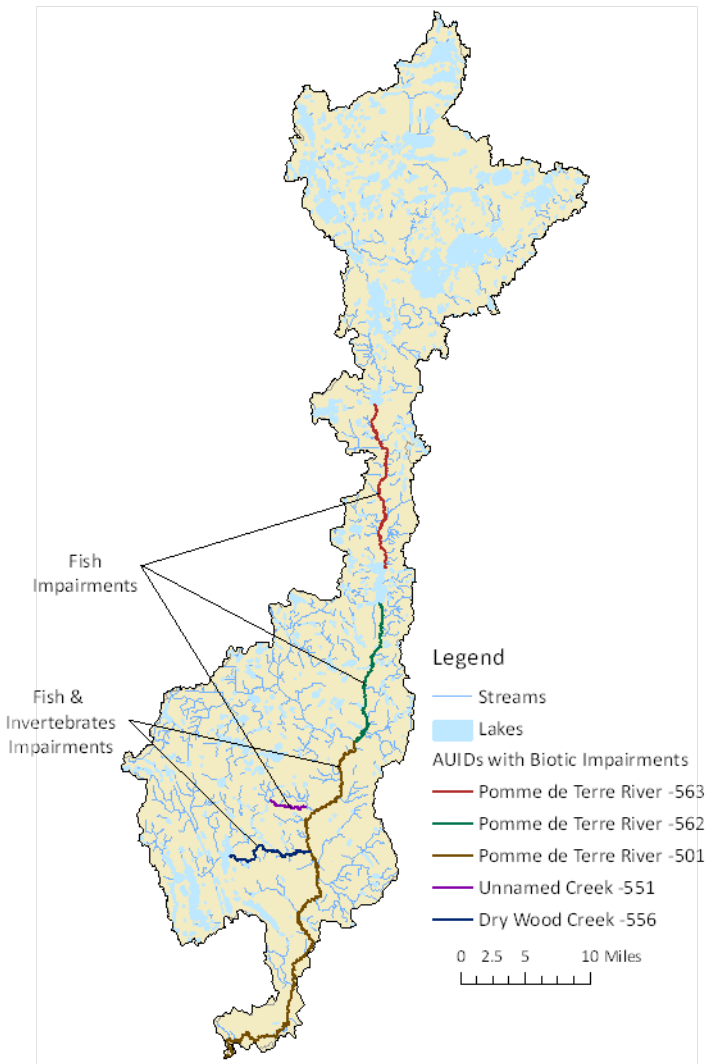

Figure 4. Map of the Pomme de Terre River watershed showing AUIDs with biological impairments

The fish and invertebrate thresholds and confidence limits are shown by class in Table 1. More information on classes (based on geographical area, drainage area and gradient) for fish and invertebrates can be found in the appendix. Table 2 shows the fish invertebrate IBIs 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 Table 3.

Each IBI is made up of a fish or invertebrate metric that is based on community structure and function and produces a metric score. The number of metrics that make up an IBI will determine the metric score scale. For example, an IBI with 8 metrics would have a scale from 0 - 12.5 and an IBI with 10 metrics would have a scale from 0 -10.

Table 1. Fish and invertebrate IBI thresholds and confidence limits

Class	Class Name	Fish IBI Thresholds	Upper CL	Lower CL
1	Southern Rivers	39	50	28
2	Southern Streams	45	54	36
3	Southern Headwaters	51	58	44

Class	Class Name	Invertebrate IBI Thresholds	Upper CL	Lower CL
2	Prairie Forest Rivers	30.7	41.5	19.9
5	Southern Streams RR	35.9	48.5	23.3
7	Prairie Streams GP	38.3	51.9	24.7

Table 2. Fish and invertebrate IBI scores by biological station within AUID with descriptive color

AUID & Reach	Station	Year	Fish IBI Score	Fish class	Invertebrate IBI Score	Invertebrate class
7020002-563	03MN003	2003	18	1	39.33	7
	03MN003	2007	27 31	1	54.82 57.54	7
Pomme de Terre River (Barrett Lk to N. PdT Lk)	03MN003	2009	36	1	40.87	7
	09MN084	2009	34	1	48.42	7
	09MN085	2009	40	1	32.99	5
	07MN014	2007	45	1	44.25	7
07020002-562 Pomme de Terre River (Perkins Lk to Muddy Ck)	07MN009	2007	37	1	44.65	7
07020002-551 Unnamed Creek	07MN021	2007	2	3	NA	NA
07020002-556	08MN087	2008	32	2	7.54	5
	08MN088	2008	40	2	10.87	7
Dry Wood Creek (Dry Wood Lk to PdT R)	07MN022	2007	18	2	11.95	7
	07MN022	2008	30	2	30.08	7
	08MN089	2008	46	2	16.74	5
07020002-501	07MN011	2007	41	1	32.85	2
	09MN086	2009	47	1	28.11	2
	07MN027	2007	39	1	25.15	2
Pomme de Terre River (Muddy Ck to Minnesota R)	07MN027	2009	42	1	32.32 27.93	2
	07MN032	2007	45	1	33.92	2
	01MN069	2001	54	1	NA	2
	01MN069	2009	50	1	34.6	2
	07MN029	2007	36	1	40.55	2

Table 3. IBI descriptors by color

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	NA = Not Available

Hydrological Simulation Program - FORTRAN (HSPF) Model

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

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

Within the Pomme de Terre River watershed, sediment and flow simulated output were used for analysis. The subwatersheds are numbered and shown in Figure 5 along with the impaired reaches for biology.

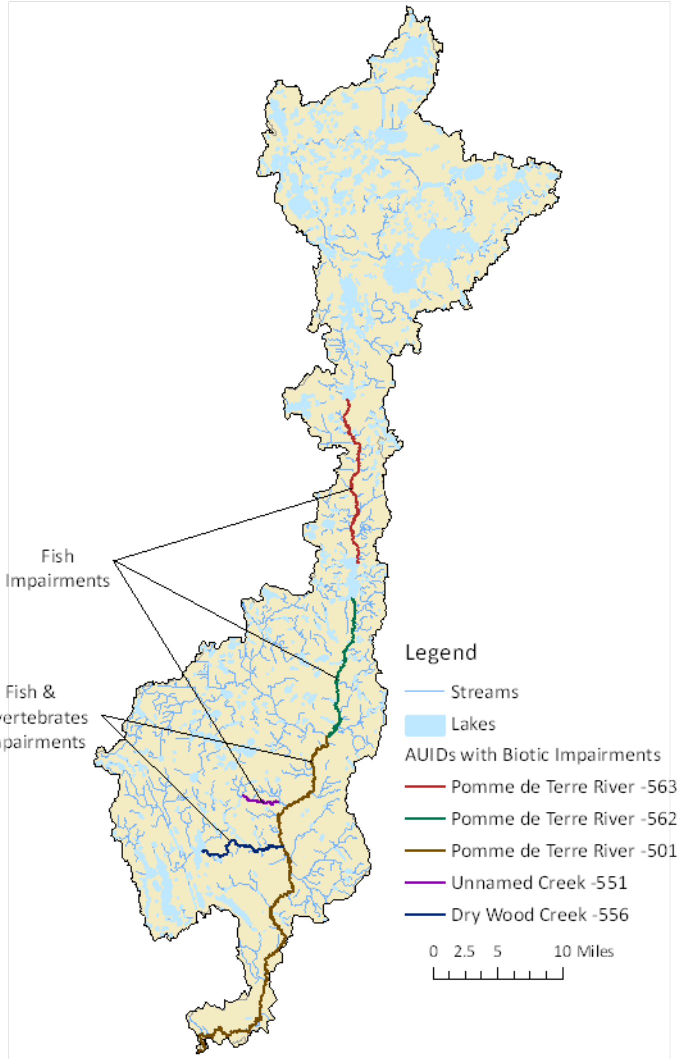

Figure 5. Map of numbered HSPF subwatersheds with biologically impaired reaches

Geomorphic Study of Select Locations

Geomorphic studies were completed on the Pomme de Terre River during the 2009 and 2010 summer field seasons. The purpose of these studies was to collect baseline data on the dimension, pattern, and profile of the river and its tributaries, to assess river stability and sediment supply, to relate the findings to water quality and biological impairments, and to suggest potential restoration activities in the locations where they would be most effective.

Five reaches of the Pomme de Terre River were assessed by Pomme de Terre Watershed, MPCA, DNR, and MCC staff from kayaks on four dates during the summer and early fall of 2009. Locations and dates for these reconnaissance assessments are shown in Table 6. These assessments roughly covered the area between Barrett Lake and the chain of lakes and from above Highway 12 to the mouth of the river at Marsh Lake. The goals of the recon surveys included collecting data on stream condition, including stream classification, bank erosion potential, stream habitat condition, riparian condition, indices of stream stability, identification of representative areas for collection of additional data, and identification of potential problem and restoration areas.

Figure 6. Geomorphology reconnaissance stations

The procedure for estimating bank erosion rates and total erosion during the reconnaissance portion of our investigation was a modified version of the “Bank Assessment for Non-point source Consequences of Sediment” (BANCS) model (Rosgen, 1996, 2001b, 2006b). This empirical model uses the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) erosion estimation tools. Visual estimates of the BEHI were made as we traveled downstream for stream banks where erosional processes were observed. Waypoints and photographs were collected along with bank height and length measurements using laser range finders and waypoint information. NBS was estimated through analysis of aerial photos using method 2, found in the River Stability Field Guide. 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 (Figure 7). The annual streambank erosion rate can then be estimated using the BEHI and NBS ratings, and known erosion rates using those relationships. We used known erosion rates from North Carolina, Colorado, and Yellowstone National Park data to estimate a range of possible erosion rates for our study. As we validate more of these erosion rates with bank studies we will develop local erosion rate relationships with BEHI and NBS estimates, which will greatly strengthen our estimates.

Other reconnaissance tasks included; 1) determining bankfull indicators and relative bankfull elevation, 2) estimating the degree of channel incision by comparing bankfull elevation with low bank elevation, 3) determining stream classification to describe the reach, and 4) identifying potential fluvial geomorphology assessment stations, and 5) identifying possible problem areas.

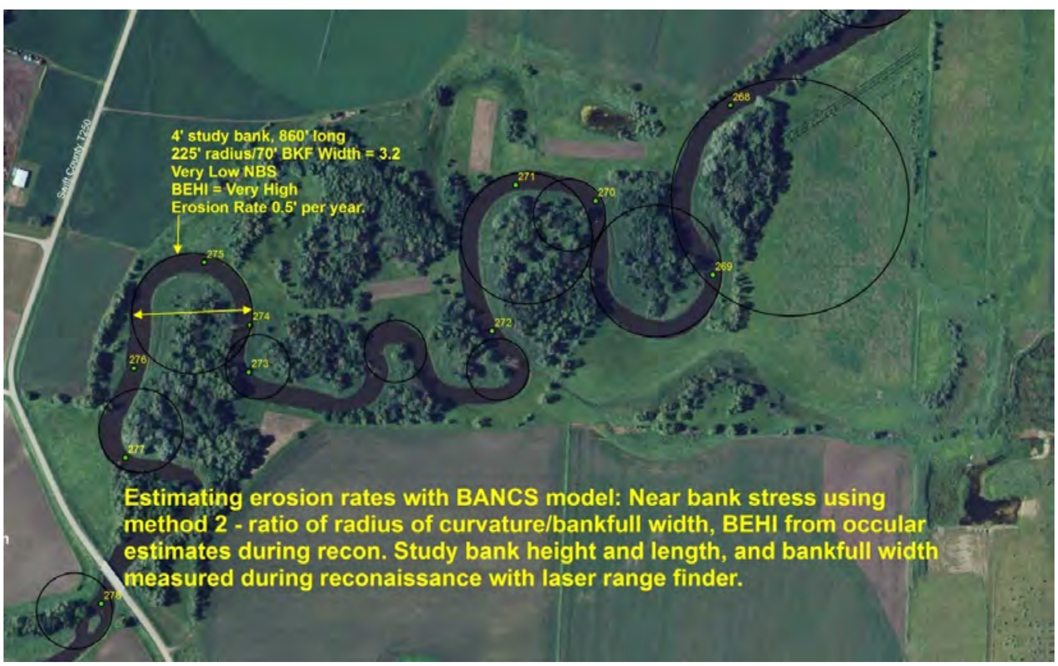

Figure 7. Example of methodology used to estimate erosion rates with BANCS model

Stream reaches were subjected to more intensive geomorphic assessments at 13 locations on the Pomme de Terre and tributaries (Figure 8). These assessments followed the procedures outlined in the “River Stability Field Guide” (Rosgen 2008) levels I-IV. Level I assessment procedures were completed during field reconnaissance including broad level stream classification and valley classification. Level II tasks included cross sections, longitudinal profiles, pebble counts, hydraulic relations, level II stream classification, morphological descriptions, and dimensionless ratios. Level III procedures included the prediction of annual streambank erosion rates using the BANCS empirical model (uses the Bank Erosion Hazard Index and Near Bank Stress). Level IV procedures included the validation of streambank erosion rates by setting up study banks with bank and bed pins and measuring actual annual erosion rates to start to develop local bank erosion relationships.

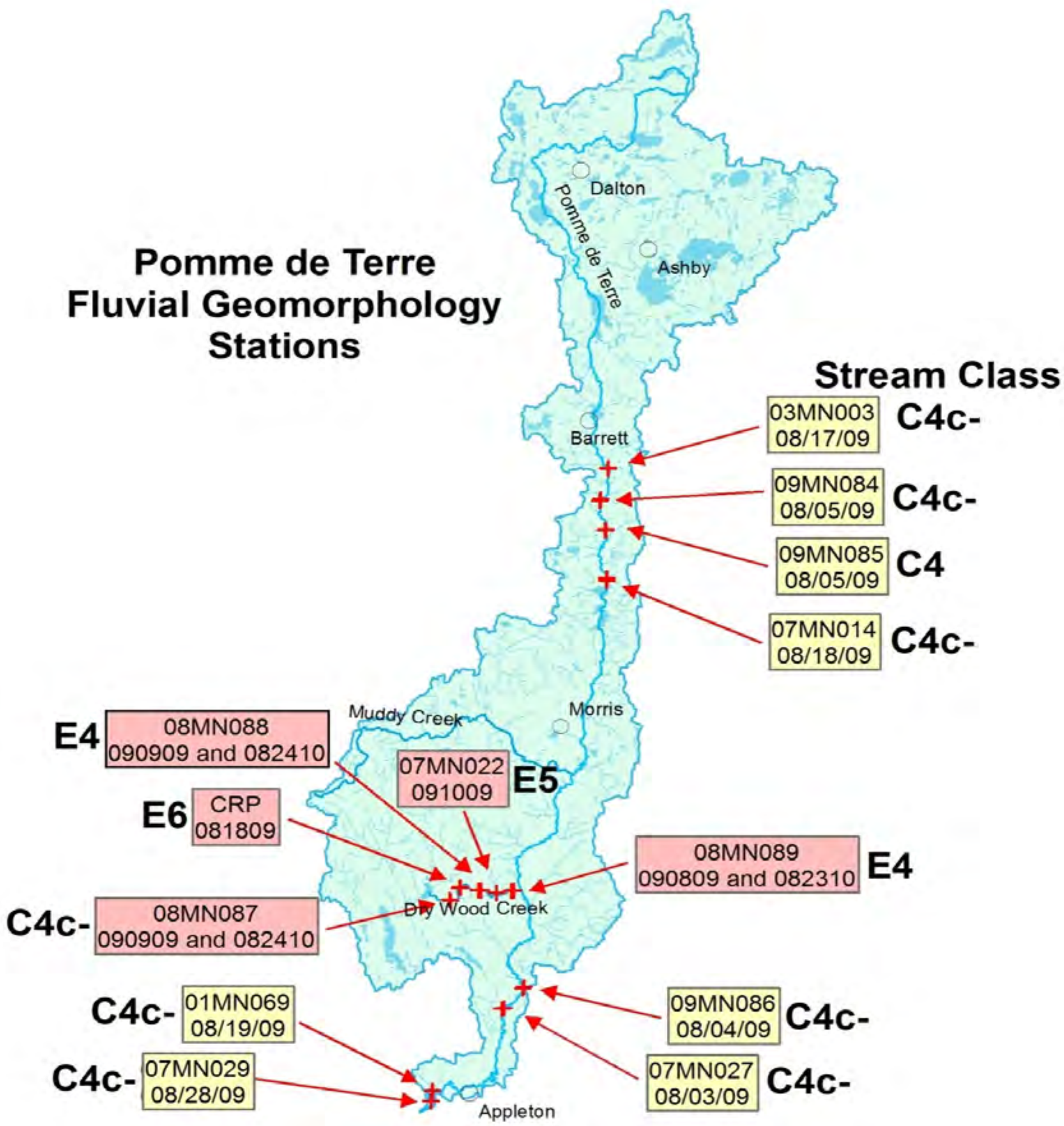

Figure 8. Fluvial geomorphology stations and classifications

Candidate Cause: Dissolved Oxygen

Dissolved oxygen (DO) 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). DO 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 dissolved oxygen concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995). Some invertebrates that are intolerant to low levels of dissolved oxygen include mayflies, stoneflies and caddisflies (Marcy, 2007). Many species of fish avoid areas where dissolved oxygen concentrations are below 5 mg/L (Raleigh et al., 1986). Additionally, fish growth rates can be significantly affected by low dissolved oxygen 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 baseflow. As temperatures increase, the saturation levels of dissolved oxygen decrease. Increased water temperature also raises the dissolved oxygen needs for many species of fish (Raleigh et al., 1986). Low dissolved oxygen 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 dissolved oxygen 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 dissolved oxygen data is available throughout the watershed and can be used as an initial screening for low dissolved oxygen. 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 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)

A series of longitudinal synoptic dissolved oxygen surveys were conducted throughout the Pomme de Terre River Watershed in 2010. A synoptic monitoring approach aims to gather data across a large spatial scale and minimal temporal scale. In terms of dissolved oxygen, the objective was to sample a large number of sites from upstream to downstream under comparable ambient conditions. For the most part, the surveys took place in mid to late summer when low dissolved oxygen is most commonly observed. Dissolved oxygen readings were taken at pre-determined sites in the early morning in an attempt to capture the daily minimum DO reading.

Diurnal (Continuous)

YSI sondes were deployed for 3-16 day intervals throughout the watershed in late summer to capture diurnal fluctuations over the course of a number of diurnal patterns. This information was then used to look at the diurnal flux of DO along with the patterns of DO fluctuation.

Overview of Dissolved Oxygen in the Pomme de Terre River Watershed

Dissolved oxygen was measured throughout the watershed. Lower PdT did not have any low DO measurements (i.e. below the minimum standard of 5 mg/l) during this study. Similarly, the unnamed creek to the Pomme de Terre River did not have any indication of low dissolved oxygen. The Middle PdT had one low measurement of dissolved oxygen, 3.21 mg/L on July 20, 2010 at 7:25 am, which was the only measurement below the DO standard on this AUID.

Two reaches in the watershed were investigated further to see if DO was affecting the biotic communities: Upper PdT and Dry Wood Creek.

Sources and Causal Pathways Model for Low Dissolved Oxygen

Dissolved oxygen concentrations in lotic 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 dissolved oxygen regime of a waterbody. Agricultural and urban land-uses, impoundments (dams), and point-source discharges are just some of the anthropogenic factors that can cause unnaturally high, low, or volatile DO concentrations. The conceptual model for low dissolved oxygen as a candidate stressor in the Pomme de Terre River watershed is modeled at [EPA's CADDIS Dissolved Oxygen webpage].

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 invertebrates (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).

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 Pomme de Terre watershed that are impaired for biota are classified as Class 1 streams. Minnesota currently does not have a nitrate standard for other waters of the state besides for class 1.

Ecoregion Data

McCollor & Heiskary (1993) developed a guidance of stream parameters by ecoregion for Minnesota streams. The Pomme de Terre River Watershed encompasses portions of three ecoregions: North Central Hardwood Forest (NCHF), Northern Glaciated Plains (NGP), and a small portion of Western Corn Belt Plains (WCBP). The annual 75th percentile nitrate-N values where used for comparison (Table 4). The majority of the Pomme de Terre (from Muddy Creek to the Minnesota River) is within NGP and only 3.2 square miles are within WCBP. For ease in analysis, the NGP is used.

Table 4. Ecoregions in the Pomme de Terre with the associated annual 75 percentile nitrate-nitrite level

Ecoregion	75 Percentile value (mg/L)
North Central Hardwood Forest (NCHF)	0.28
Northern Glaciated Plains (NGP)	0.52
Western Corn Belt Plains (WCBP)	6.9

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 oxidizing to nitrate. The water samples collected were analyzed for nitrate-N at a Minnesota Department of Health certified lab. Additionally, nitrate and nitrite concentrations were measured, individually, in Dry Wood Creek through the use of field HACH test strips as an estimation of duration associated with elevated nitrate levels.

Nitrate and Nitrite in the Pomme de Terre River Watershed

Calculations of the Pomme de Terre River's nitrate plus nitrite-nitrogen loads indicate yearly increases from 2007-2009 (see Pomme de Terre River Watershed Monitoring and Assessment Report for more information). In 2008, snowmelt, rain events and baseflow conditions were targeted within the Dry Wood Creek watershed. In 2009 and 2010, the focus expanded to the entire watershed with particular interest in the areas with biotic impairments. Nitrate concentrations during those targeted sampling times are shown in Figure 10. Nitrate levels in Dry Wood Creek, an unnamed tributary and the Pomme de Terre River were found to be elevated (above 5mg/l) at least once during targeted sampling.

Throughout much of the watershed, elevated levels of nitrate were measured during 2008 – 2010 snowmelt events. Some monitored agricultural ditches that drain to minor tributaries and the Pomme de Terre River had particularly high nitrate levels, such as 504PDT801 (agricultural or open ditch draining directly to Dry Wood Creek), which had 18 mg/L nitrate on April 15, 2008. The 2010 rain event showed a variable pattern of nitrate levels throughout the watershed with higher levels generally occurring in the unnamed tributary and ditches draining to Dry Wood Creek.

Meador and Carlisle (2007) derived tolerance indicator values (TIVs) for common fish species of the U.S.). The species in the Pomme de Terre River watershed were compared with the TIVs, and quartiled for comparison. The first quartile species are more sensitive to nitrate while the fourth quartile species are less sensitive to nitrate (some fish did not have tolerance data available, (Table 5). Figure 9 shows the 2007 fish quartiled by weighted averages for the impaired reaches in the Pomme de Terre River watershed.

Table 5. Pomme de Terre River fish quartered based on weighted averages (WA) for nitrate (Meador and Carlisle, 2007).

1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
CommonName	*WA*	*CommonName*	*WA*	*CommonName*	*WA*	*CommonName*	*WA*
bowfin	0.3	hornyhead chub	0.87	common shiner	1.28	blackside darter	1.74
golden shiner	0.44	central stoneroller	0.88	pumpkinseed	1.31	yellow bullhead	1.77
logperch	0.47	black crappie	0.98	rock bass	1.32	spotfin shiner	1.81
mimic shiner	0.53	brown bullhead	0.99	spottail shiner	1.32	bluntnose minnow	1.96
tadpole madtom	0.68	northern pike	1.03	shorthead redhorse	1.35	common carp	2.45
yellow perch	0.7	channel catfish	1.04	green sunfish	1.42	sand shiner	2.46
largescale stoneroller	0.72	freshwater drum	1.04	white bass	1.43	fathead minnow	2.57
banded darter	0.79	johnny darter	1.04	emerald shiner	1.47	white sucker	2.6
silver redhorse	0.79	largemouth bass	1.15	stonecat	1.49	black bullhead	2.61
bluegill	0.8	creek chub	1.21	golden redhorse	1.55	orangespotted sunfish	2.66
walleye	0.81						

Sensitive to Nitrate → Less Sensitive to Nitrate

Tolerance Data Not Available			
Common Name			
banded killifish	brook stickleback	greater redhorse	northern redbelly dace
bigmouth buffalo	carmine shiner	hybrid sunfish	pugnose shiner
blackchin shiner	central mudminnow	Iowa darter	slenderhead darter
blacknose shiner	Gen: redhorses	least darter	trout-perch
brassy minnow			

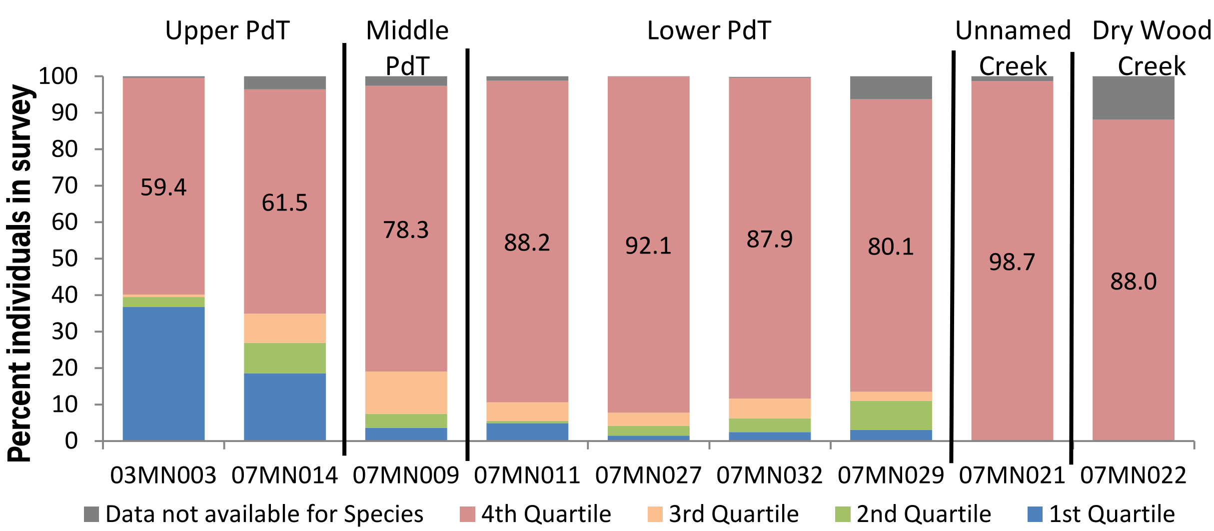

Figure 9. Percent individuals by biological site sampled in 2007 in impaired reaches, for each quartile based nitrate tolerance indicator values, separated by AUID, last three digits shown (Meador and Carlisle, 2007)

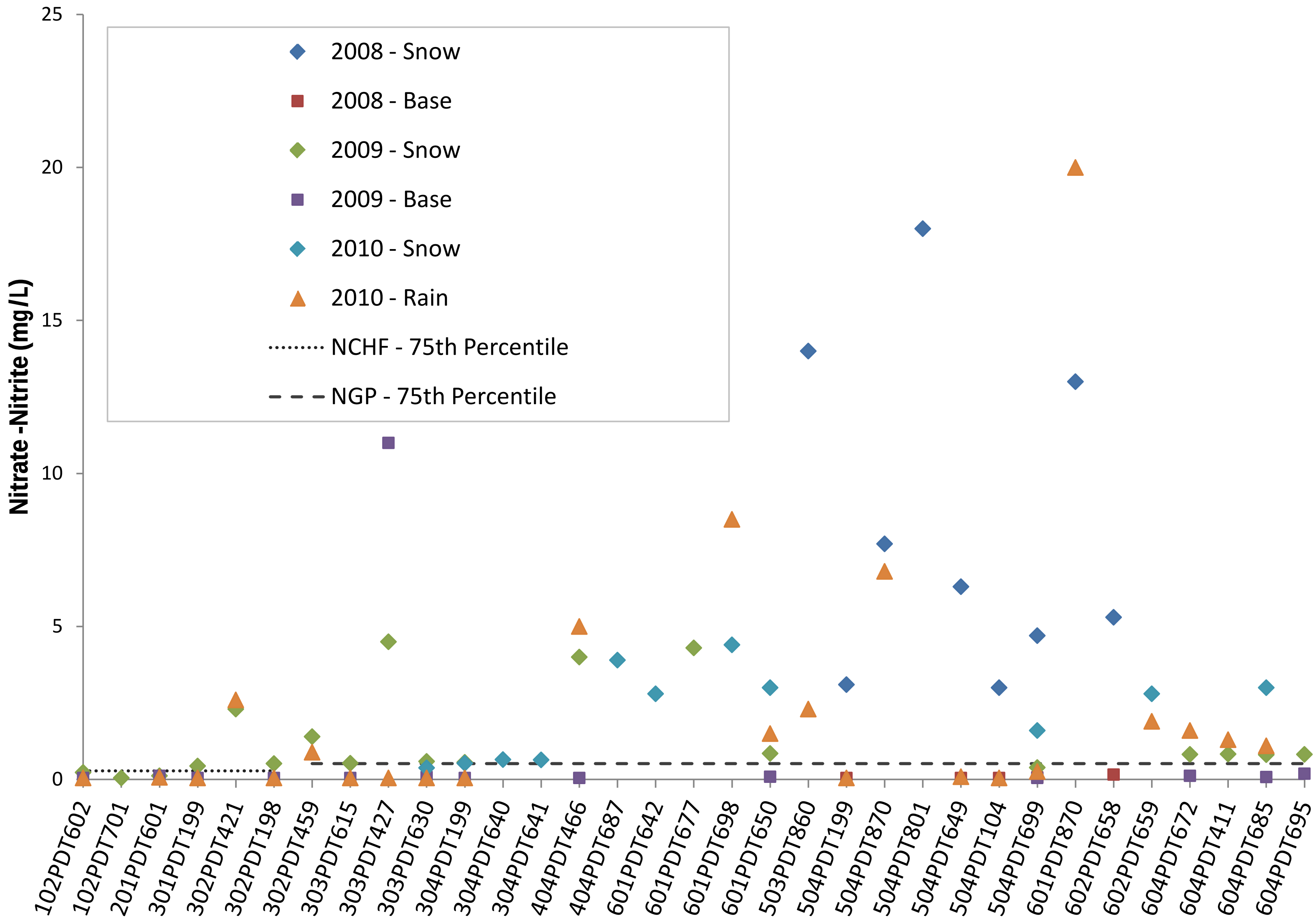

Figure 10. Nitrate-N measurements collected from 2008 to 2010 throughout the Pomme de Terre River watershed

Sources and Causal Pathways Model for Nitrate and Nitrite

The causes and potential sources for nitrate-nitrite in the Pomme de Terre River watershed are modeled in Figure 11. Helsel (1995) reported nitrate concentrations were the highest below agricultural or urban areas. Figure 10 indicates that nitrate concentrations are elevated during snow melt events and rain events. Some of the highest measurements of nitrate were observed in the drainage system to Dry Wood Creek.

Nitrogen is commonly applied as a crop fertilizer. Over half of the Pomme de Terre watershed is comprised of cropland (Table 6); it is likely that various forms of nitrogen including nitrate and ammonia are being applied to the cropland throughout the watershed. The specific timing and rate of nitrogen fertilizer application is unknown, but nitrogen isotopes could assist in the source identification of excess nitrate in future monitoring.

There has been limited ambient groundwater monitoring in the agricultural portion of the watershed. The Minnesota Department of Agriculture has three monitoring wells with nitrate data available. The concentrations of nitrate (as N) found in these three wells ranged from none detected to 24 mg/L, which is more than double the state drinking water standard.

Table 6. Summarized landcover data from 2009 NASS Landcover Profile for select watersheds encompassing biotic impairments

	Unnamed Creek (07020002-551)		Dry Wood Creek: Dry Wood Lake to Pomme de Terre River (07020002-556)		Pomme de Terre: Barrett Lake to North Pomme de Terre Lake (07020002-563)		Pomme de Terre: Perkins Lake to Muddy Creek (07020002-562)		Pomme de Terre: Muddy Creek to Minnesota River (07020002-501)	
Land Cover	**ACRES**	**PERCENT**	**ACRES**	**PERCENT**	**ACRES**	**PERCENT**	**ACRES**	**PERCENT**	**Acres**	**Percent**
Cropland	3,584.0	82.32%	43,091.1	69.75%	87,129.2	34.19%	118,271.0	38.36%	298,354.5	53.24%
Water	14.7	0.34%	4411	7.14%	38,046.4	14.93%	40,774.9	13.22%	50,212.7	8.96%
Grassland	235.6	5.41%	3,643.7	5.90%	57,758.1	22.66%	67,241.6	21.81%	88,140.5	15.73%
Forestland	33.3	0.77%	609.9	0.99%	35,062.9	13.76%	36,070.3	11.70%	38,934.4	6.95%
Developed	278.2	6.39%	3,883.9	6.29%	18,354.8	7.20%	23,838.2	7.73%	42,413.8	7.57%
Wetland	207.7	4.77%	6,139.7	9.94%	18,348.6	7.20%	21,907.8	7.10%	41,931.8	7.48%
NoData/Barre	0	0.00%	2.3	0.00%	168.2	0.07%	246.4	0.08%	388.2	0.07%
TOTAL	4,353.5	100.00%	61,781.5	100.00%	254,868.1	100.00%	308,350.2	100.00%	560,375.9	100.00%

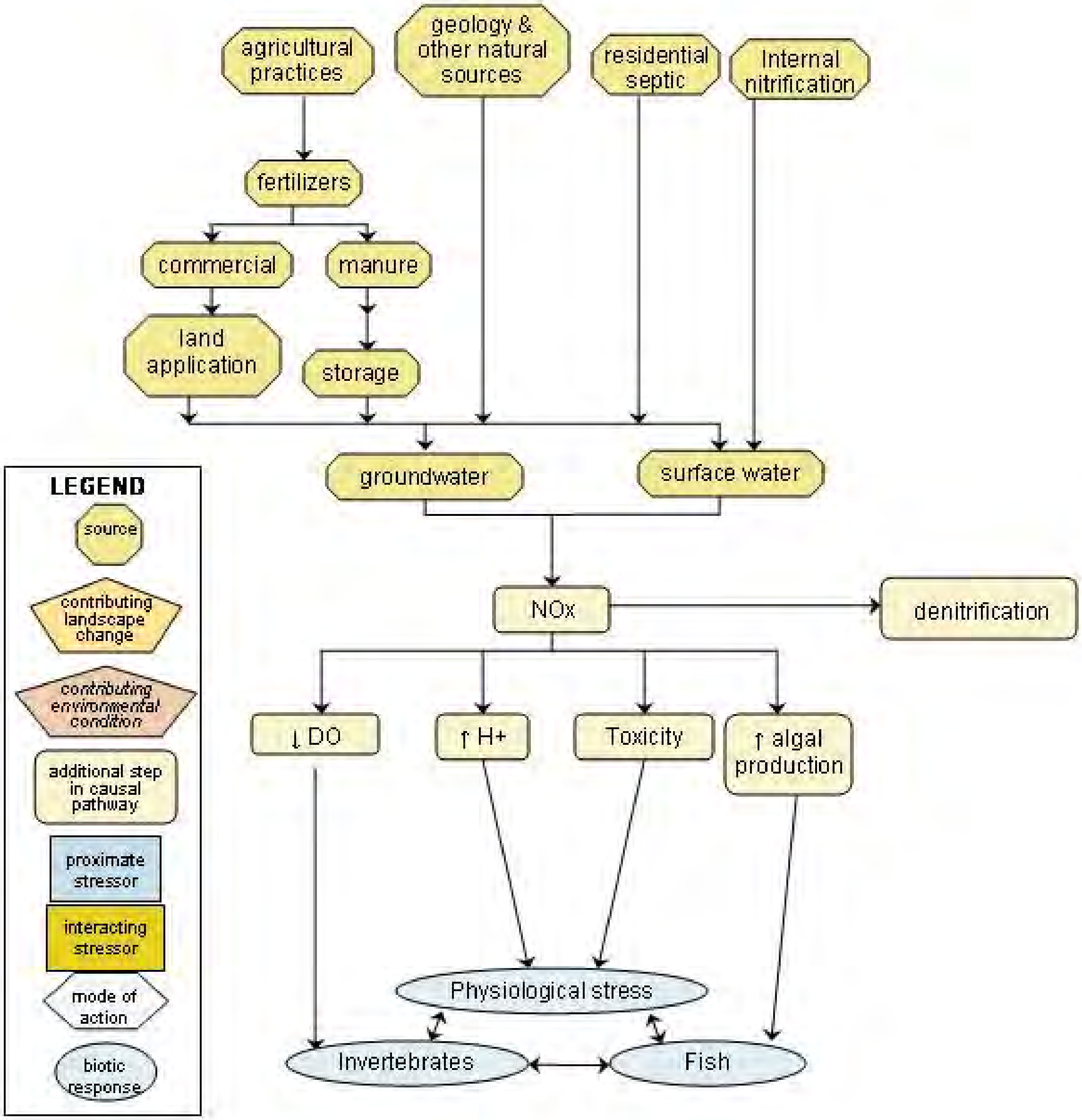

Figure 11. Conceptual model for nitrate stressor on the biotic community

Candidate Cause: Excess Phosphorus

Phosphorus is an essential nutrient for all aquatic life, but elevated phosphorus concentrations can result in an imbalance which can impact stream organisms. Excess phosphorus does not result in direct harm to fish and invertebrates. Rather, its detrimental effect occurs as it alters other factors in the water environment. Dissolved oxygen, pH, water clarity, 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 0.15 mg/l with at least one response variable for the lower Pomme de Terre River. For more information, please reference the Pomme de Terre River Watershed Monitoring and Assessment Report.

Phosphorus in the Pomme de Terre River Watershed

As stated in the Pomme de Terre River Assessment report, total phosphorus concentrations have decreased in the Pomme de Terre River in Appleton, but it has exceeded the draft nutrient standard 91, 63, and 48 percent of the time in 2007, 2008 and 2009, respectively. Measured phosphorus concentrations exceeding the standard have been identified in the reaches of Pelican Creek, Lower PdT, and Dry Wood Creek, with the latter two also impaired for fish and invertebrates described further in this section. Pelican Creek has elevated levels of phosphorus, but it is not described further in this document.

Sources and Causal Pathways for Excess Phosphorus

Phosphorus is delivered to streams by wastewater treatment facilities, urban stormwater, agriculture, and direct discharges of sewage. The causes and potential sources for excess phosphorus in the Pomme de Terre River watershed are modeled at EPA's CADDIS Nutrients webpage. As stated previously, much of the watershed is agricultural, particularly in the lower sections where phosphorus concentrations are often elevated. Dry Wood Lake and the watershed inputs to the lake are major contributors of excess phosphorus to Dry Wood Creek.

Candidate Cause: Turbidity

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

Water Quality Standards

The water quality standard for turbidity is 25 Nephelometric Turbidity Units (NTUs) for Class 2b waters. Total suspended solids and transparency tube measurements can be used as surrogate standard. A regression of the Total Suspended Solids to turbidity indicates impairment at 60 mg/L for waters within the Northern Glaciated Plains Ecoregion.

Turbidity is a measure of reduced transparency that can increase due to suspended particles such as sediment, algae and organic matter. Minnesota currently has a turbidity standard of 25 Nephelometric Turbidity Units (NTU) for protection of aquatic life.

A strong correlation exists between the measurements of TSS concentration and turbidity. In 2010, MPCA released draft Total Suspended Solids (TSS) standards for public comment (Markus). 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. The draft TSS standard for the Pomme de Terre River has been set at 65 mg/L. For assessment, this concentration is not to be exceeded in more than 10 percent of samples within a 10-year data window.

As well as TSS, sestonic algae can 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 (volatile suspended solids – VSS) and by total phosphorus. There are no current standards for either.

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 invertebrate populations.

Turbidity in the Pomme de Terre River Watershed

In 2007 and 2008, 59 and 46 percent of the individual TSS samples, respectively, exceeded the 60 mg/L surrogate standard. In 2009 however, 23 percent of the individual TSS samples exceeded the surrogate standard. During each of the three years, the samples with the highest recorded TSS concentrations were collected during the month of June. Annual TSS loads have shown a constant decline from 2007 to 2009.

A TMDL report for turbidity was submitted to the EPA in 2010 for the downstream section of the Lower PdT and approved in 2011. Dry Wood Creek is also listed for turbidity. More information about the turbidity in the Pomme de Terre River Watershed can be found in the Pomme de Terre River Monitoring and Assessment Report.

Meador and Carlisle (2007) derived tolerance indicator values (TIVs) for common fish species of the U.S.). The species in the Pomme de Terre River watershed were compared with the TIVs, and quartered for comparison (Table 7). The first quartile species are more sensitive to suspended sediment while the fourth quartile species are less sensitive to suspended sediment (some fish did not have tolerance data available) .

Table 7. Pomme de Terre River watershed fish quartiles based on weighted averages (WA) for suspended sediment (Meador and Carlisle, 2007)

1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
CommonName	*WA*	*CommonName*	*WA*	*CommonName*	*WA*	*CommonName*	*WA*
largescale stoneroller	11	golden shiner	30	black crappie	56	spottail shiner	74
silver redhorse	20	pumpkinseed	30	johnny darter	56	black bullhead	76
yellow perch	21	largemouth bass	31	shorthead redhorse	61	channel catfish	81
banded darter	24	tadpole madtom	34	green sunfish	62	emerald shiner	84
bowfin	24	bluegill	36	white sucker	62	common carp	93
mimic shiner	24	golden redhorse	37	stonecat	63	fathead minnow	106
logperch	25	common shiner	38	hornyhead chub	64	sand shiner	111
brown bullhead	26	walleye	45	spotfin shiner	65	freshwater drum	127
rock bass	28	creek chub	46	blackside darter	67	white bass	137
central stoneroller	29	bluntnose minnow	48	yellow bullhead	73	orangespotted sunfish	174
		northern pike	48				

Sensitive to High Suspended Sediment → Less Sensitive to High Suspended Sediment

Tolerance Data Not Available			
CommonName			
banded killifish	brook stickleback	greater redhorse	northern redbelly dace
bigmouth buffalo	carmine shiner	hybrid sunfish	pugnose shiner
blackchin shiner	central mudminnow	Iowa darter	slenderhead darter
blacknose shiner	Gen: redhorses	least darter	trout-perch
brassy minnow			

Sources and Causal Pathways for Turbidity

The causes and potential sources for increases in turbidity in the Pomme de Terre 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 construction, mining, agriculture, or insufficiently vegetated pastures. Decreases in bank stability may also lead to sediment loss from the stream banks, often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, and increases in impervious surfaces. In the Pomme de Terre River watershed, June is often the month in which the highest levels of TSS concentrations are recorded.

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, dissolved oxygen) and will be addressed separately. Fish passage will also be addressed in a separate section.

Physical habitat diversity enables fish and invertebrate 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 by way of resource extraction, agriculture, forestry, silviculture, urbanization, and industry. These landscape alterations can lead to reduced habitat availability, such as decreased riffle habitat; or reduced habitat quality, such as embedded gravel substrates. Biotic population changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (Griffith et al. 2010).

Water Quality Standards

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

Habitat Characteristics in the Pomme de Terre River

Habitat is variable throughout the Pomme de Terre River watershed and is vital in understanding the biological communities. Throughout the Pomme de Terre River watershed, qualitative habitat was measured with the Minnesota Stream Habitat Assessment (MSHA) along with the fish survey Figure 12. 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.

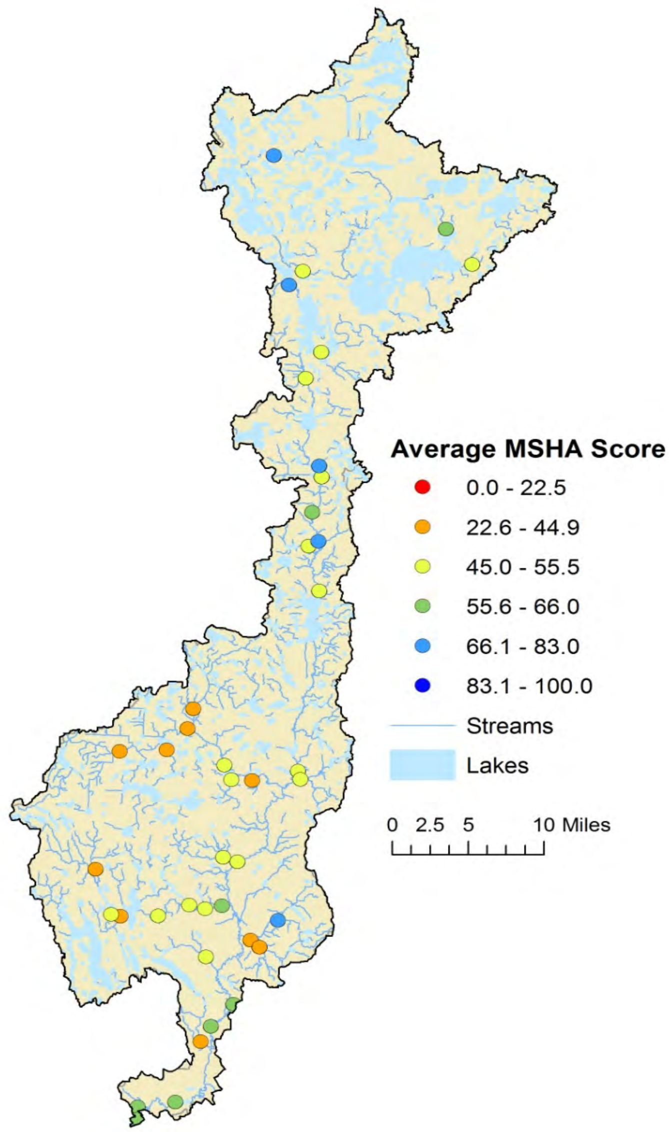

Figure 12. Average MSHA total scores for all biological sites in the Pomme de Terre River watershed

The IBI scores in the Pomme de Terre River watershed have a positive relationship with the total MSHA score (Figure 13). The IBI is comprised of numerous metrics that measure biotic response to various stresses including, but not limited to, habitat.

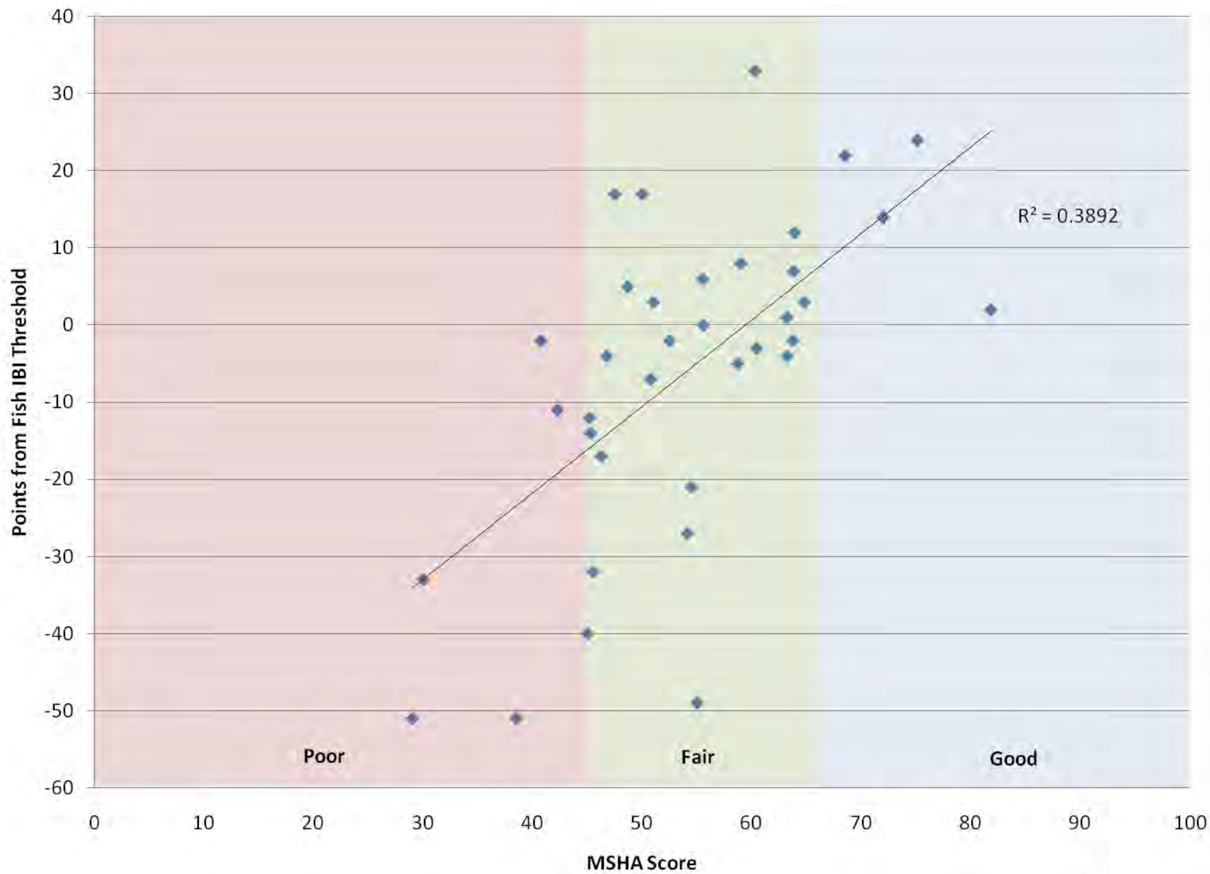

Figure 13. MSHA scores and points above or below fish IBI threshold for all natural channel sites in the Pomme de Terre River watershed

Sources and Causal Pathways Model for Habitat

The causes and potential sources for lack of habitat in the Pomme de Terre River watershed are modeled at [EPA's CADDIS Physical Habitat webpage]. Many riparian areas along the Pomme de Terre River and tributaries are influenced by cattle and row crop agriculture, this in turn decreases 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.

Candidate Cause: Connectivity

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

Dams, both human made and natural, can cause changes in flow, sediment, habitat and chemical characteristics of a waterbody. 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 surrounding (Mitchell and Cunjak, 2007).

Humans have placed dams on the landscape for many reasons including flood control, livestock watering, 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.

Water Quality Standards

There is no applicable water quality standard for connectivity impacts.

Connectivity in the Pomme de Terre River

Connectivity to the Pomme de Terre River watershed was altered in 1938 when the dam on Marsh Lake was constructed and the Pomme de Terre River was rerouted into the lake (Figure 14; Marsh Lake Feasibility Study). The impact of the dam and rerouting blocked fish movement between the Lac qui Parle Lake and the Pomme de Terre River and increased the number of lentic fish species in Marsh Lake.

Eleven dams were built on the Pomme de Terre River (DNR, 2010). Two of these dams have since been removed, one in the city of Appleton, and another just upstream at Highway 12. Fish surveys conducted before and after the removal of the Appleton dam revealed a shift in the fish community from species of black bullheads and common carp to more native riverine species.

Currently, the Pomme de Terre River has nine dams along the mainstem (Figure 15). The dams that are considered fish barriers include the dam in Morris (Figure 16), Perkins Lake (Figure 17), and Rose Lake (DNR, 2003). There are five dams that are considered to be partial fish barriers and include Barrett Lake, Pomme de Terre Lake, Ten Mile Lake, old rough fish barrier at mile 110 from mouth, and Stalker Lake.

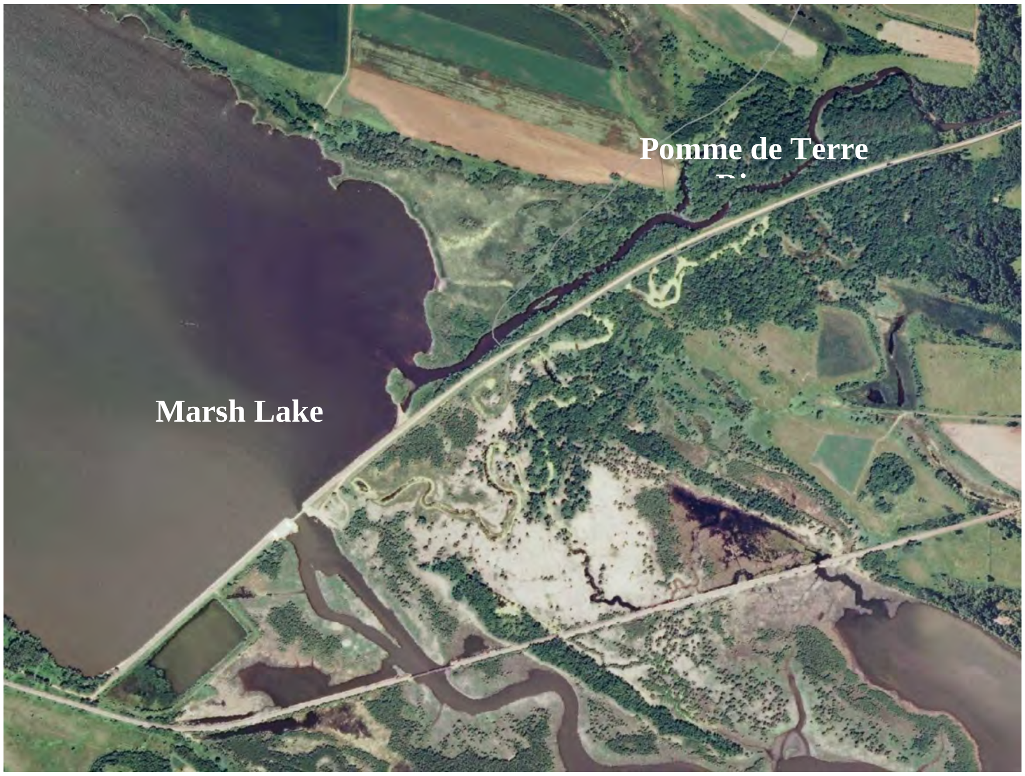

Figure 14. Aerial photograph of the mouth of the Pomme de Terre River to Marsh Lake on the Minnesota River

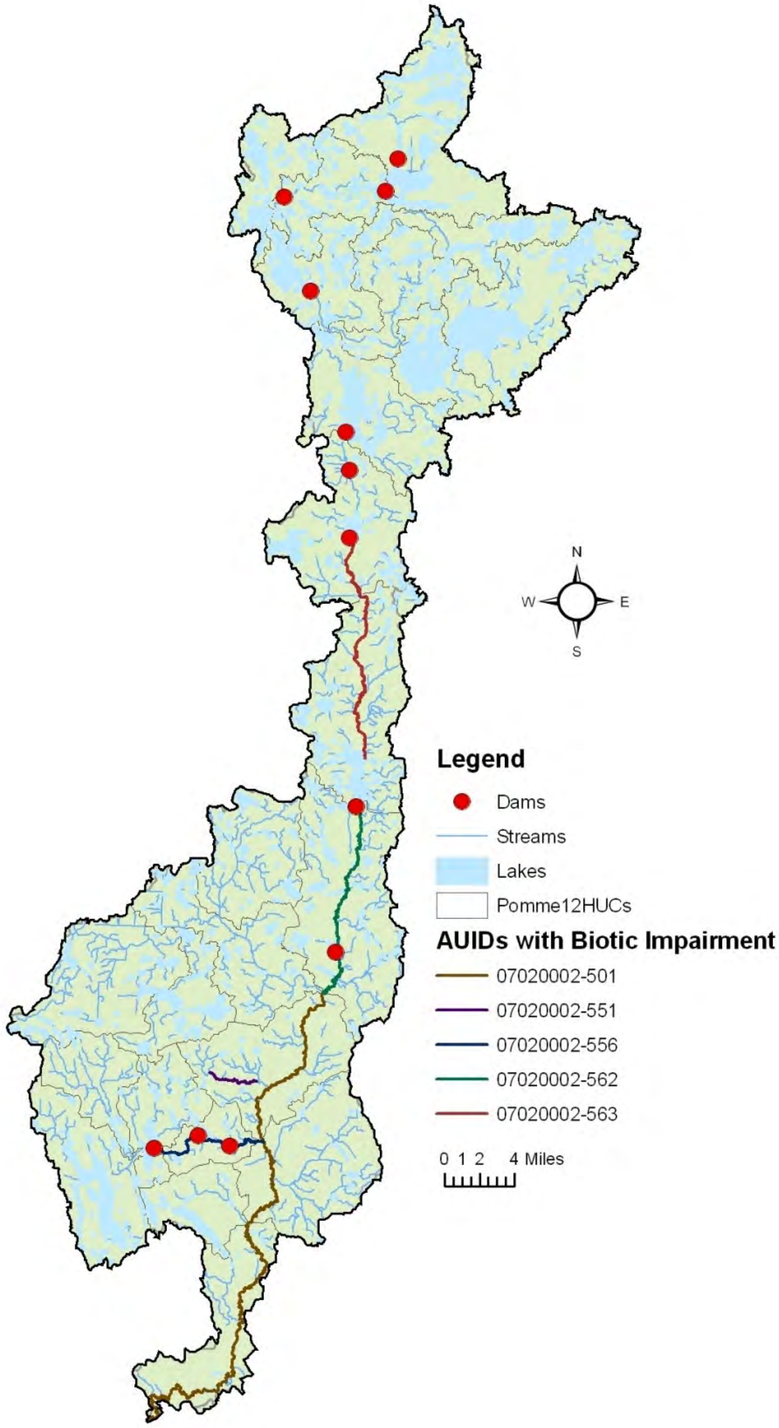

Figure 15. Impoundments located on the Pomme de Terre River and Dry Wood Creek

Figure 16. Dam in Morris

Figure 17. Dam at Perkins Lake (Image courtesy of Brett Arne, Stevens County SWCD)

Sources and Causal Pathways Model for Connectivity

The causes and potential sources for connectivity in the Pomme de Terre River watershed are modeled in Figure 18. Impoundments placed on rivers and streams can create barriers to fish passage and can alter the aquatic community.

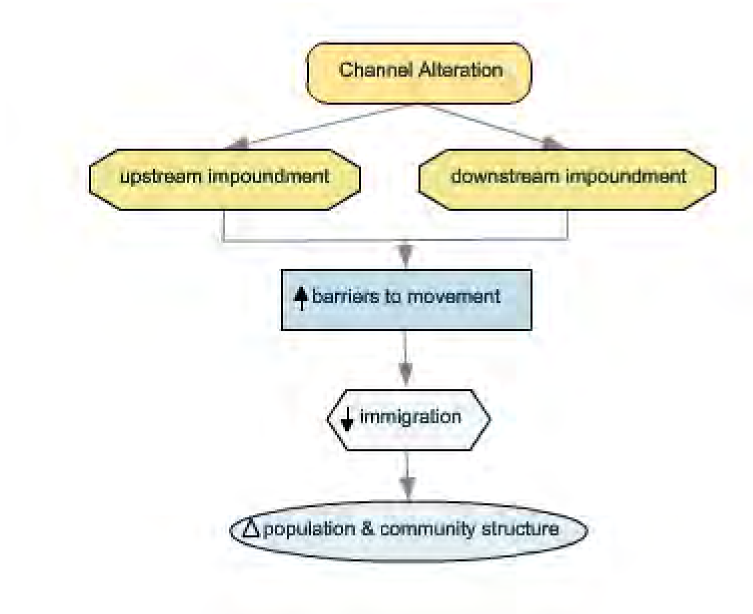

Figure 18. Conceptual model for connectivity

Candidate Cause: Flow Alteration

Increased flows may directly impair the biological community or may contribute to additional stressors. Increased channel shear stresses, associated with increased flows, often causes increased scouring and bank destabilization. With these stresses added to the stream, the fish and invertebrate community may be influenced by the negative changes in habitat and sediment.

High flows can also cause the displacement of fish and invertebrates downstream if they cannot move into tributaries or refuges along the margins of the river; or if refuges are not available. Such aspects as high velocities, the mobilization of sediment, woody debris and plant material can also be detrimental especially to the fish and invertebrates which 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 population. Invertebrates 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).

Across the conterminous U.S., Carlisle et al. found that there is a strong correlation between diminished streamflow and impaired biological communities (2010). 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 baseflow, 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. Often tolerant individuals that can outcompete in limiting situations will thrive. Low flows of prolonged duration tend to lead to invertebrate and fish communities that have preference for standing water or are comprised of generalist species (CADDIS, 2011).

When baseflows are reduced, fish communities respond with an increase in nest guarding species 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). Fifteen nest guarding species (excluding lithophilic spawners) are found in the Pomme de Terre River watershed (most common in the Pomme de Terre are fathead minnows, brook stickleback, and bluntnose minnows).

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 invertebrate communities exhibit changes with increasing swimming species and decreasing taxa with slow crawling rates. 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, Subp. 7 is:

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

Flows in the Pomme de Terre River Watershed

Since 1931, the USGS has collected discharge measurements at a flow station in Appleton (05294000). Additionally predicted flows generated by an HSPF watershed model at the outlets of 12 digit HUC spanning the period from1995 to 2009. The HSPF model is segmented at a HUC 12 scale, or finer, and has 52 delineated subwatersheds.

The Pomme de Terre River has a direct relationship with the aquifer adjacent to the Pomme de Terre River Valley (MPCA, 2011). Many of the aquifers within the watershed are used for domestic water supplies and irrigation. These aquifers appear to be connected to surficial aquifers near the river. Groundwater withdrawal for irrigation is prevalent in the watershed and in the groundwater supply area surrounding the Pomme de Terre River. The groundwater withdrawals have the potential to reduce streamflow (Wen and Chen, 2006).

The peak flows in a river are a response of overland and shallow subsurface pathways. Baseflow, which sustains river flow between runoff events, is supplied by aquifers (derived from various subsurface paths). Impermeable surfaces, lack of vegetative cover, and extensive drainage systems occur in both urban and agricultural land areas in the Pomme de Terre River watershed, 7.57 and 53.24 percent respectively. All of these conditions can cause an increase in the surface runoff flow component produced by a given runoff event. The increased surface runoff component can result in channel scour and a long-term reduction in infiltration, which lowers the water table and reduces the seasonal baseflow component (Poff et al., 1997).

Pomme de Terre River Watershed

At the USGS stream gage location in Appleton, the Pomme de Terre River average annual flows have increased to a degree that cannot entirely be attributed to an increase of precipitation (Figure 19). Jason Ulrich, University of Minnesota, is currently evaluating factors contributing to changes in runoff ratio in 21 tributaries to Lake Pepin, including the Pomme de Terre River. In Ulrich's estimates, precipitation accounts for less than 10 percent of the total change in flow in the Pomme de Terre River watershed (personal communication, November 2, 2011). As reflected similarly in Figure 19, Ulrich has found that the annual water yield has increased significantly between the periods of 1940 to 1974 and 1975 to 2009 (50 – 60 percent increase), yet the annual precipitation has not increased significantly between the two time periods. In addition, the frequency of 2 inches per 24 hours storms and 1 inch per 1 hour storms did not increase at the 8 and 4 stations, respectively, in the vicinity of the watershed.

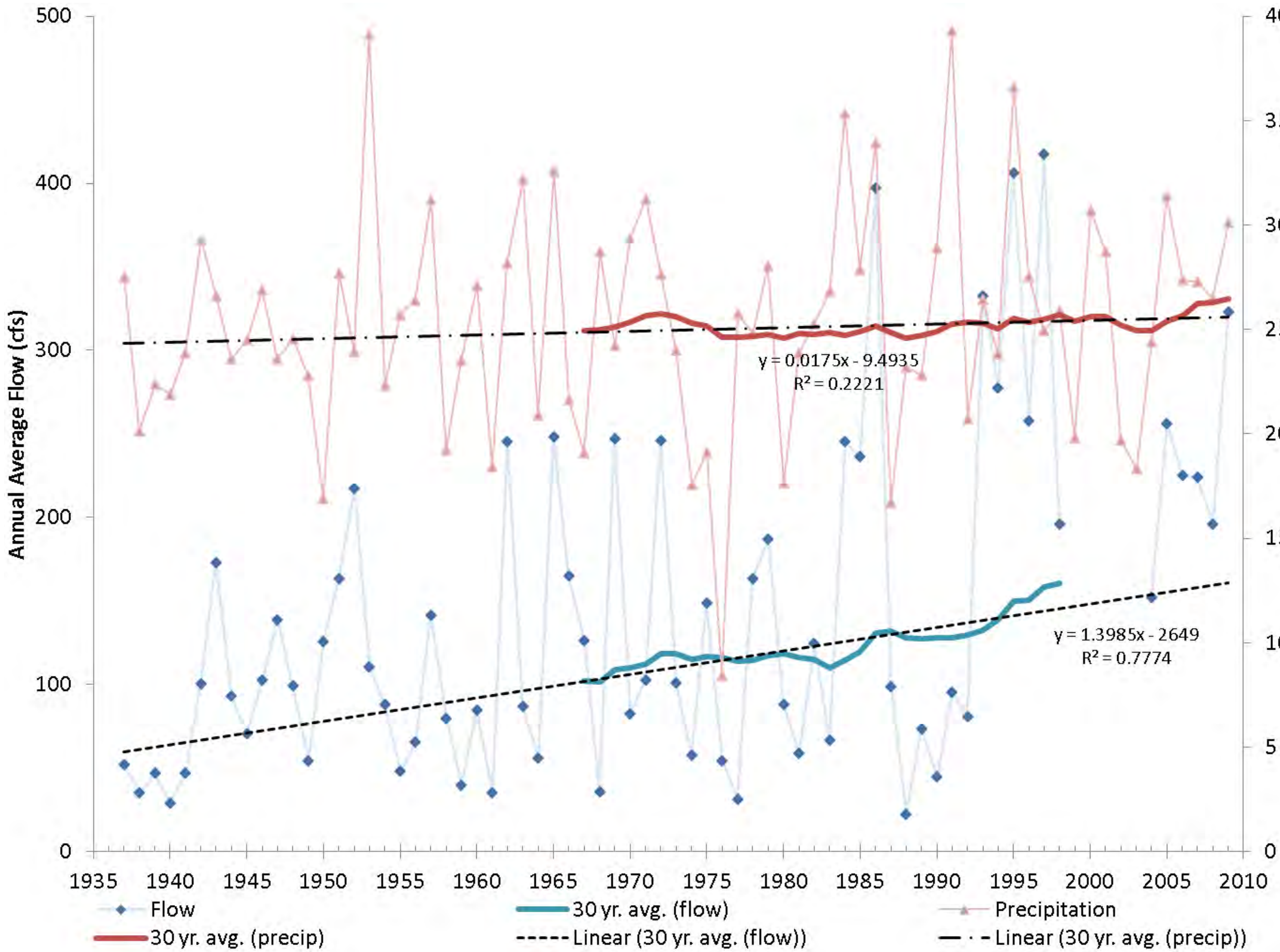

Figure 19. Pomme de Terre River average annual flow and total annual precipitation at Appleton, MN, 1937 – 2009

Poff and Allan (1995) compared fish assemblages at hydrologically stable and variable streams in Minnesota and Wisconsin. They found that stable streams had more fast velocity and moderate velocity fishes than those from variable streams. The variable streams also had fish assemblages with generalized feeding strategies enabling adaptation to stream conditions.

In the Pomme de Terre River watershed, fish assemblages were lacking in those preferring fast velocities, as defined by Poff and Allan. Most of the watershed also showed a depressed proportion of fishes preferring moderate velocities, except in the reach of the Pomme de Terre from Muddy Creek to Minnesota River.

Stream slope was an important factor to determine whether or not the response observed was a natural occurrence due to gradient. There were no apparent trends between slope and the average proportion of moderate velocity fish utilizing both topographic maps and geomorphic surveys to calculate slope. The average slopes of the reaches with more than one biological station (Pomme de Terre River above Barrett Lake, Upper PdT, Lower PdT and Dry Wood Creek) were not significantly different from each other.

As defined by Frimpong and Angermeier, the percent fish individuals that prefer moderate or fast velocities (excluding tolerant) vary regardless of slope in the Minnesota River Basin, of similar drainage, with a mean of 10.83 percent (2009; Figure 20). The mean for the Minnesota River Basin class 1 sites above the IBI threshold was 29.20 percent. The sites along the Pomme de Terre mainstem range from 0 to 48.5 percent. All fish sampling that occurred in the Upper PdT, resulted in less percent individuals that prefer moderate or fast velocities than the mean for the MRB class 1 sites above the IBI threshold. Similarly, 07MN009 was below the mean for all class 1 sites in the MRB. Contradictory are the two sites that are below the mean for all class 1 sites in the MRB, yet above the IBI threshold, including a site in the far northern section of the watershed, 07MN003.

Although there is a relationship between drainage area and the percent individuals that prefer moderate or fast velocities (excluding tolerant) for the Pomme de Terre River mainstem, the relationship does not exist when considering the MRB class 1 sites. The relationship with drainage area that is apparent on the mainstem of the Pomme de Terre River may be due to the migratory barriers present rather than truly drainage area since the relationship is not observed in a broader scope.

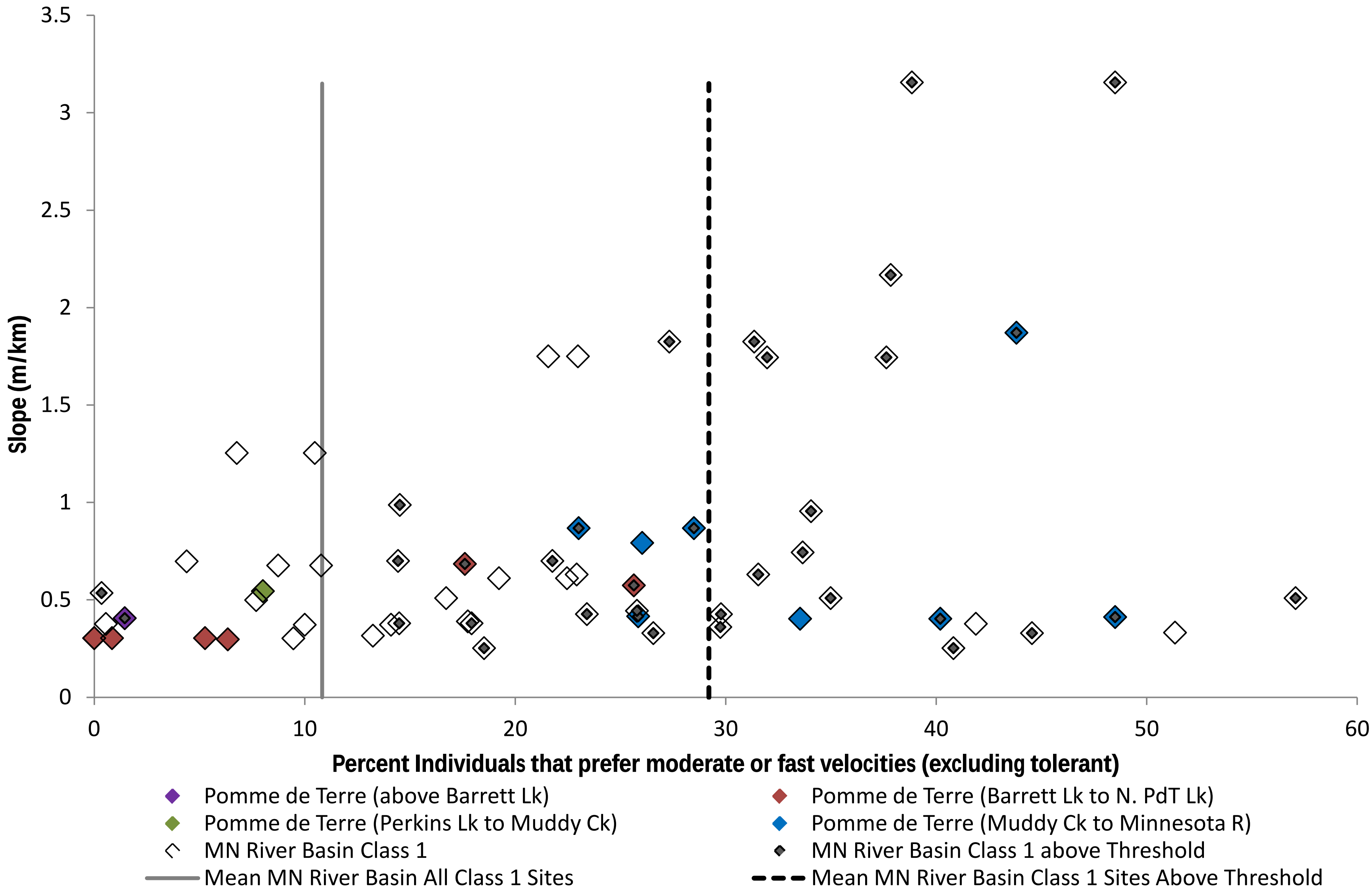

Figure 20. Fish individuals that prefer moderate or fast velocities (excluding tolerant) for reaches in the Pomme de Terre River watershed and MN River Basin Class 1 with means for all MN River Basin class 1 sites and for those above the threshold, as related to slope

Six of the migratory fish taxa that are found below the dam in Morris are also fish that prefer fast and moderate velocities. It is difficult to distinguish if these migratory fish are lacking only due to the connectivity issues or if the apparent altered hydrology has contributed to their observed absence in the upper reaches of the Pomme de Terre River. In contrast, there are also six fish taxa found in the Pomme de Terre River watershed that are not migratory and are in the fast and moderate velocity preference categories. Therefore even if the connectivity is preventing the colonization of migratory species above the dam in Morris, it may be expected that the proportions of those non-migratory taxa would be greater. The proportion of fish preferring moderate and fast velocities would also be expected to be higher at site 07MN009, which does not have a dam separating it from the reach further downstream.

Sources and Causal Pathways Model for Altered Flow

The Pomme de Terre River watershed has transitioned from perennial to agricultural landcover, with loss of wetlands, increases in groundwater withdrawal, and channelization with surface and subsurface drainage. The combination of these landscape altering modifications has led to alteration of the river's hydrologic regime.

As stated in the nitrate section, cropland accounts for over 53 percent of the entire Pomme de Terre River watershed and developed areas make up over 7.5 percent (Table 6). These landscape alterations have direct connections with the hydrologic system and agriculture, irrigation, channelization and ditching are common in the Pomme de Terre River watershed. Significant irrigation occurs in the watershed, especially in the surficial aquifer adjacent to the Pomme de Terre River (Figure 21; see Pomme de Terre River Watershed Monitoring and Assessment Report for more information on irrigation). Channelization occurs on ditches serving as first and second order streams to larger streams and rivers. The channelized reaches and subsurface tiling serve to route water quickly off the landscape which alters the natural hydrologic regime of the system. Subsurface tiling in the watershed was estimated utilizing a derived 100 meter resolution raster using the following criteria: 2009 USDA Crop Data for row crops (corn, sweet corn, soybeans, dry beans, peas, potatoes, sunflowers, sugar beets); USGS National Elevation Dataset, with a 30-meter Digital Elevation Model, and a slope ranging from 0-3 percent; and SSURGO soil drainage classes of very poorly drained or poorly drained. The highest estimated tiling occurs in the southern portion of the watershed (Figure 22). The causes and potential sources for altered flow in the Pomme de Terre River watershed are modeled at EPA's CADDIS Flow Alteration webpage.

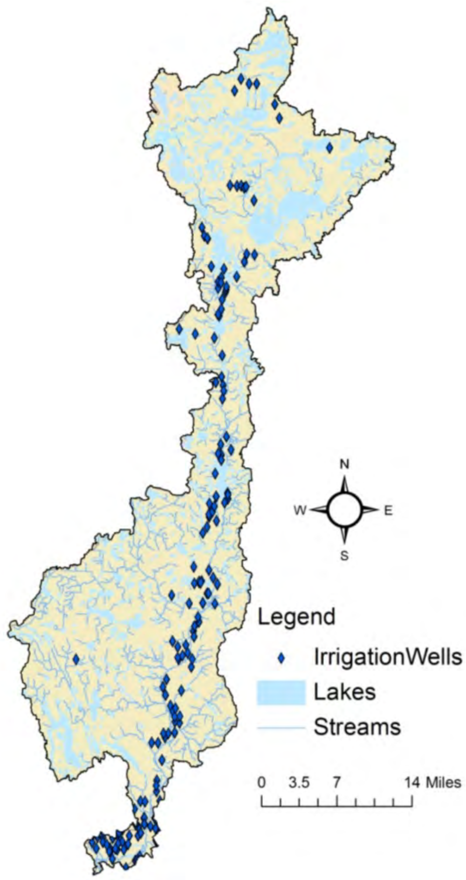

Figure 21. Wells used for irrigation throughout the Pomme de Terre River watershed

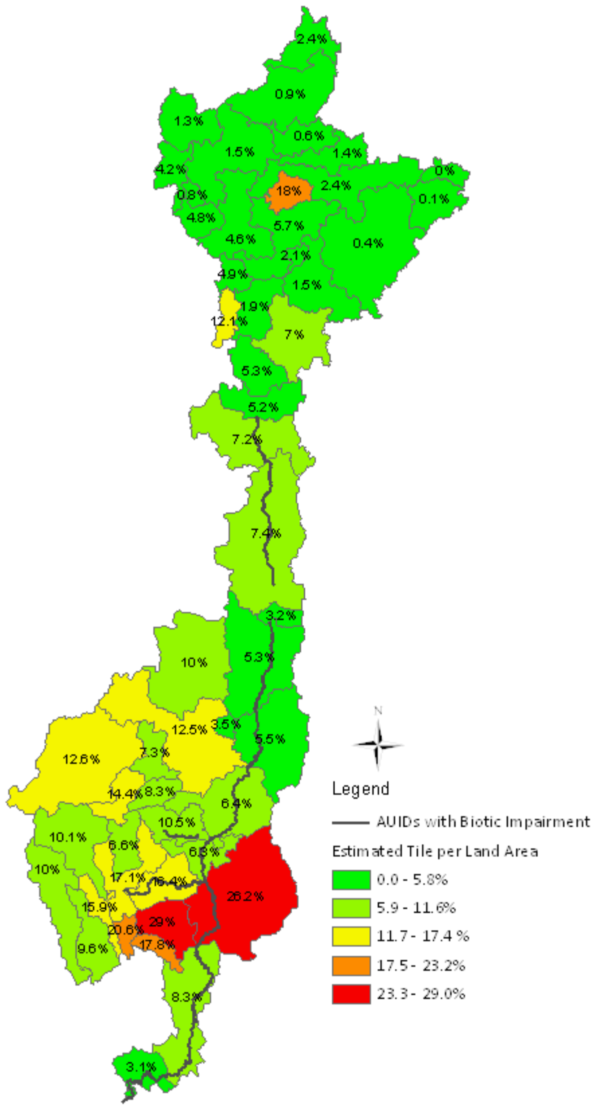

Figure 22. Estimates for tile drainage in the Pomme de Terre River watershed, by HSPF subwatershed

Dry Wood Creek

Biology in Dry Wood Creek

Dry Wood Creek is impaired for fish and invertebrates from North Dry Wood Lake to the confluence with the Pomme de Terre River. The fish community of Dry Wood Creek is dominated by two species, as indicated by the metric DomTwoPct (Figure 23). The metric's mean score was near zero, with one outlier at 08MN089. The percent tolerant individuals, TolPct, also had a mean score of zero, with no outliers. The fish community in Dry Wood Creek is dominated by a few species that are tolerant and reach maturity within two years. Fathead minnows were the most abundant species throughout the sites surveyed in Dry Wood Creek. Other prevalent species included common carp, bigmouth buffalo and orangespotted sunfish.

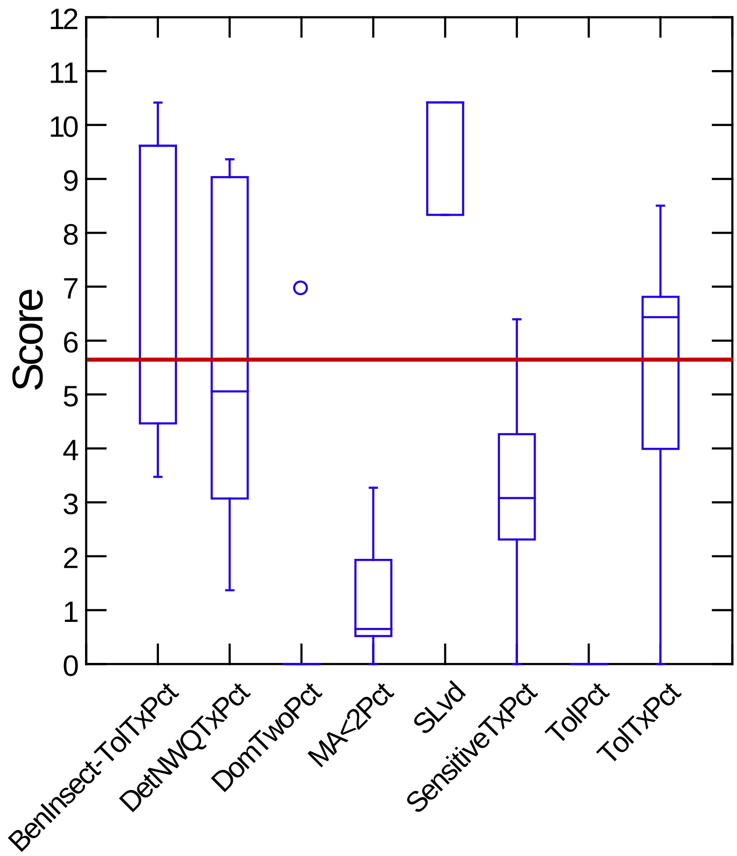

Figure 23. Fish metric scores belonging to the Southern Streams IBI for Dry Wood Creek. Red line indicates the average metric score (5.6) needed for IBI score to be at the threshold

Invertebrate metrics in Dry Wood Creek indicate potential issues with habitat with the relatively low mean metric score for ClingerCh, the abundance of clinger taxa, and the low mean score for EPT taxa (Figure 24 and Table 8). As well as habitat, water quality is a potential issue as shown by the low metric score for Intolerant2lessCh, which means taxa richness was low for invertebrates that are considered intolerant or less able to endure elevated levels of pollution. The invertebrates present in Dry Wood Creek are adaptable to variable conditions.

There is a lack of intolerant taxa, EPT taxa and percent Trichoptera (caddisflies). Caddisfly taxa have a variety of feeding preferences based on the individual species such as leaf shredders, algae grazers and invertebrate predators. The caddisflies that were present at 07MN022 in 2008 were *Cheumatopsyche* and *Phryganeidae*, while in 2007 there were no caddisflies at the site. Site 08MN088 had no caddisflies collected in 2008. The presence of caddisflies is dependent on both water quality and quantity, which relates to the availability and diversity of specific, unique habitats. A diversity of habitats means a greater diversity of species will be able to find their appropriate, required niche.

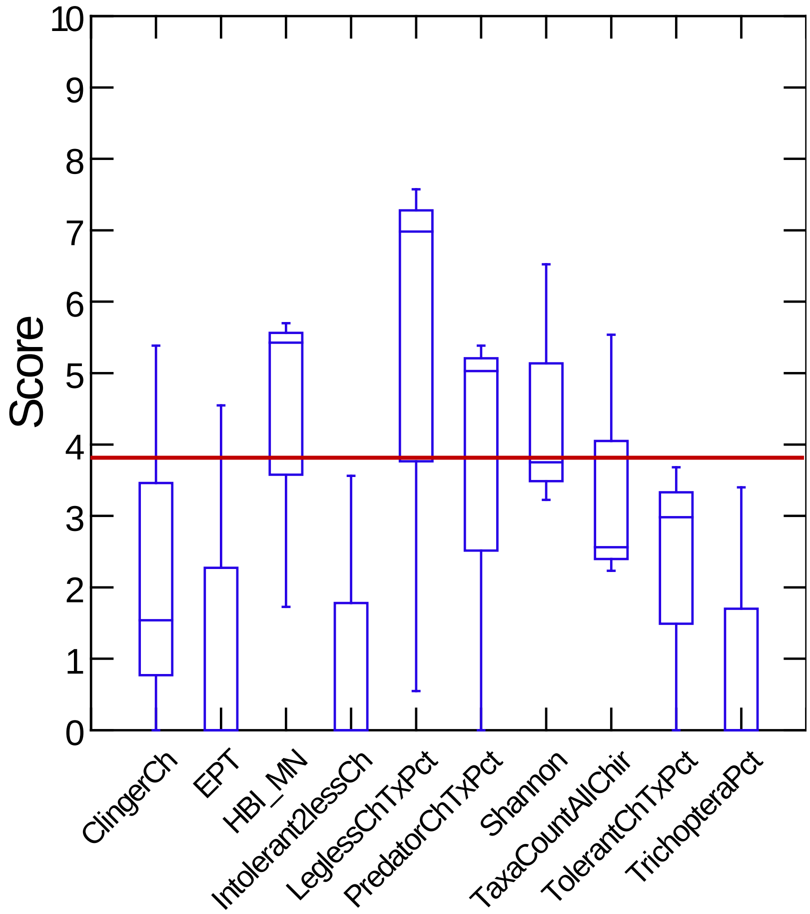

Figure 24. Invertebrate metric scores belonging to the Prairie Streams GP IBI for Dry Wood Creek. Red line indicates the average metric score (3.8) needed for IBI score to be at the threshold

Table 8. Invertebrate metric scores belonging to the Southern Streams RR IBI for Dry Wood Creek. Bold indicates score is below the average metric score (5.9) needed for IBI score to be at the threshold

Site	ChiroDip	ClingerCh	Collector-filtererCh	HBI_MN	Intolerant2lessCh	SimuliidaePct
08MN087	**0**	**0.1**	**0**	**0**	**0**	**0**
08MN089	6.1	**3.9**	**3.3**	**1.2**	**5.3**	16.7

Candidate Cause: Dissolved Oxygen

Throughout Dry Wood Creek, fathead minnows dominated the fish communities surveyed in 2007 and 2008 (Figure 25). Site 08MN089 had fewer fathead minnows, but it is the most abundant taxa. Fathead minnows are tolerant of low dissolved oxygen levels. The other high abundant taxa are orangespotted sunfish, white sucker, and common carp (22.8 percent, 17.9 percent, and 10.3 percent respectively). These taxa are also tolerant to adverse conditions. Very few EPT were found in the invertebrate communities of Dry Wood Creek which are intolerant to low dissolved oxygen (Table 9).

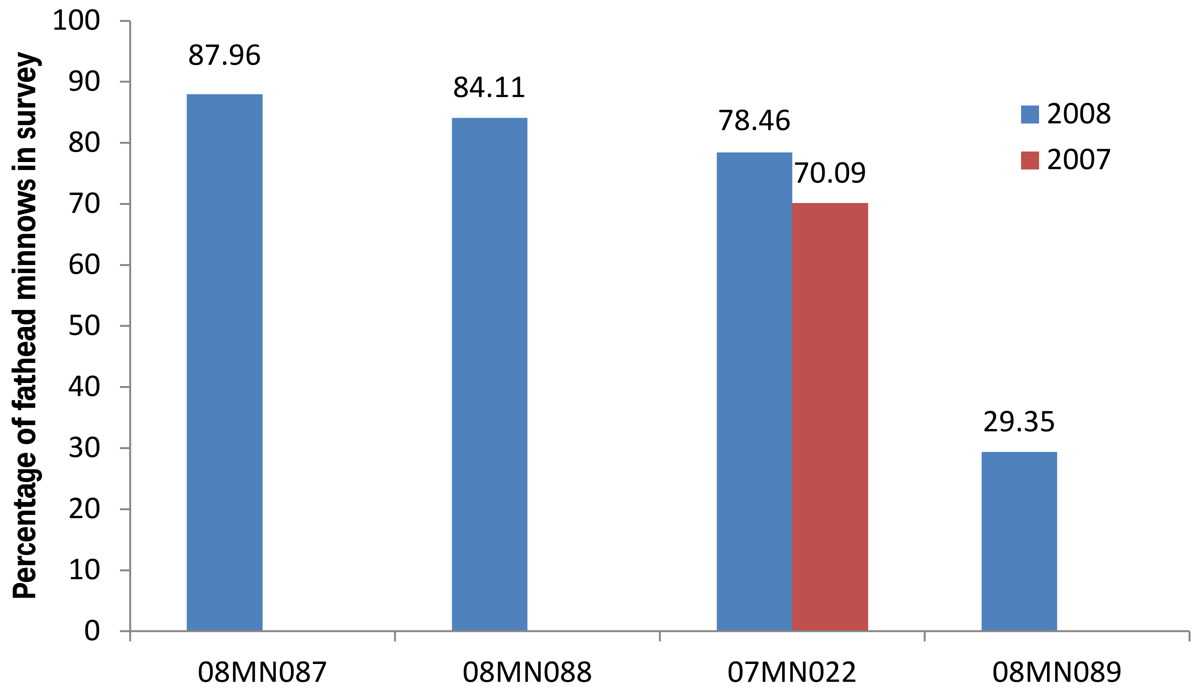

Figure 25. Percentage of fathead minnows in 2007 and 2008 fish surveys on Dry Wood Creek

Table 9. Percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in invertebrate samples at sites in Dry Wood Creek

	2007	2008
08MN087		3%
08MN088		0%
07MN022	0%	2.5%
08MN089		2%

In 2008, as a follow up to the 2007 condition monitoring in the Dry Wood Creek watershed, three YSI sondes were deployed for a short period from August 25 - 27 (Figure 26). All three locations measured below the standard for Class 2B streams at least one time during the deployment. At site 504PDT649, measured dissolved oxygen concentration was below 1 mg/L for 7.25 hours (32 measurements) during the early mornings of August 26 and 27.

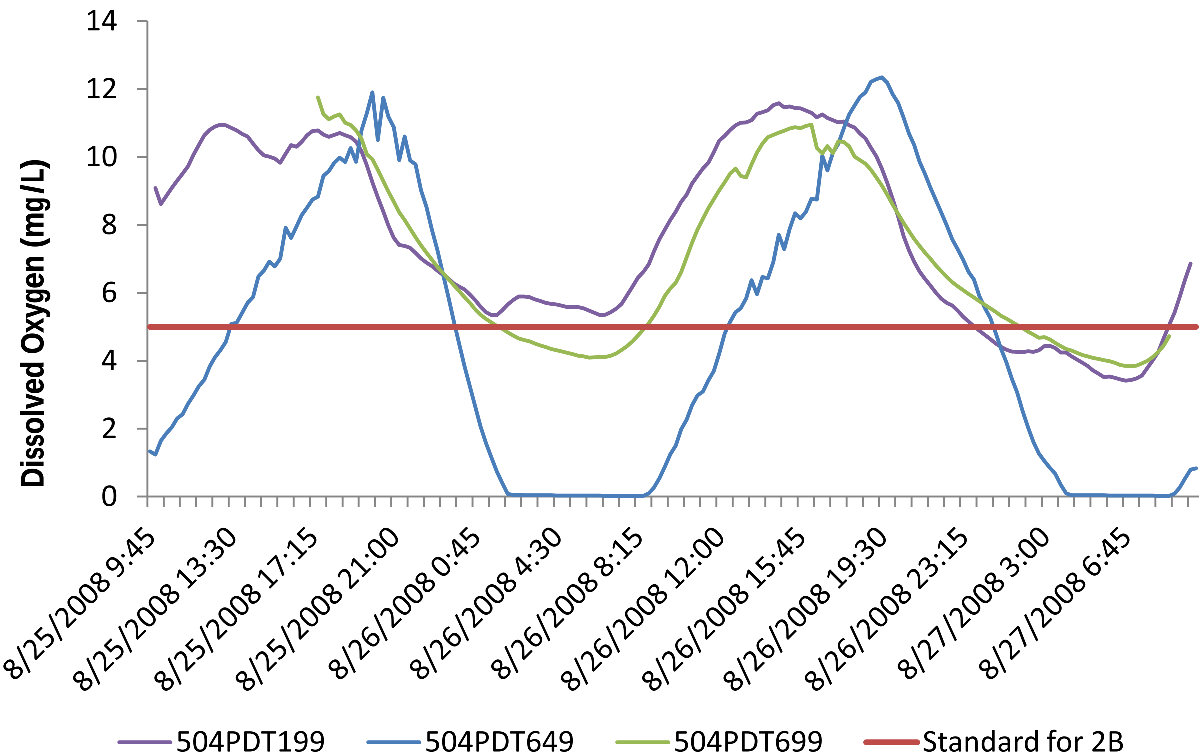

Figure 26. Measurements of dissolved oxygen from August 25 to 27, 2008 for three sites in Dry Wood Creek

Additionally, synoptic measures of dissolved oxygen were taken longitudinally in Dry Wood Creek at eight sites. Measurements were taken early in the morning when dissolved oxygen is typically at its lowest and also taken in the afternoon when dissolved oxygen is often at its highest. Figure 27 shows that all eight sites had low dissolved oxygen readings, often in the early morning measurements, but also in some of the afternoon measurements.

Diurnal measurements were also collected in 2009, at three locations and all had dissolved oxygen measurements below the standard (Figure 28, Figure 29, and Figure 30).

Abnormal amounts of algae were observed and photographed (Figure 31) at site 504PDT199 on August 27, 2008. This site is located immediately downstream of North Dry Wood Lake. Due to the high algal content and a low dissolved oxygen concentration at 504PDT199, it was determined a winter and summer dissolved oxygen profile on North Dry Wood Lake would be beneficial. Profiles were collected on March 5, 2009 and June 18, 2009 (Figure 32). The winter dissolved oxygen profile had very low oxygen levels. This is not uncommon for shallow productive lakes in late winter. At the time of sampling on March 5, 2009, there was approximately 24 inches of ice and the water smelled of sewage. The summer dissolved oxygen profile was fairly consistent but oxygen levels decreased as depth increased.

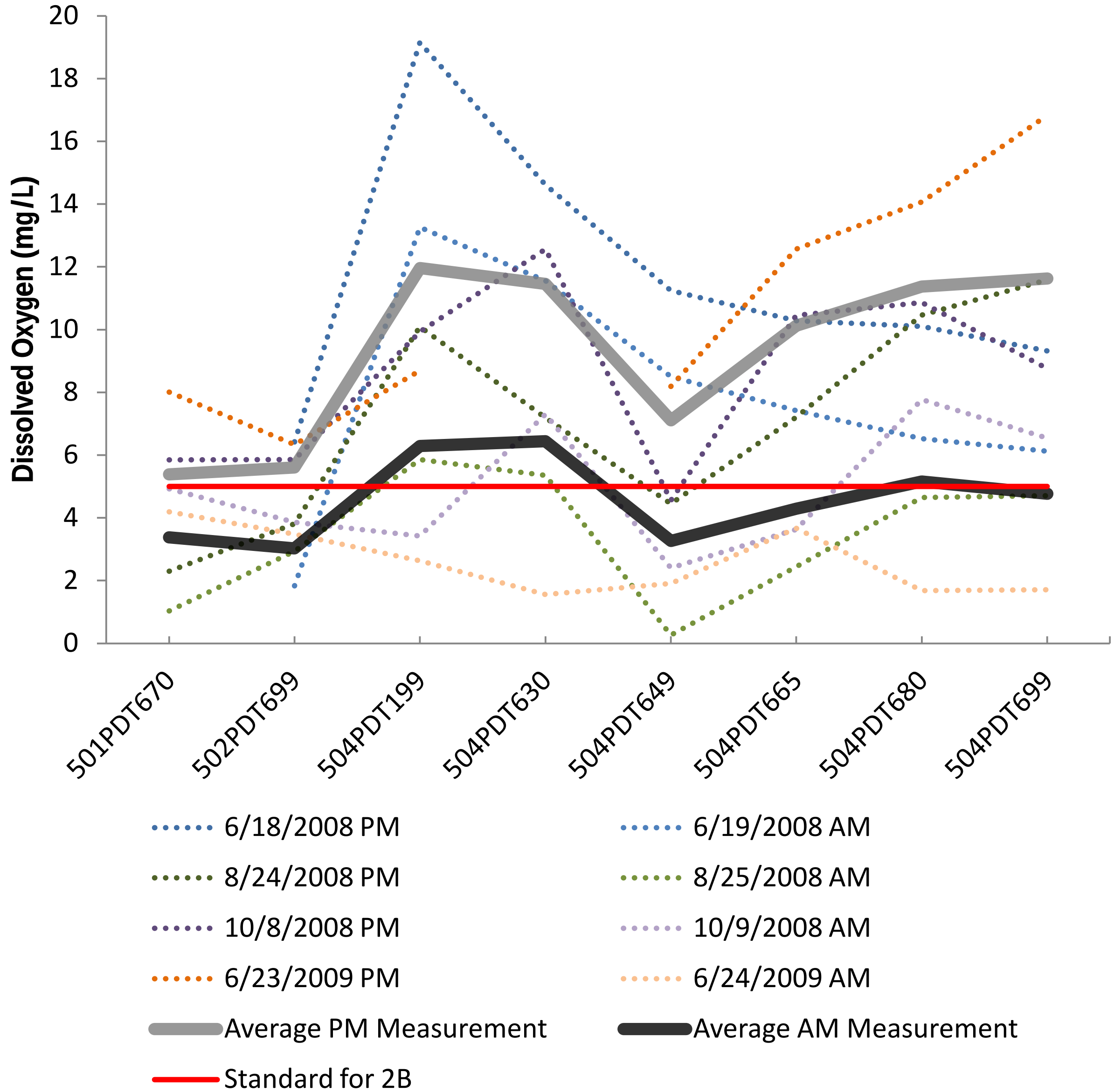

Figure 27. Dissolved Oxygen longitudinal synoptic measurements in Dry Wood Creek

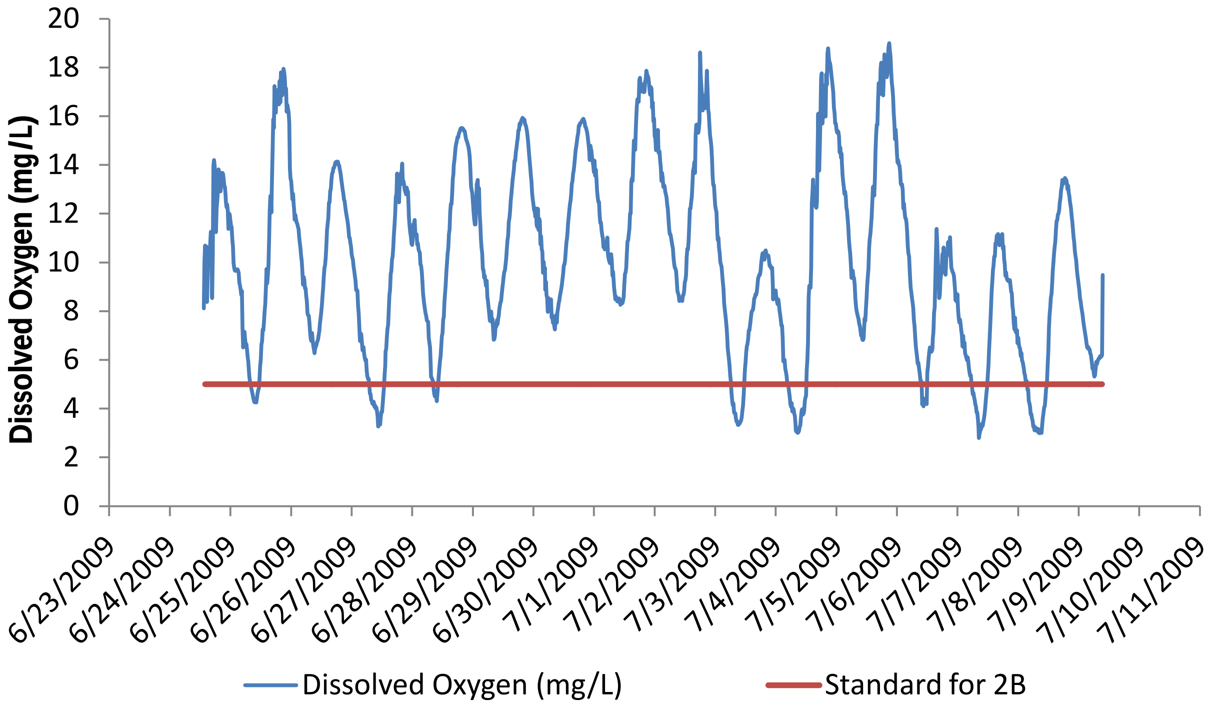

Figure 28. Dissolved oxygen measurements per 15 minute intervals for site 504PDT199, from June 23 to July 11, 2009

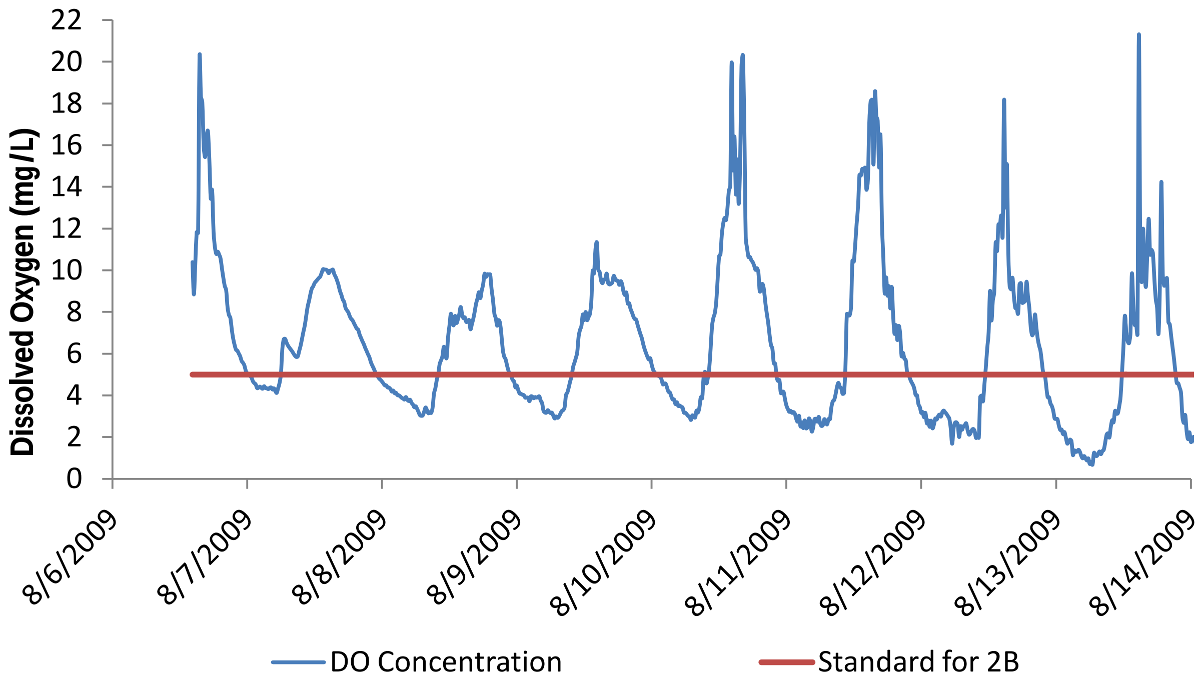

Figure 29. Dissolved oxygen measurements per 15 minute intervals for site 504PDT680, from August 6th to 14th, 2009

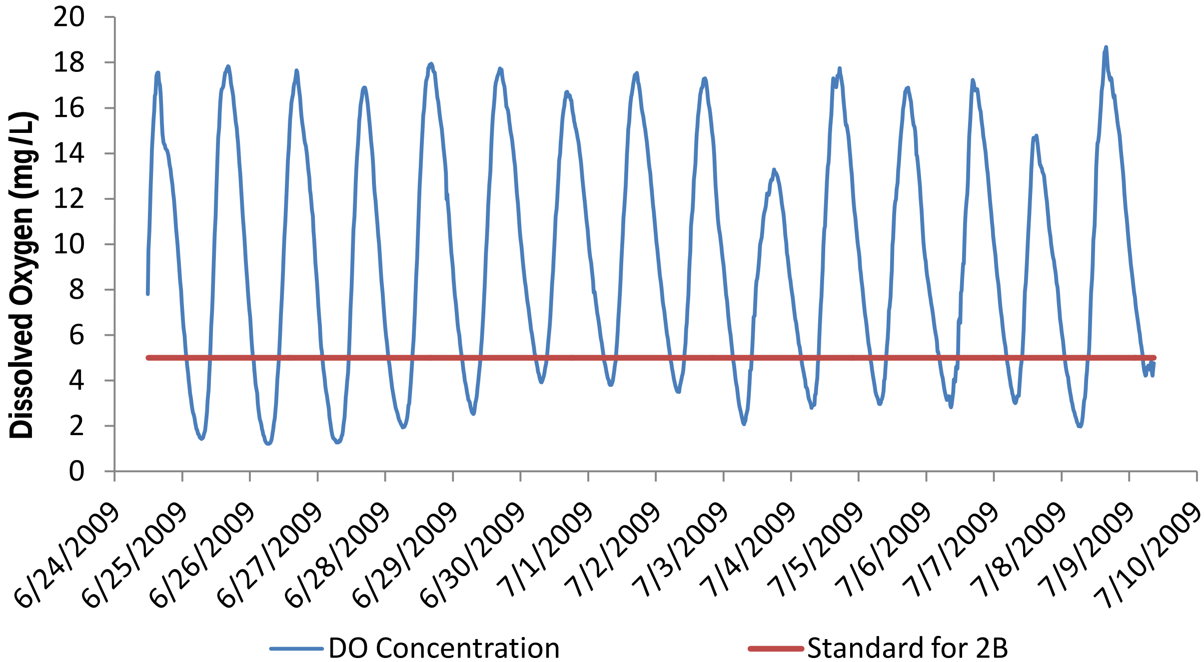

Figure 30. Dissolved oxygen measurements per 15 minute intervals for site 504PDT699, from June 24th to July 9th, 2009

Figure 31. 504PDT199 (upstream of road crossing), August 27, 2008

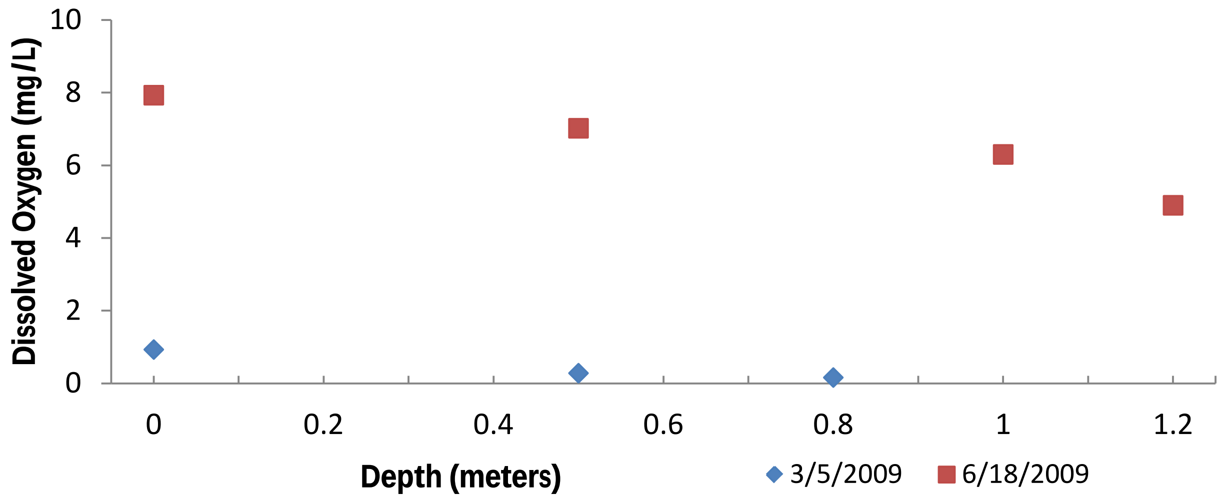

Figure 32. North Dry Wood Lake dissolved oxygen profile

Stressor Pathway: Impoundments

DO levels can be affected by impoundments by collecting nutrients and organic materials leading less to availability. In the Dry Wood Creek watershed, there are two constructed impoundments and one known natural impoundment. Figure 33 shows photos of one of the constructed impoundments, where the creek has cut around the impoundment wall so that it is no longer functioning. The upstream impoundment is linked to the lake and difficult to discern the attributes associated with the lake from the impoundment. The creek has also had a beaver dam downstream of 504PDT649 altering flow and thus decreasing dissolved oxygen concentrations upstream of the dam.

Stressor Pathway: Riparian condition

The riparian buffers along Dry Wood Creek are minimal in some areas (Figure 34). This can allow high amounts of nutrients, sediment and pesticides from adjacent fields to enter adjacent streams and rivers. This nutrient enrichment can lead to an increased oxygen demand.

Stressor Pathway: Source-water pollution

North Dry Wood Lake, the headwater source of Dry Wood Creek, is rich in nutrients as measured by its outlet at site 504PDT199. The sources of nutrients to the lake are thus also contributing a high load of nutrients to Dry Wood Creek.

In Dry Wood Creek, dissolved oxygen is a stressor to both fish and invertebrate communities throughout the creek. Dissolved oxygen was low at all stations on the creek and the biology responded at all four biological sites with high numbers of fathead minnows and minimal EPT present.

Figure 33. Impoundment on Dry Wood Creek no longer functioning, May 5, 2008

Figure 34. Dry Wood Creek between 200th Avenue NW and 190th Avenue NW, June 19, 2008

Candidate Cause: Phosphorus

Total phosphorus concentrations in Dry Wood Creek are excessive. The mean phosphorus levels in 2007 were above the proposed standard and ecoregion expectations. Blue green algae were also observed during the 2008 monitoring season by MPCA staff. Algal blooms are often caused by high phosphorus concentrations.

Fathead minnows, as previously stated, dominate the fish population in Dry Wood Creek. They can be abundantly found in waterbodies with floating and submerged algae and a wide range of water clarity (Becker, 1983). The fish community was not heavily comprised of planktivorous (algae-eating) species as would be expected with high nutrients and high phytoplankton. However, there are many interacting stressors that complicate responses, particularly the high amount of suspended sediment in Dry Wood Creek that may actually be an impediment for planktivores to thrive.

Percent EPT, percent Tanytarsini, and percent intolerant are invertebrate metrics that are expected to decrease with increased nutrients and all respond as expected in Dry Wood Creek (CADDIS, Figure 35). Invertebrate metrics that are expected to increase as nutrients increase are percent mollusca and crustacean, percent dominant, percent scrapers and percent tolerant. In Dry Wood Creek, percent dominant and percent tolerant increased when compared to unimpaired reaches of the Pomme de Terre River watershed (Figure 36). The percent mollusca and crustacean metrics do not show a difference and the percent scrapers metric does not show the expected response. The scrapers may not be increased because the algae found in Dry Wood Creek is observed to be mostly within the water column and not found on hard surfaces where it would be available to invertebrates that feed via scraping.

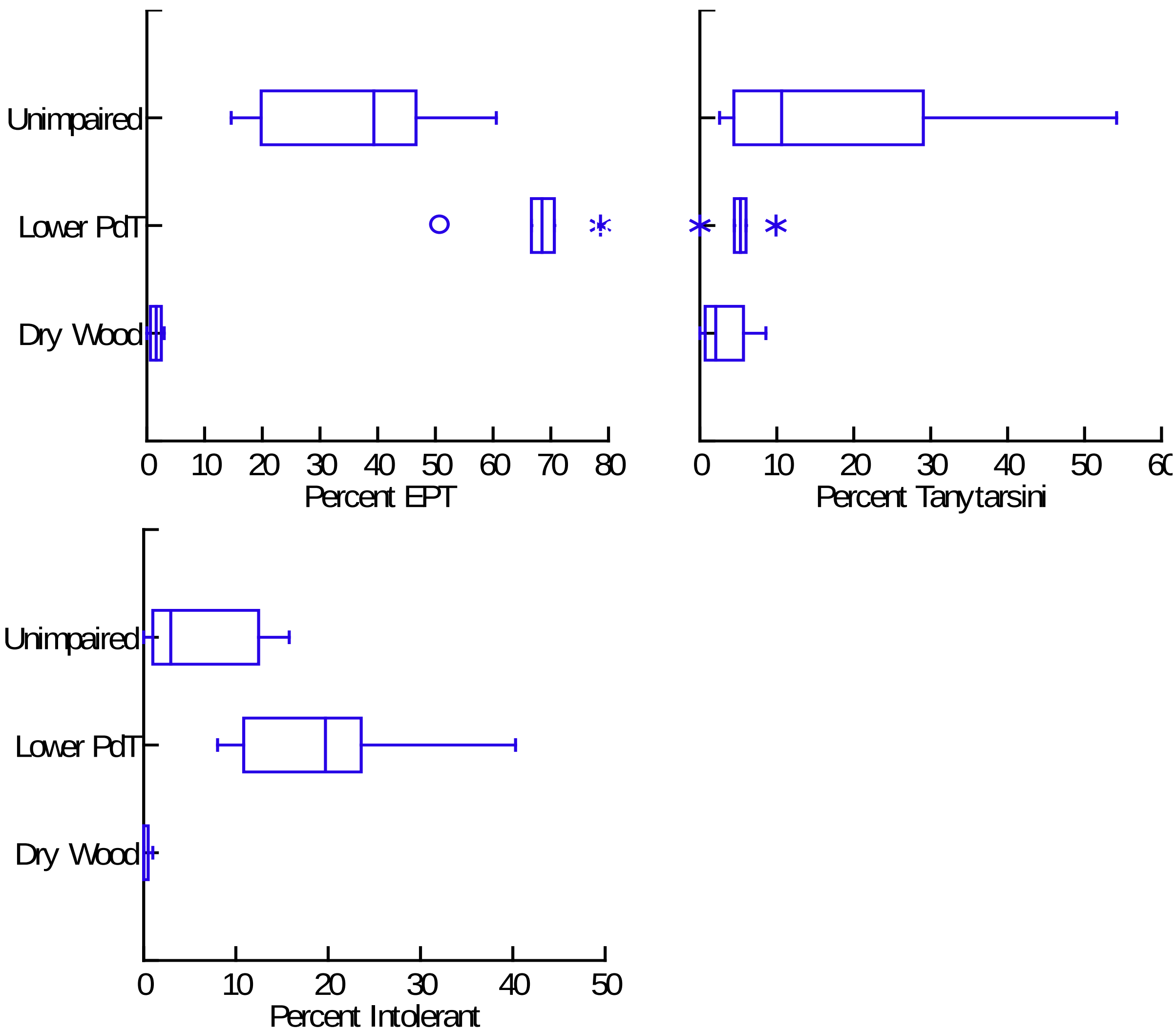

Figure 35. Invertebrate metrics that commonly decrease with increase nutrients

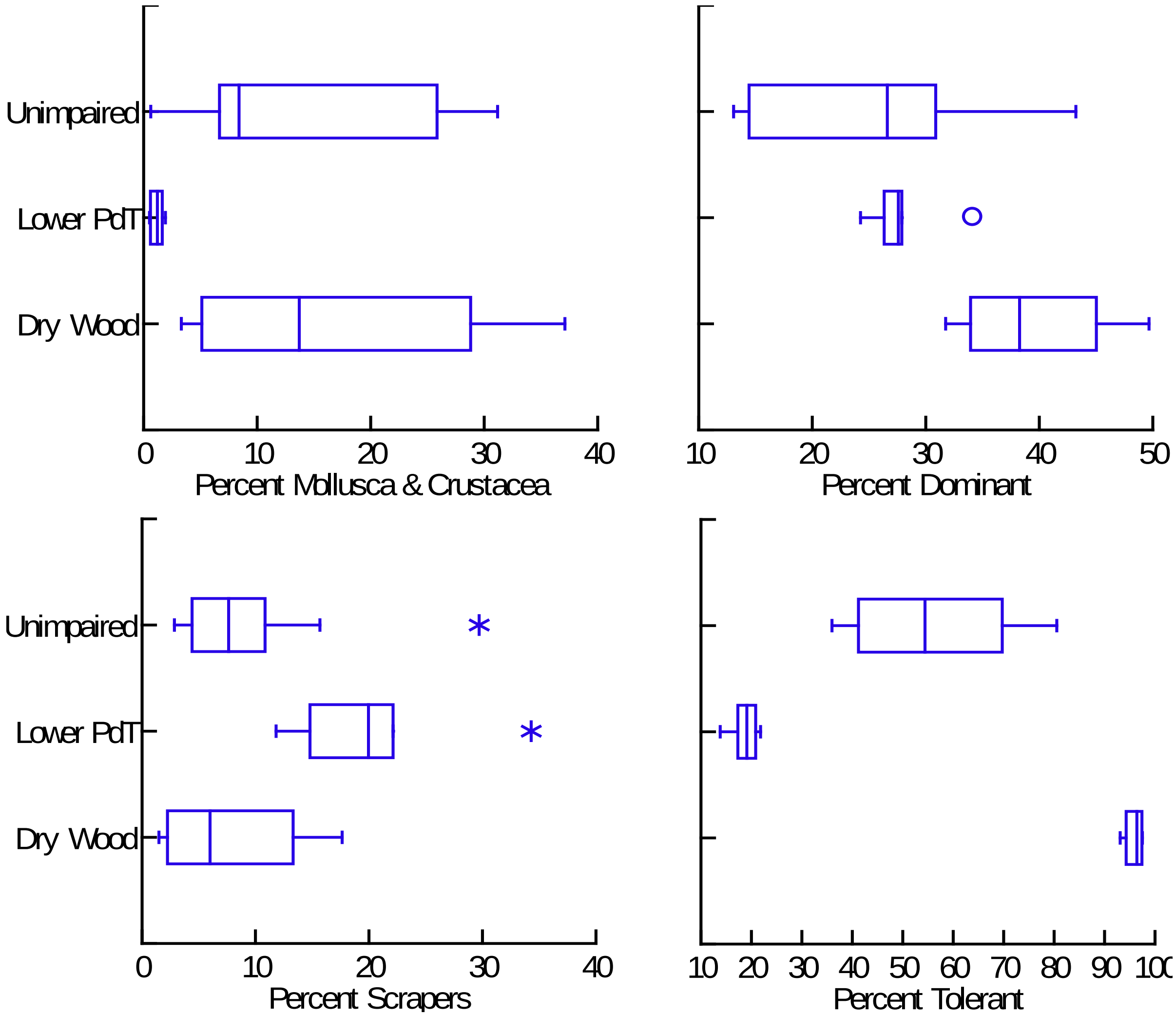

Figure 36. Invertebrate metrics that commonly increase with increase nutrients

Stressor Pathway: Riparian condition

The riparian buffers along Dry Wood Creek are minimal in some areas. This can allow high amounts of nutrients, sediment and pesticides from adjacent fields to enter adjacent streams and rivers.

Stressor Pathway: Source-water pollution

North Dry Wood Lake, the headwater source of Dry Wood Creek, is rich in nutrients as measured by its outlet at site 504PDT199. The sources of nutrients to the lake are thus also contributing a high load of nutrients to Dry Wood Creek.

Of the various regions within the PdT watershed, available data shows Dry Wood Creek to be the most strongly influenced by elevated levels of phosphorus. Phosphorus in this system is likely to be directly contributing to the dissolved oxygen and turbidity stressors also present in this system. Habitat and altered food resources for the biotic community are also likely influenced by excess phosphorus.

Candidate Cause: Nitrate

In a study of species' tolerance along physiochemical gradients, four species in Dry Wood Creek (in 2008) had mean TIV in the first quartile, indicative of the greatest sensitivity to nitrate (Figure 37; Meador and Carlisle, 2007). Those species included banded darter, golden shiner, tadpole madtom, and walleye. Although these species were present, they were not present in great numbers. Starting at Dry Wood Lake and going downstream, the nitrate sensitive species made up less than 0.5 percent of the sample size, except at the furthest downstream site, 08MN089, where the seven individuals made up 3.8 percent.

In 2008 and 2009, the invertebrate samples in Dry Wood Creek were comprised of more than 98 percent tolerant individuals at each of the sites. Less than 3.1 percent of the individuals were caddisflies, and, as previously mentioned, some caddisflies can be sensitive to nitrate. The identification level of the caddisflies present does not allow for discernment of those more sensitive than others.

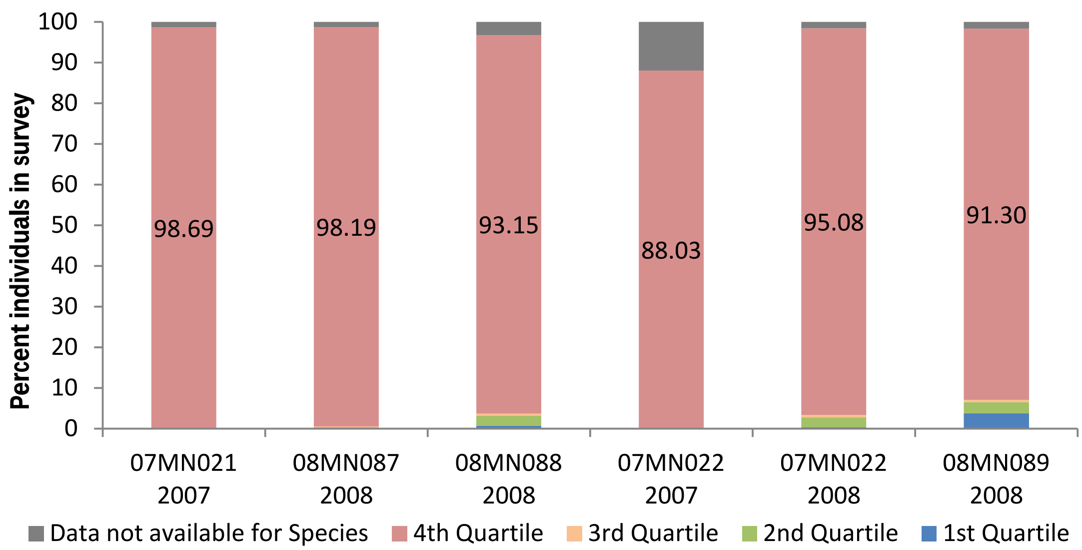

Figure 37. Percent fish individuals by biological site in Dry Wood Creek, for each quartile based nitrate tolerance indicator values (Meador and Carlisle, 2007)

Dry Wood Creek had elevated nitrate levels during snowmelt events in 2008 (Figure 38), whereas under baseflow conditions, the three sites all had nitrate levels less than 0.1 mg/L. During the 2009 snowmelt event, further investigation utilizing HACH nitrate and nitrite test strips assisted in evaluating the duration of high levels of nitrate during snowmelt events. Two sites, 504PDT199 and 504PDT699 were sampled each week during the snowmelt timeframe. Nitrate concentrations were elevated for four consecutive weeks at both sites (Figure 39). One sample was collected from a ditch that drains directly to Dry Wood Creek - the nitrate level was 15 mg/L.

Nitrite was also measured at each of the sites (Figure 40). Alonso (2005) developed a range of nitrite levels that is protective of sensitive aquatic species (in Camargo and Alonso, 2006). Using Alonso's range, nitrite concentrations were only considered elevated during the initial sampling week.

Stressor Pathway: Riparian condition

The riparian buffers along Dry Wood Creek are minimal in some areas. This can allow high amounts of nutrients, sediment and pesticides from adjacent fields to enter adjacent streams and rivers.

Stressor Pathway: Source-water pollution

Channelized intermittent tributaries to Dry Wood Creek are high in nitrates during snowmelt and rain events. It is assumed that nitrogen and forms of nitrogen, such as ammonia, are being applied to the cropland throughout the watershed as it is nearly 70 percent cropland. It is unknown how much groundwater contributes nitrate.

Nitrate is an identified stressor to the biotic community of Dry Wood Creek. Nitrite would need further information to determine its direct impacts.

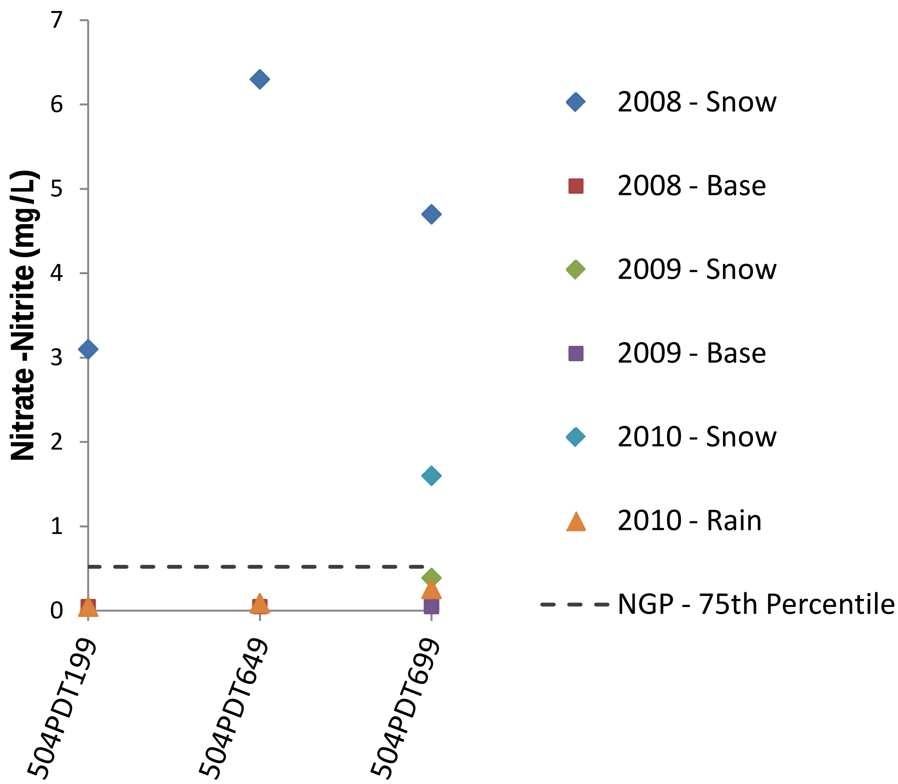

Figure 38. Nitrate-N measurements collected in Dry Wood Creek watershed

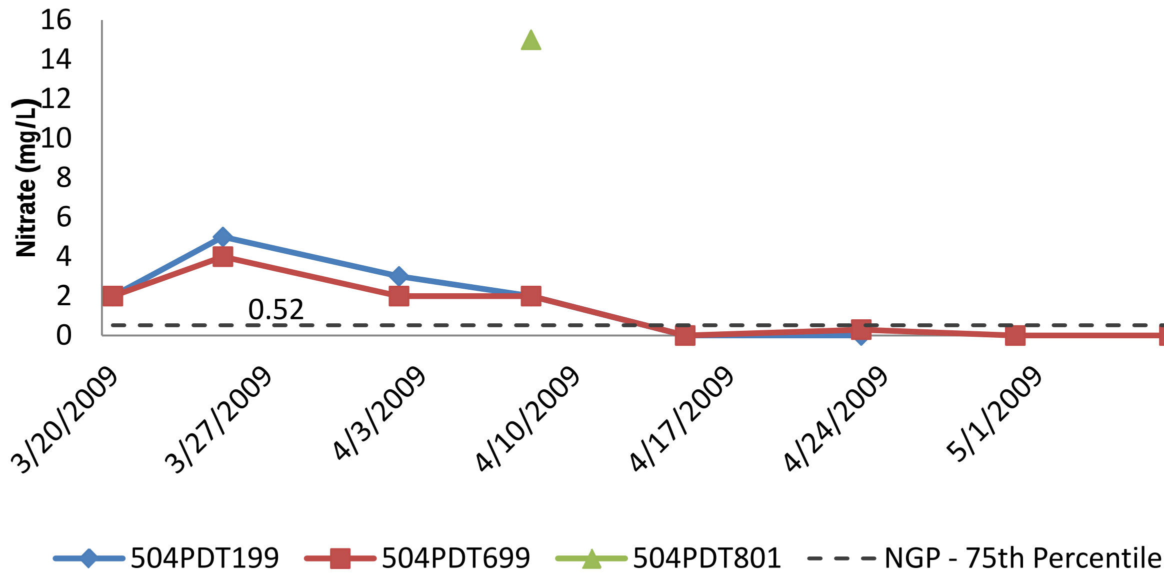

Figure 39. Nitrate measurements collected via test strips in 3 locations in Dry Wood Creek watershed

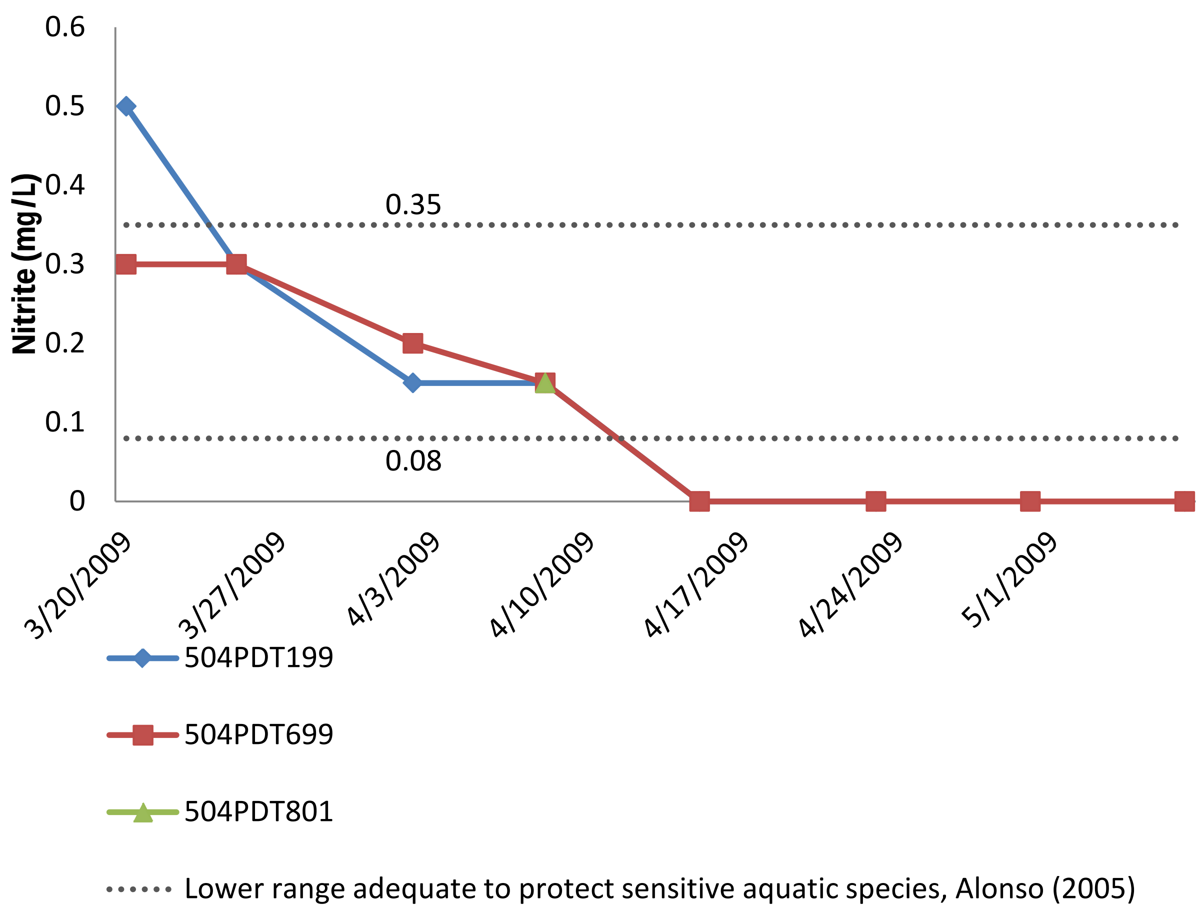

Figure 40. Nitrite measurements collected via test strips in 3 locations in Dry Wood Creek watershed

Candidate Cause: Connectivity

Dry Wood Creek historically had a concrete headwall dam to control lake levels in North Dry Wood Lake with stop logs, and a dam to prevent fish passage approximately two miles from the confluence with the Pomme de Terre River (Figure 41). The fish passage dam is no longer acting as a fish barrier since erosion has occurred on both sides of the dam. In 2008, a beaver dam was identified as a potential fish barrier (Figure 42 and Figure 43). In the spring of 2009, the beaver dam was washed away, but rebuilt approximately 200 feet downstream later in the year. It is uncertain if the beaver dam or human made dams on Dry Wood Creek are barriers for longitudinal fish movement. The most migratory taxa are found in the downstream biological site 08MN089 (Table 10). The three upstream sites have less migratory species, but there is no potential barrier between 07MN022 and 08MN089 to account for the missing taxa.

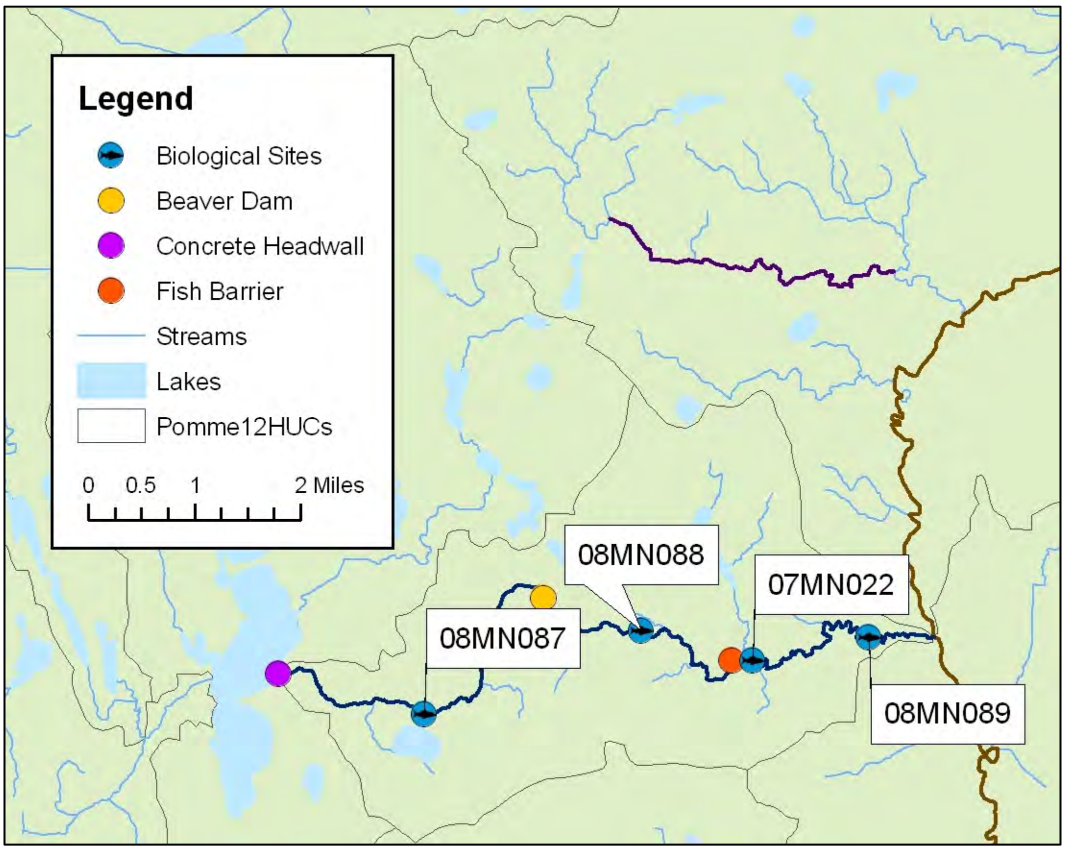

Figure 41. Biological sites on Dry Wood Creek with location of beaver dam, concrete headwall and fish barrier structures

Figure 42. Beaver lodge on Dry Wood Creek

Figure 43. Beaver dam on Dry Wood Creek

Table 10. Migratory fish species present in the Dry Wood Creek, by biological site

CommonName	08MN087	08MN088	07MN022 (2007 & 2008)	08MN089
blackside darter		x	x	x
slenderhead darter				x
spottail shiner	x			x
walleye		x		x
white sucker		x	x	x
TOTAL	**1**	**3**	**2**	**5**

In Dry Wood Creek, it is unlikely that the potential barriers are the cause of the lack of migratory species to move upstream in the creek. Other stressors currently appear to have larger influences in Dry Wood Creek. The human made and beaver made dams in the watershed not only have the potential to be barriers but also can create instability in the channel leading to increased sediment loads, changes in habitat and flow characteristics.

Candidate Cause: Habitat

Dry Wood Creek has fair habitat as scored by the MSHA during fish survey visits (Figure 44). The land use scored the weakest followed by cover and riparian zone (Figure 45). The land use along Dry Wood Creek is predominantly row crop and pasture, both of which contribute to the lack of decent riparian vegetation. Sites 08MN087 and 07MN022 both were cattle pastures in 2008. The lack of perennial vegetation at 08MN087 has unraveled that reach widening the stream to a C stream type rather than an E stream type that is typical of a prairie stream with low slope such as Dry Wood Creek. The other three geomorphic sites on the creek were observed to have better riparian vegetation.

Embeddedness in the reaches is common but was considered light at all of the biological reaches in 2008 and moderate at 07MN022 in 2007. This is likely due to a flushing of sediment caused by a large rain event in 2008. In 2009, the reach titled CRP (for the land use surrounding it upstream of 220th Avenue) was found to have over a foot of fine sediment covering the gravel substrate (observed in 2008).

Woody debris was found heavily throughout 08MN087, a major determinant in the amount of cover available to the biological community. This abundance of woody debris is likely due to the widening of the stream in this reach, causing the trees originally on the floodplain to be undercut and fallen over the stream channel. In other biological reaches, the cover was found to be mostly sparse with some boulders, undercut banks, and overhanging vegetation to provide cover. The cover throughout Dry Wood Creek could be improved. Figure 46, Figure 47, Figure 48 and Figure 49 show the biological sites throughout Dry Wood Creek and the lack of cover provided at each site.

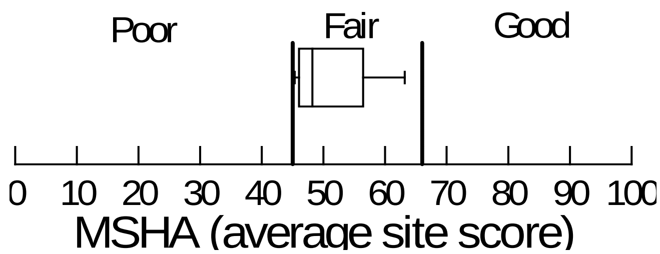

Figure 44. MSHA scores in Dry Wood Creek

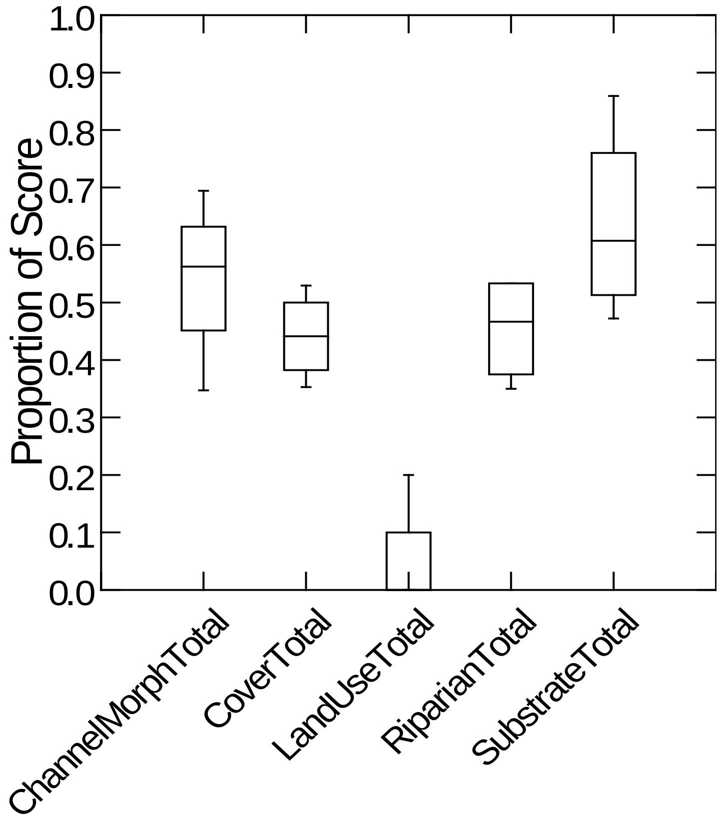

Figure 45. Proportion of possible subcategory scores in Dry Wood Creek

Station 08MN087

Dry Wood Creek at station 08MN087 is classified as a C4c- stream type, characterized by a gravel bed, low entrenchment ratio with good connectivity to the flood plain, moderate to low width depth ratio, moderate sinuosity, and low slope. The reach is protected from down-cutting by riffles with subpavement materials that are resistant to degradation. Some of these riffles may have been placed by landowners for stream crossings. The width/depth ratio of 10.9 falls in the upper 10 percent of the range for this stream classification which might reflect the impacts of stream channel alteration upstream or previous onsite grazing in this reach. The slightly wider channel would have the capacity to move more water. The hydraulically controlling riffles and stable stream bed in this reach help resist down cutting. This leaves the stream banks as the weakest link in adjusting to the higher annual discharge flows being documented for the Pomme de Terre River Watershed.

Figure 46. Station 08MN087 Picture

Station CRP

Station CRP is the second most upstream reach sampled and is located about a mile downstream of station 08MN087 and about two and one half miles downstream of Dry Wood Lake. The contributing drainage area is approximately 88 square miles. The land surrounding this station is entirely enrolled in the conservation reserve program and has a diverse vegetative community of grasses and forbs with woody brush species near the stream. A geomorphic assessment was completed on August 18, 2009 that included a longitudinal profile and pool and riffle cross sections. Pebble counts were completed showed the entire stream bed was covered in a deep layer of fine sediment (100 percent silt/clay, 0-0.062mm particle size).

Dry Wood Creek at station CRP is classified as an E6 stream type, with silt and clay bed, a width depth ratio near the modal value of the E stream classification, good connectivity to the flood plain, low sinuosity for an E stream type, and low slope. The water surface slope was extremely flat (0.00002) and was influenced by beaver dams located below 220th Avenue. E channels are highly stable with low erosion rates, and are narrow and deep with low width to depth ratios (modal value of 8). They have low gradients, high sinuosity (usually), low entrenchment with excellent floodplain connectivity, and well vegetated stream banks that maintain bank stability. They are very efficient at moving water and sediment and usually provide excellent habitat for fish and other aquatic species.

A reconnaissance of the reach during the spring of 2008 revealed high flows, a gravel stream bed, and breached beaver dams below 220th Ave, indicating that the stream is seasonally an E4 with gravel bottom when not being influenced by the dams, lower flows, and accumulated sediment. Contributing sources of the fine sediment in this reach are the upstream pastures below Dry Wood Lake. During high flow events and when the dams are breached, the accumulated fine sediment, like that observed during the 2009 assessment, flushes downstream, contributing to the turbidity impairment of downstream reaches of Dry Wood Creek and the Pomme de Terre River.

The longitudinal profile was 475 feet long with a riffle and pool cross section located at station 1+32 and 3+45, respectively. The hydraulically controlling riffle had a bankfull cross sectional area of 49.8 square feet, a mean bankfull depth of 2.21 feet, and a bankfull width of 22.6 feet. Bankfull discharge at the riffle was estimated at 58 cfs. The cause of the atypically low sinuosity for an E stream type at this reach is unknown but may be a characteristic of a naturally laterally confining narrow valley or the stream may have undergone straightening in the past.

Station 08MN088

This 08MN088 reach lies in the midsection of the Dry Wood Creek watershed where there are no notable tributaries entering above this stream section. Aerial photo interpretation indicates some possible significant channel modification has occurred about a half mile above this study reach. These possible channel modifications include straitening and over widening nearly a mile of stream channel. The loss of sinuosity and changes to the hydrologic functions of the channel in this altered reach either has or is still causing impacts in this study reach. These impacts may include higher stream velocities, greater bedload of fine material and possible increased stream bank sheer stress.

The riparian corridor for this stream section is vegetated by reeds canary grass along the immediate stream channel with native prairie grasses and forbs covering the majority of the flood prone area and adjoining uplands (Figure 47). The current corridor produces very little surface runoff while promoting high infiltration and low evapotranspiration rates.

Figure 47. Station 08MN088 Picture

Station 07MN022

Dry Wood Creek at station 07MN022 is classified as an E5 stream type, with a bed composed of almost equal parts of silt/clay, sand, and gravel. Other characteristics include a high entrenchment ratio (low entrenchment), low width to depth ratio, good connectivity to the flood plain, moderate sinuosity, and low slope. The width to depth ratio of 8.8 is right at the modal value for E stream types, providing evidence for evolutionary stability. The riparian corridor is an active pasture largely composed of grasses including reed canary grass. The condition of bank and riparian vegetative appeared to be near the threshold for negative consequences for bank erosion and stream stability. Despite of the streams dimensional resilience, some bank sloughing and accelerated erosional processes were evident. Figure 48 shows the condition of the riparian corridor and stream banks. Without the accelerated erosion present due to the impacted riparian vegetation, this reach would likely have an E4 (gravel bed) designation, an even lower width to depth ratio, improved water quality, and improved habitat for fish and aquatic organisms.

Figure 48. Station 07MN022 pictures

Station 08MN089

The 08MN089 reach on Dry Wood Creek is located roughly a mile from the confluences with the Pomme de Terre River and represents a drainage area of 97 square miles. This reach was assessed and classified in 2009 as an E4 stream channel supporting a gravel stream bed with fine sands, silts and clays also present (Figure 49). The stream in this reach has a moderate water slope at 0.0003 ft/ft, an estimated bankfull discharge of 84 cfs using a bankfull channel width of 19.7 feet and average bankfull depth of 2.3 feet. The median bed particle in the 0+97 riffle cross section was also gravel.

Characteristics of the reach include prominent steep riffles, short runs with long moderately deep pools containing fine silt, sand and clay materials. The bankfull field and low bank height elevations were not similar in this reach. Instead these two field indicators reflect two independent trends that did not correlate well to the water slope for this reach. The bankfull slope for the reach demonstrates a more rapidly declining trend to that of the water slope. While the low bank height has a steadily increasing trend to the water slope. These trends clearly represent a pattern of stream channel incision that is occurring in this reach.

The E stream channel in this reach is highly sinuous with large meander lengths, belt widths and a wide flood prone area. The width/depth ratio and entrenchment ratio for the reach both fall within the modal range for this stream classification. The channel in is not entrenched and still demonstrates good floodplain connectivity. A large diameter corrugated metal culvert under County Road 7 is immediately upstream of the study site is restricting the floodplain connectivity and causing some study site impacts that include increased stream velocities contributing bed and bank erosion and stream channel incision.

The study reaches meanders through a lightly grazed pasture consisting of native grasses and forbs. The area reflects signs of both active and remnant channel degradation due to grazing activities. These direct and indirect grazing impacts are considerably more pronounced at other location immediately upstream of this site like station 08MN087, 07MN022, and at several other reaches along Dry Wood Creek. Riparian grazing impacts are clearly a leading variable linked the turbidity, E. coli impairments and indirectly to the low species IBI scores for Dry Wood Creek. The direct impacts from over grazing activity are profound enough to cause stream channel instability and channel alteration far beyond what the system is capable of assimilating.

Figure 49. Station 08MN089 Picture

Similar to other impaired areas in the Pomme de Terre River watershed, the fish communities at sites in Dry Wood Creek are dominated by a high proportion of just two species (Figure 50). At all sites, fathead minnows made up the largest proportion of the fish survey. Fathead minnows are known to be tolerant and are common in low gradient, silt substrate streams and ditches (Becker, 1983). At sites 08MN087, 08MN088, and 07MN022 common carp were the second most abundant species in 2008; as they are a non-discriminatory of substrate type (Becker, 1983). In 2007, bigmouth buffalo were the second most common species at site 07MN022. Bigmouth buffalo are often found in slow moving waters with a silt laden bottoms (MN DNR, 2010). In 2008, at site 08MN089, orange spotted sunfish were the second most prolific fish species observed, and are known to be tolerant of silt as well as promoted by the "tilling and clearing of land" (Becker, 1983).

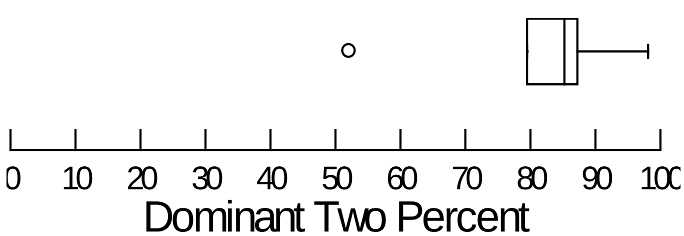

Figure 50. Percentage of dominant two fish species in Dry Wood Creek

The invertebrates are also depressed throughout Dry Wood Creek. Clingers show a similar pattern to the average MSHA scores, showing dependency of clingers to their habitat (Figure 51).

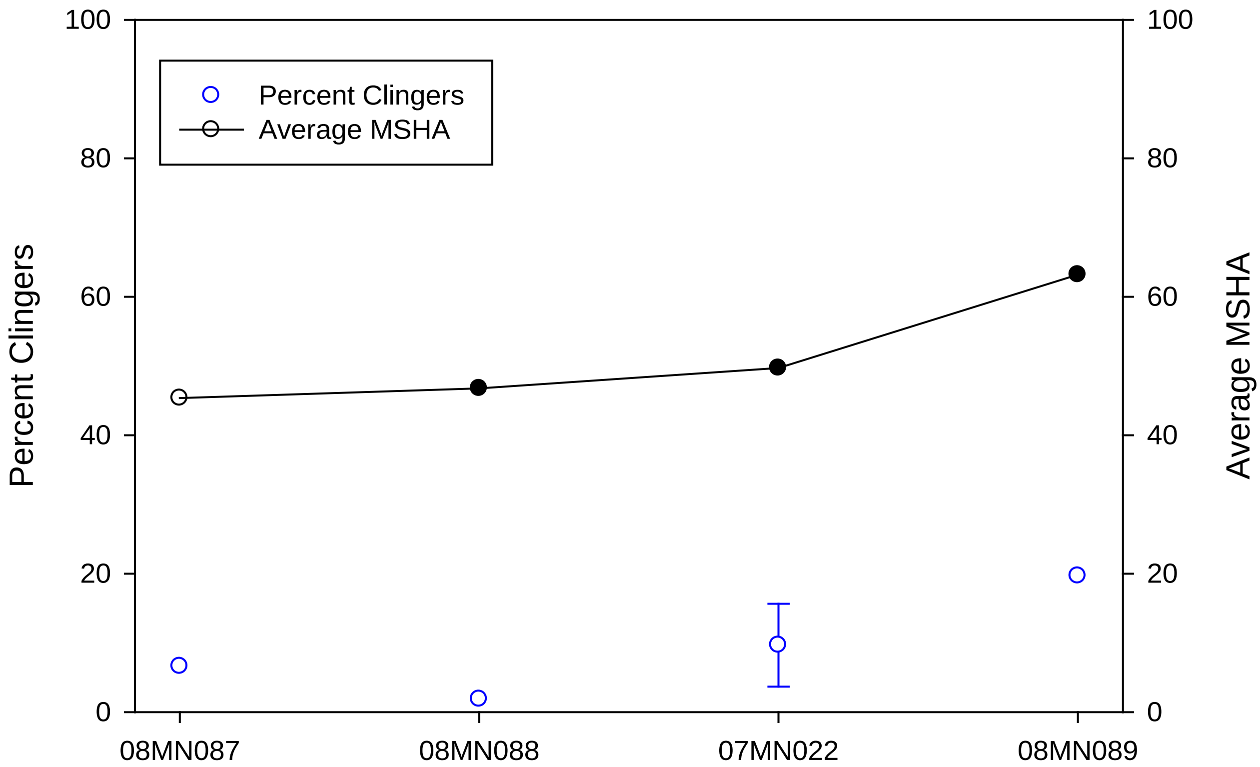

Figure 51. Percent clingers and average MSHA scores in Dry Wood Creek

Stressor Pathway: Riparian condition

The riparian buffers along Dry Wood Creek are minimal in some areas. In portions of the creek, the stream banks have gone through increased trampling and decreased riparian and bank vegetation. The riparian condition has led to changes in cover availability, stream stability and led to other alterations.

Stressor Pathway: Channelization

Channelization of reaches within Dry Wood Creek and the channelization of reaches contributing to the creek have led to changes in the hydrological and geomorphological condition. This has led to changes in discharge patterns, changes in substrate, changes in sinuosity, and increases in erosion.

Stressor Pathway: Impoundments

Impoundments in Dry Wood Creek have led to instability creating increased erosion around impoundments as well as channel alteration to regain stability.

In Dry Wood Creek, there is overwhelming evidence that the lack of habitat afforded to the aquatic community is poor and that poor habitat is clearly a stressor causing biotic impairment.

Candidate Cause: Turbidity

Turbidity, which is a measure of transparency, can be increased with sediment, algae and organic matter. The TSS concentration was 74 mg/L at 08MN088 and 170 mg/L at 08MN089 prior to fish surveys. One banded darter was surveyed at 08MN088, and the sample at 08MN089 captured three banded darters. Banded darters were the only fish species surveyed in Dry Wood Creek belonging to the first quartile of sensitivity to suspended sediment from Meador and Carlisle's species tolerance assignments (Table 7 and Figure 52). Fathead minnows dominated the majority of the surveys, and are particularly tolerant not only to wide dissolved oxygen fluctuations but to high turbidity levels as well. Another common species found in Dry Wood Creek was common carp. In Wisconsin, they are found "most frequently in turbid water at depths of 0.6 -1.5m" (Becker, 1983).

In a comparison of invertebrate class 5 stations in the MRB the average taxa count of collector-filterers was 5.59 among all natural sites. The lowest scores of percent collector-filterers in the Pomme de Terre class 5 streams were measured on Dry Wood Creek. Sites 08MN087 and 08MN089 had 3 and 4 taxa, leading to metric scores of 0 and 2. In terms of the percentage of collector-filterers, all sites on Dry Wood Creek ranged from 0 -15 percent with an average of 5.9 percent (average for all class 5 streams in MRB was 26.9 percent). The high amount of suspended sediment is interfering with the activities of collecting and filtering fine organic particles.

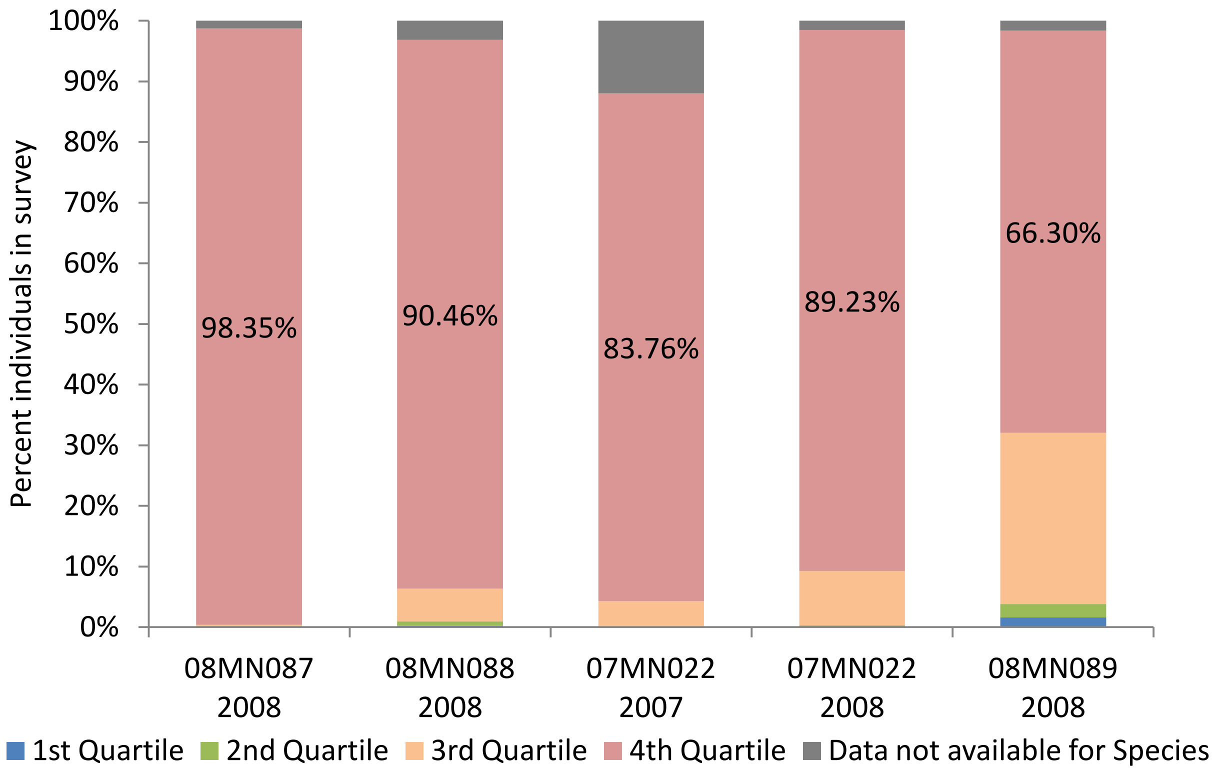

Figure 52. Percent individuals by biological site sampled in Dry Wood Creek, for each quartile based on suspended sediment weighted averages (Meador and Carlisle, 2007)

Estimated stream bank erosion rates for the entire 900 foot reach of 08MN087 ranged from 16 to 90 tons per year, or 0.0176 to 0.1010 tons per year per foot, depending on whether the North Carolina, Colorado, or Yellowstone erosion rate was used for the prediction. Erosion rate predictions for the 100 foot study bank ranged from 0.200 to 1.200 feet per year. The actual erosion rate at the study bank was 0.263 feet per year (Figure 53), which was closest to the North Carolina rates, suggesting that the overall erosion rate for the reach may be closer to the lower end of the range, or around 16 tons per year. However, very little evidence of erosion or channel migration over the past 19 years is evident when overlaying the 2010 and 1991 aerial photos, indicating overall low bank erosion rates.

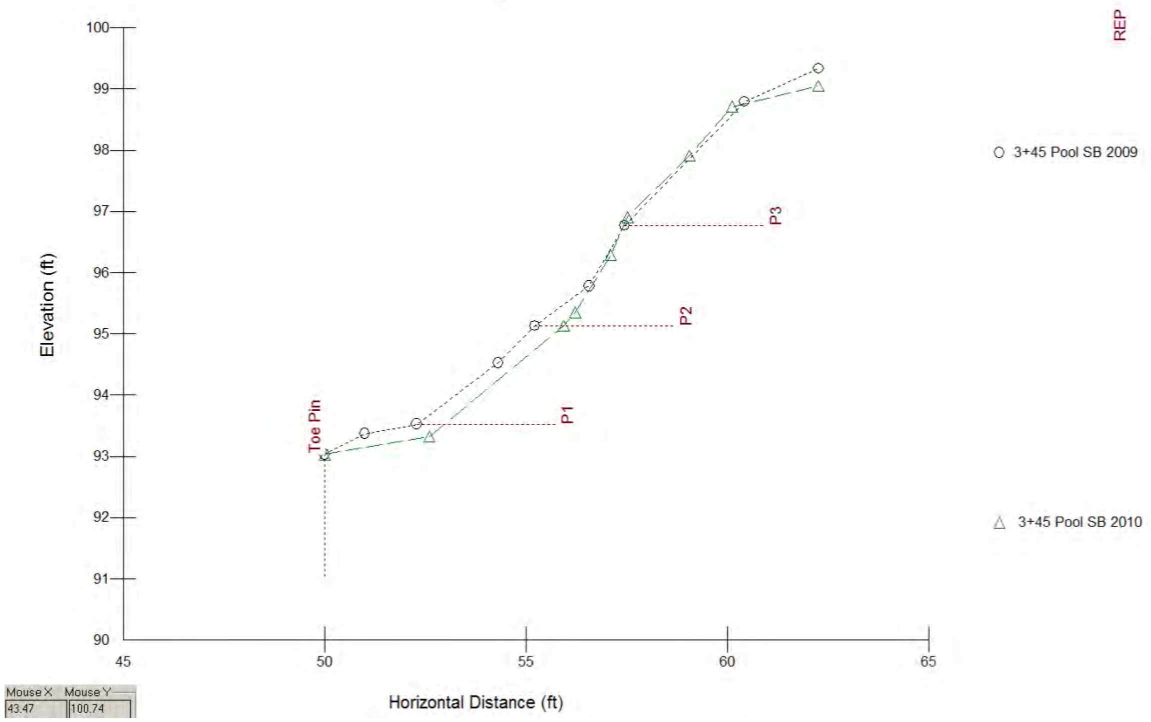

Figure 53. Site 08MN087 study bank showing measured average erosion rate of 0.2625 ft/yr from 2009 to 2010

Figure 54. Pasture condition at site 08MN087

The 08MN088 study reach was evaluated in 2009 following the Bank Assessment for Non-point source Consequences of Sediment (BANCS) method which included a Bank Erosion Hazard Index (BEHI) for predicting reach stream bank erosion rate and total stream bank sediment contributions for the reach. The predicted annual loss sediment loss from stream bank erosion rate for the reach was estimated to range between 10-61 tons per year on the 1674 foot study banks in the reach. The estimated range of stream banks erosion rates in this reach were 0.009-0.0052 tons/foot/year. This is relatively low when compared with rates we estimated on the lower Pomme de Terre River at 0.21-0.48 tons/foot/year. Lower stream bank heights, high surface protection, deep rooting depth to bank height, lower bankfull to bank height ratios and high root density of the grasses all helped lower the risk of stream bank erosion potential in this reach.

A study bank evaluation site was installed at pool cross section 6+13 in 2009. Rebar stakes were placed in the stream bed, vertical eroding bank and top of the bank to monument the cross section. This cross section could then be used to evaluate stream bank and bed erosion rates at this reach and used to compare between predicted and measured erosion estimates. In 2010, study pool 6+13 was resurveyed to measure the active erosion rate for the site over the last year. The actual measured stream bank erosion rate we found was 0.726 ft per year while our predicted bank erosion rates ranged between 0.06-0.340 ft per year (Figure 55). The discrepancy between our actual and predicted stream bank erosion rates might be related to the possible stream channel alterations immediately upstream of the site.

The possible loss of channel sinuosity through the altered reach could be transferring additional hydraulic energy into this study reach that is being dissipated through higher stream bank erosion. This higher stream bank erosion rate could also be a cumulative attribute of the higher than normal precipitation this study area observed during the last year. Frequent significantly higher rainfall events could magnify the observed stream bank erosion rate at this site as well as the others we evaluated.

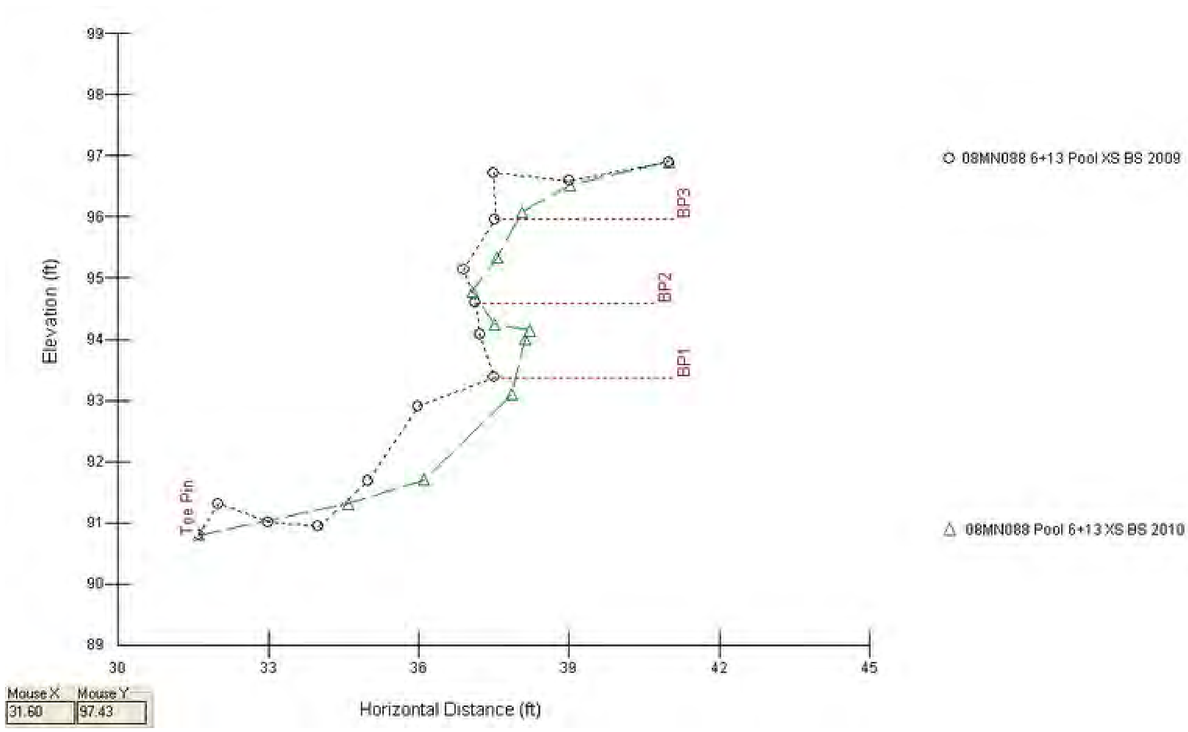

Figure 55. Site 08MN088 study bank showing measured average erosion rate of 0.726 ft/yr from 2009 to 2010

For the entire 1248 foot reach of station 07MN022, erosion ranged from 58 to 149 tons per year, or 0.0469 to 0.1193 tons per year per foot, depending on whether North Carolina, Colorado, or Yellowstone erosion rates were used for the prediction. Erosion rate predictions for bank segments within the reach ranged from 0.0 to 0.7 feet per year.

The predicted annual loss sediment loss from stream bank erosion rate for station 08MN089 was estimated to range between 10-58 tons per year on the 1040 foot study reach depending on the erosion rate applied. The observed erosion rate for the 08MN089 reach was between 0.0088-0.0531 tons/foot/year. This observed erosion rate was significantly less than what was observed on more heavily grazed sites upstream. These heavily impacted sites ranged between 0.01-0.119 tons/foot/year which is several magnitudes higher in direct stream bank sediment contributions.

In 2010, study bank 5+27 was resurveyed to measure the active erosion rate for the site. The actual measured erosion rate was found to be 0.533 ft per year while our predicted erosion rates ranged between 0.15-0.700 ft per year for the study site (Figure 56). At this location our predicted erosion rate fell within the estimated range. Table 11 shows the 2009 predicted and 2010 measured erosion rates for study banks in Dry Wood Creek.

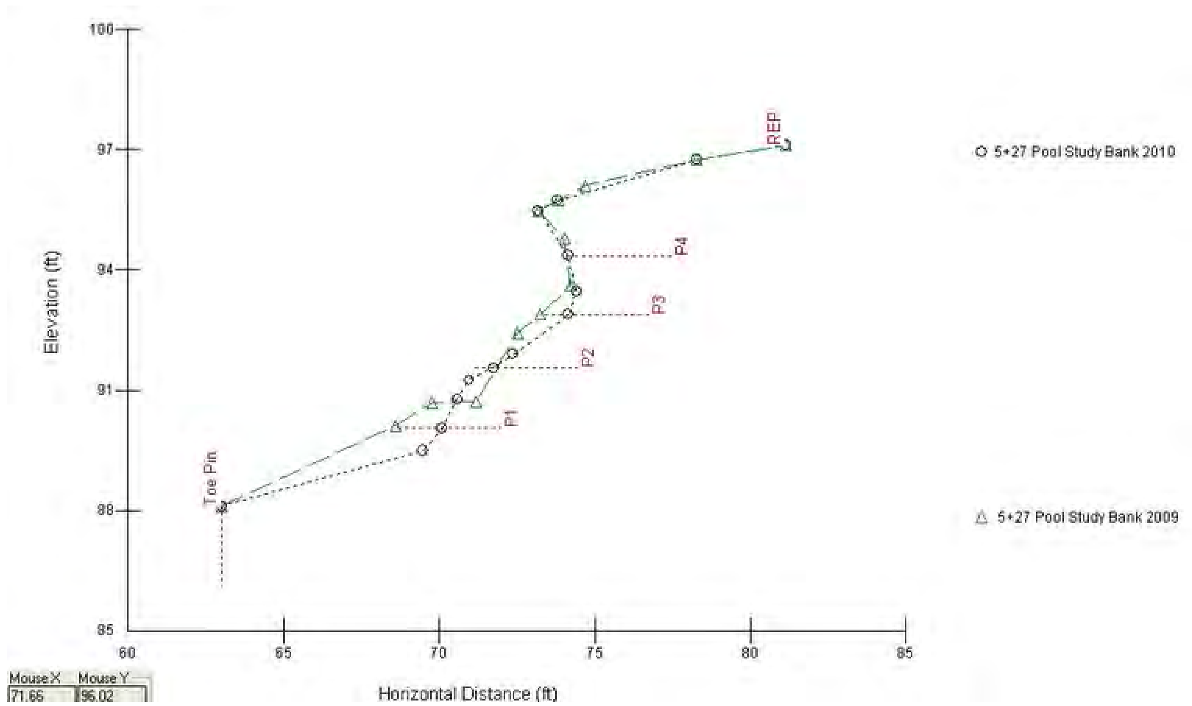

Figure 56. Site 08MN089 study bank showing measured average erosion rate of 0.533 ft/yr from 2009 to 2010

Table 11. Dry Wood Creek predicted (2009) and measured (2010) erosion rates for study bank sites

Study Bank Dimensions (ft)					Predicted Erosion Rates		Measured Erosion Rates	
Study Reach	Length	Height	BEHI Rating	NBS Rating	Loss (ft/yr)	Loss (tons/yr)	Loss (ft/yr)	Loss (tons/yr)
08MN087	100	5	High	High	0.200-1.200	4.81-28.89	0.263	6.32
08MN088	74	7	Moderate	Moderate	0.060-0.340	1.50-8.48	0.726	18.11
08MN089	38	8	High	Moderate	0.150-0.700	2.18-10.17	0.533	7.80

The beaver dam appears to have a dampening effect during the sampling dates in August and October for turbidity (Figure 59). In June 2008, an over bankfull event occurred and the turbidity is, in part, a response of the event that scoured out areas where fine material collects, such as in the area immediately upstream of the beaver dam. In 2008, the substrate comprised of coarse gravel and in August 2009 the substrate was embedded with approximately a foot of fine sediment. During high flow events and when the dams are breached, the accumulated fine sediment, like that observed during the 2009 assessment, flushes downstream, contributing to the turbidity impairment of downstream reaches of Dry Wood Creek and the Pomme de Terre River.

In 2007, total suspended solids in Dry Wood Creek were measured at two locations and follow similar patterns as shown in Figure 57. Measured TSS concentrations were elevated in the spring and early summer and subsequently decreased in mid-summer. In 2008, mid-summer, single-date samples of TSS concentrations and transparency tube were elevated at all of the locations, but particularly high at 07MN022 and 08MN089 (Figure 58).

In 2008, turbidity was measured longitudinally in Dry Wood Creek with a YSI sonde (Figure 59). At the outlet of North Dry Wood Lake, turbidity is high and likely due to sestonic algae along with sediment loads from adjacent land. Dry Wood Lake acts as a sediment settling basin for the upper watershed so suspended sediment should theoretically be low in Dry Wood Creek below the lake. However, heavily grazed pastures between Dry Wood Lake and site 08MN087 are sources of fine sediment from sheet, rill, and gully erosion. Evidence of this can be seen in the composition of bottom sediment for this and CRP reach. The stream bed at site 08MN087 was composed of a mix of gravel, sand, and silt-clay, with some cobble also present. The reach and riffle D50 were 9.5 and 1.2 mm, respectively.

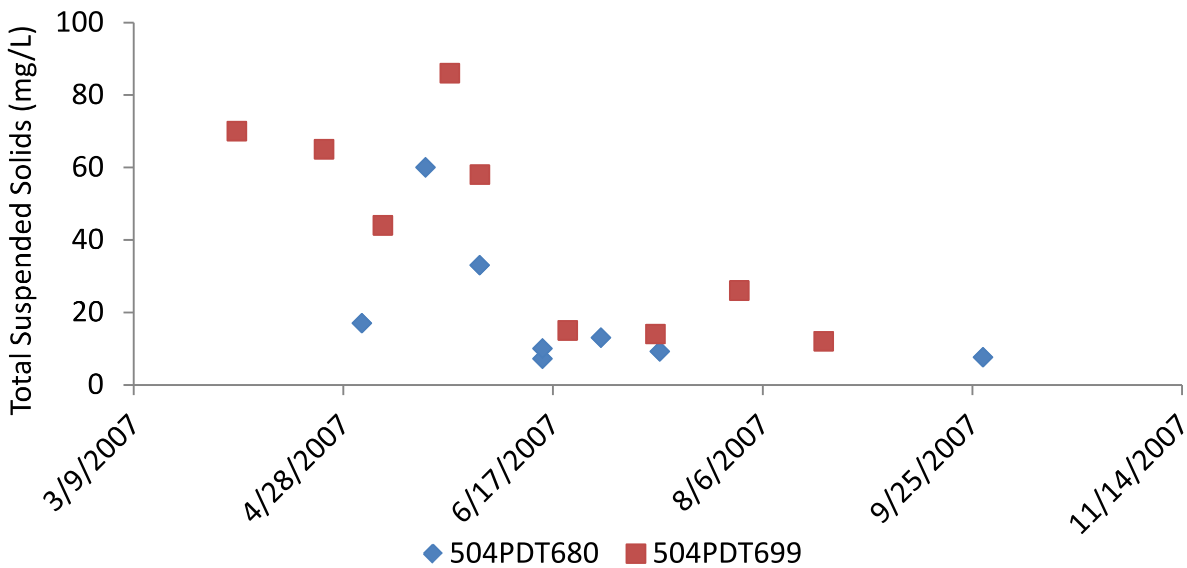

Figure 57. Total suspended solids in 2007 at two locations in Dry Wood Creek

In addition to the field measurements of turbidity and the TSS measurements analyzed at the lab, the HSPF model developed for the Pomme de Terre River watershed simulated TSS concentrations in Dry Wood Creek at the outlet of North Dry Wood Lake (reach 220) and the outlet of the creek to the Pomme de Terre River (reach 210).

In June, from 1996 to 2009, reach 210 had a simulated average TSS concentration just above the standard. TSS concentrations during the highest 20th percentile flows were predicted at 65.47 mg/L, whereas during the other flows concentrations were predicted at 26.21 mg/L. In 2007, 2008 and 2009, the maximum mean daily concentrations were 220, 766 and 184 mg/L, respectively, as simulated by HSPF.

As predicted by HSPF in 2007, six days had mean daily TSS concentrations about 65 mg/L. In 2008, 128 days were predicted above 65 mg/L, with 118 days consecutively above from May 10 to September 4. From March 23 to May 16, 2009, there were 55 days consecutively above the draft standard for TSS; and 63 days combined in 2009 above 65 mg/L. From 2007 through 2009, the sediment load contributed to the Pomme de Terre River from the outlet of Dry Wood Creek was simulated as 299.5 tons. The durations that the biotic community endured high TSS concentrations are extensive as predicted.

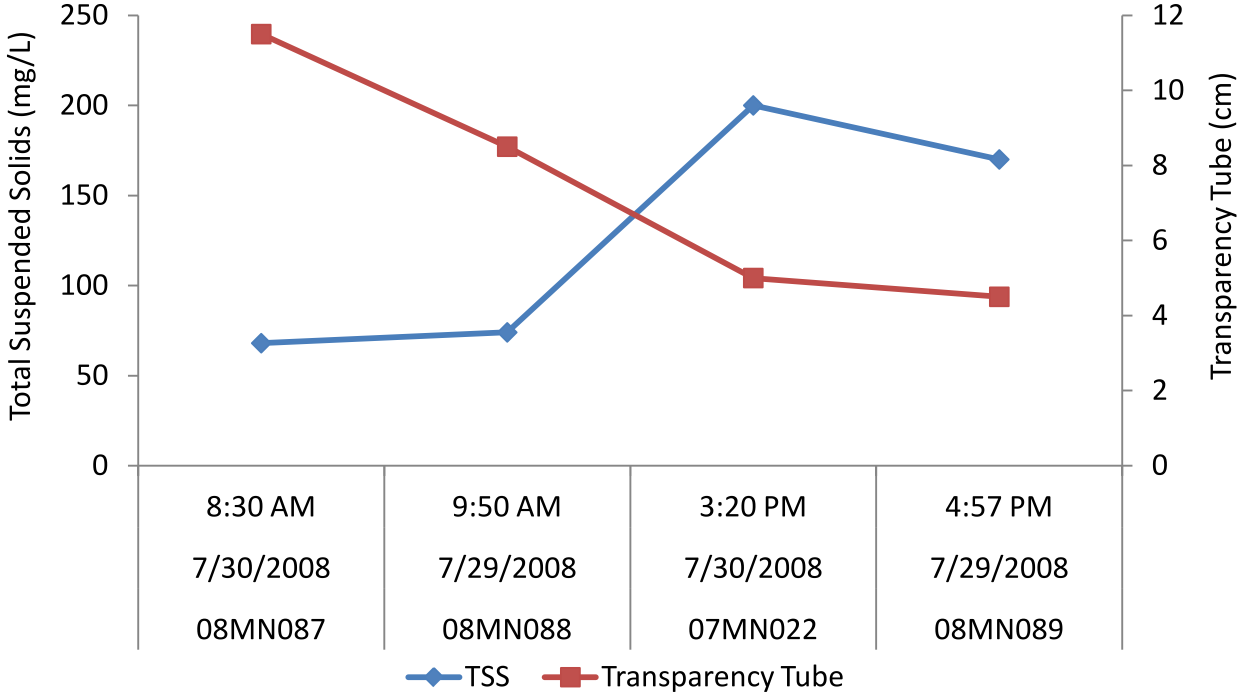

Figure 58. Total suspended solids and transparency tube measurements prior to fish surveying in 2008

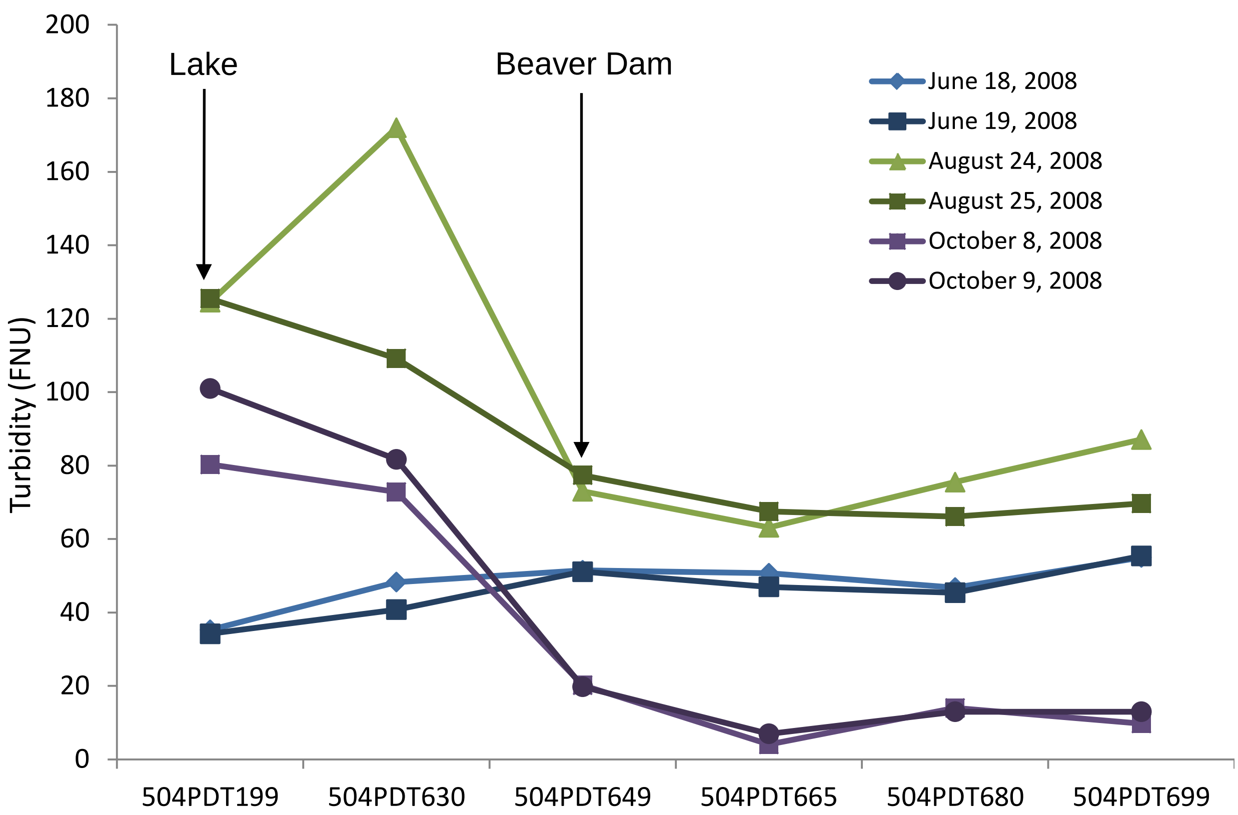

Figure 59. Turbidity (FNU), as measured longitudinally, in Dry Wood Creek from upstream to downstream on select days in 2008

Stressor Pathway: Riparian condition

The riparian buffers along Dry Wood Creek are minimal in some areas. In portions of the creek, the stream banks have gone through increased trampling and decreased riparian and bank vegetation, leading to increases in erosion potential.

Stressor Pathway: Channelization

Channelization of reaches within Dry Wood Creek and the channelization of reaches contributing to the creek have led to changes in the hydrological and geomorphological condition. This has led to changes in erosion rates that have led to an increase in turbidity.

Stressor Pathway: Source-water pollution

North Dry Wood Lake, the headwater source of Dry Wood Creek, is rich in nutrients as measured by its outlet at site 504PDT199. The sources of nutrients to the lake are thus also contributing a high load of nutrients to Dry Wood Creek that manifested in an abundance of blue green algae at times which limits water transparency.

Stressor Pathway: Impoundments

Impoundments in Dry Wood Creek have led to instability creating increased erosion around impoundments as well as channel alteration to regain stability (Figure 60).

Figure 60. Aerial photo of impoundment upstream of 520th St

The data and consistency of the evidence supports turbidity as a stressor in Dry Wood Creek. There are plausible sources and pathways as well as a biological response expected in a stream with elevated turbidity levels.

Candidate Cause: Altered Hydrology

Mean daily flows, for 1996 -2009, ranged from 0 – 1826 cfs in reach 220 and 0.05 – 2118 cfs in reach 210 (Figure 61). Bankfull discharge was estimated by geomorphic surveys at the biological stations at approximately 90.30 cfs and the flow is the 6th percentile at reach 210 with estimated velocities ranging from 0 to 2.48 ft/s. Similar to other reaches in the Pomme de Terre River watershed, the bankfull flows are initiated at the end of March or beginning of April (Figure 62). Bankfull flows have a recurrence interval of 1.46 years with the annual series method (based on peak annual discharge, Log-Pearson Type III Distribution).

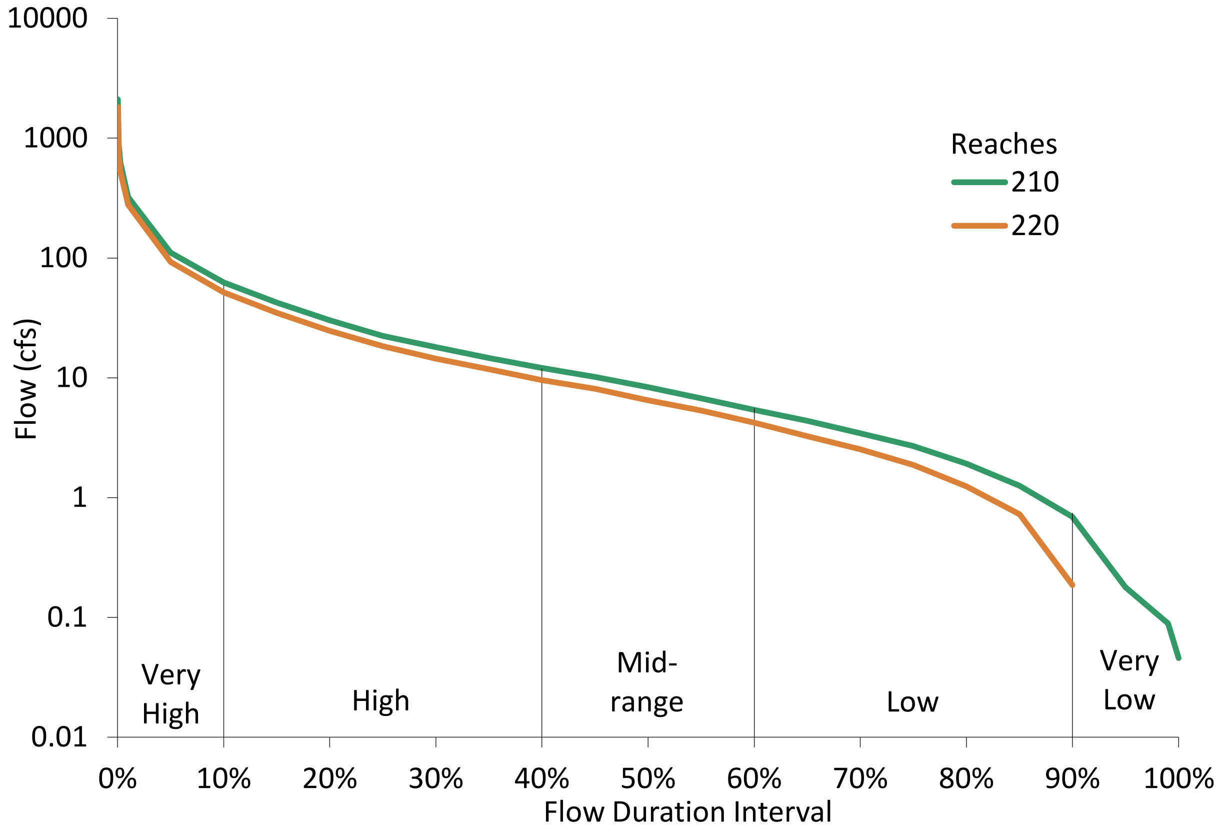

Figure 61. Flow duration curve for the outlet of North Dry Wood Lake (220) and the outlet of Dry Wood Creek (210)

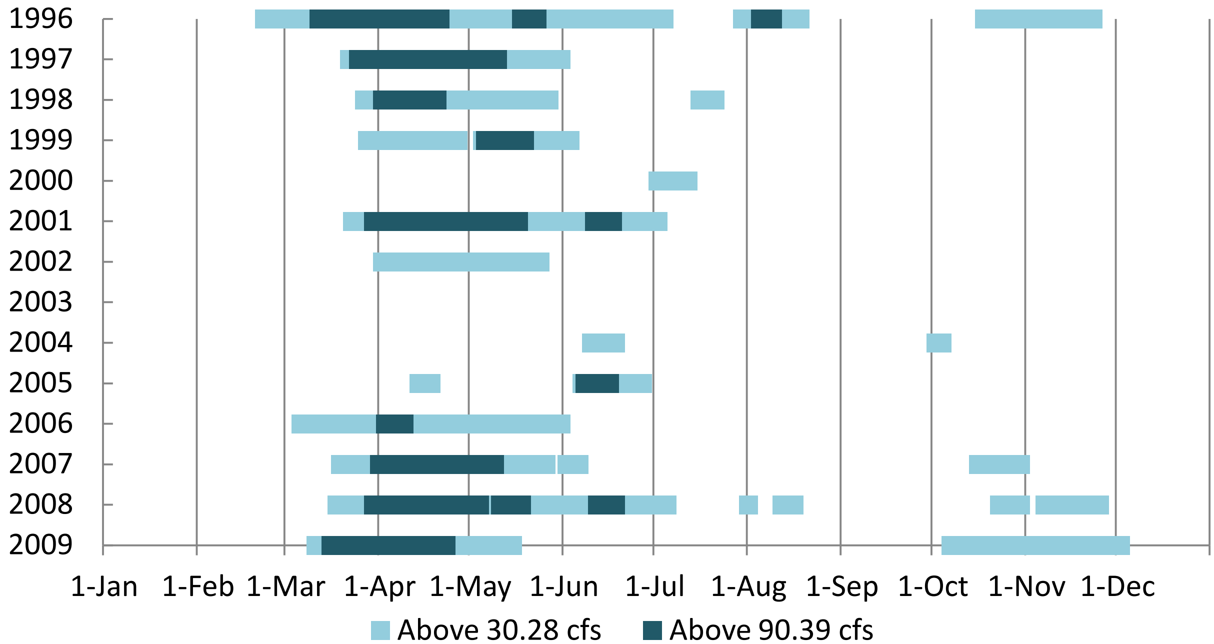

Figure 62. Bankfull flow events and flows greater than 30.28 cfs (highest 20 percent flows) at the outlet of Dry Wood Creek from 1996 to 2009

Dry Wood Creek has experienced times of dry and very low flow conditions for extended periods. Longitudinally, the stream may be flowing in the lower section and not in the upper section. In 2009, flow was discontinued from the lake to the stream. MPCA staff observed the creek consisted of a series of puddles rather than flowing water. Staff observed an absence of flowing water at site 504PDT199 on June 2, 23 and 24, August 6 and 18. Figure 63 shows the site with a large puddle on the downstream side of the road crossing. This would inhibit fish from traveling longitudinally throughout the stream. September is the month that most frequently has low flows, followed by January (Figure 64). There are also extended durations of low flow that would potentially inhibit healthy biota populations.

Figure 63. 504PDT199 downstream of road crossing on June 23, 2009

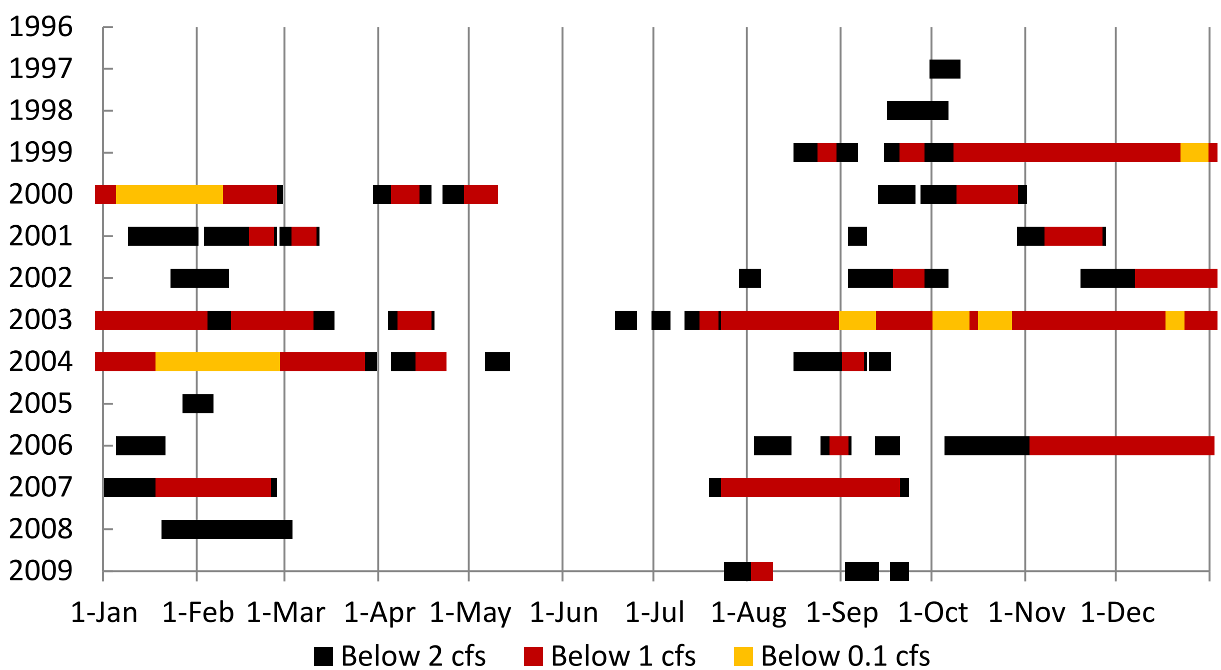

Figure 64. Low flow events at the outlet of Dry Wood Creek from 1996 to 2009

There is a lower proportion of fish that prefer moderate and fast velocities (except tolerant) in the Dry Wood Creek than found in other MN River Basin class 2 streams (Figure 65). One biological site, 08MN089, scored above the IBI threshold, yet does not have a great community of fish that prefer moderate and fast velocities.

Generalists were greater than 90 percent of the fish populations surveyed in the three upstream sites and 57.61 percent at the downstream site, 08MN089. Similarly, non-lithophilic spawners made up over 72 percent of the survey on the three upstream stations, and were less than half of that at site 08MN089 with 32.61 percent. Percent tolerant individuals ranged from 84.24 to 99.45 percent and scored zero for the metric in the IBI for all sites in Dry Wood Creek (Figure 23). The fish community is typical of a community that has been affected by altered hydrology.

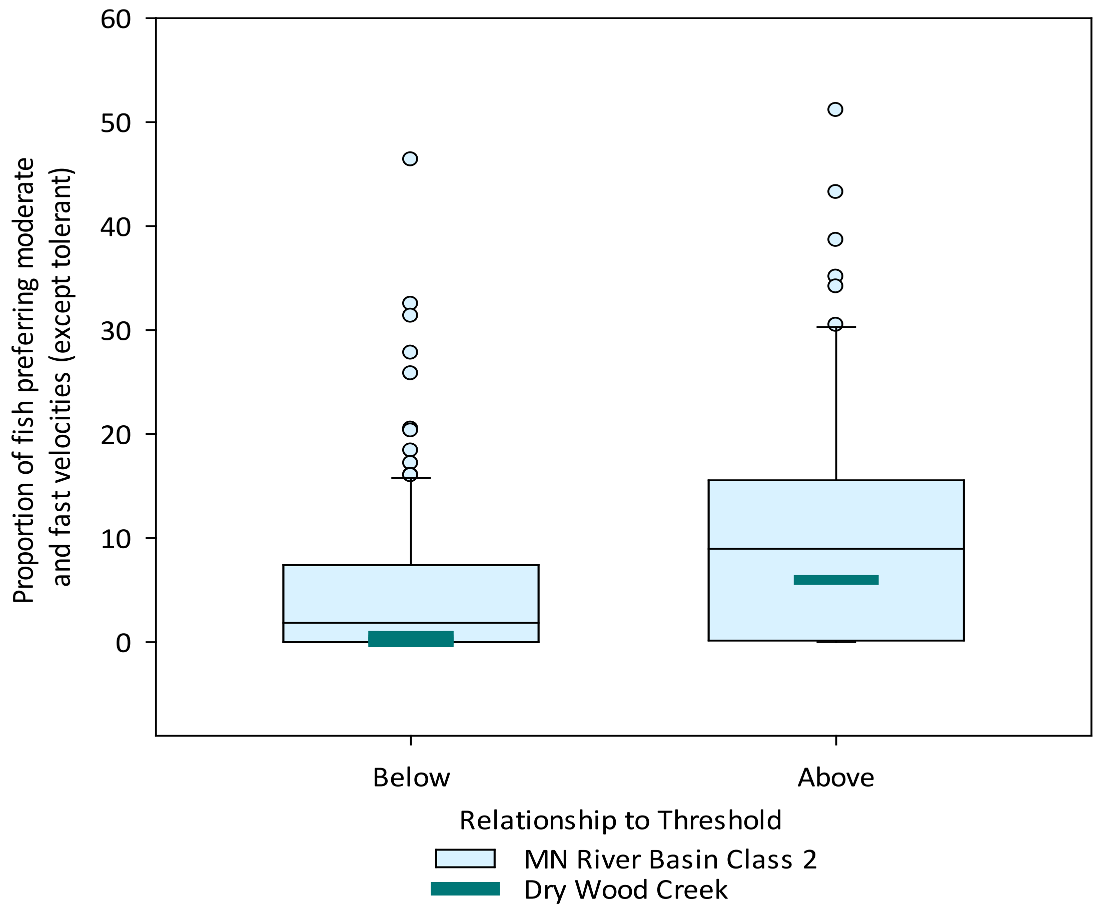

Figure 65. The proportion of fish preferring moderate and fast velocites (except tolerant) MN River Basin Class 2 Streams and Dry Wood Creek with respect to below and above the IBI threshold

The invertebrates in Dry Wood Creek consist of few clinger and EPT taxa indicating that flow may be of concern, as EPT taxa are known to be impacted by altered hydrology (Schofield and Ziegler, 2010). Few invertebrates in Dry Wood Creek are considered long lived, with the average at each biological station approximately 1.5 percent of the survey. Three samples consisted of less than 1 percent, in 2008. This indicates the invertebrate community needs to move through its life cycles quickly to adapt to changing conditions.

Corixidae (water boatman), a swimmer, consisted of 65 percent of the sample at site 08MN087. Other stations along Dry Wood Creek were not so heavily inundated with swimmers with a range of near zero at site 08MN089 to eleven percent at site 07MN022. In the MN River Basin, swimmers in invertebrate stream classes 5 and 7, of natural channels, range from 0 to 75 percent. Site 08MN087 is the highest relative to the water table elevation and is thus more likely to have reduced flow than the other 3 sites on Dry Wood Creek, and thus would have the greatest likelihood of having the greatest proportion of swimmers (Figure 66). The invertebrate community in Dry Wood Creek is also indicative of a system that has been hydrologically altered.

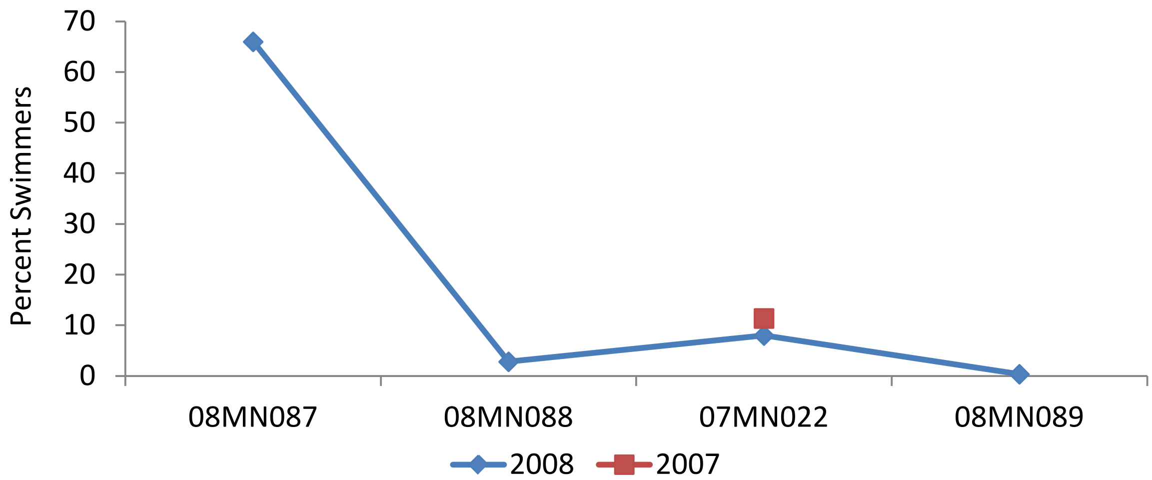

Figure 66. Percent swimmers in Dry Wood Creek in 2007 and 2008

Aerial photo interpretation of station 08MN088 indicates some possible significant channel modification has occurred about a half mile above this study reach. These possible channel modifications include straitening and over widening nearly a mile of stream channel. The loss of sinuosity and changes to the hydrologic functions of the channel in this altered reach either has or is still causing impacts in this study reach. These impacts may include higher stream velocities, greater bedload of fine material and possible increased stream bank sheer stress.

Stream channel incision reflects how the stream channel is adjusting to the altered hydrologic regime in this 97 square mile watershed. These hydrologic changes are likely driven by alterations in precipitation patterns, land use, subsurface drainage, surface drainage, added impervious surfaces and altered floodplain connectivity. The possible continuation of channel incision in this reach will likely accelerate stream bed and stream bank erosion rates for the foreseeable future. These impacts will likely reduce stream habitat, stream function and maintain the potential for low IBI indexes scores for fish and invertebrate communities in this reach.

The section of Dry Wood Creek downstream of Drywood Lake can go dry when there is no outflow from Drywood Lake. This lack of baseflow disconnects the lake from the rest of the stream. The lack of flow as well as the duration of low flow is a stressor to the biological communities. The fish are representative of a population that is tolerant and adaptable to their conditions as generalists rather than specialists. The invertebrate community is comprised of few short lived species with few clingers or EPT taxa. Clearly, Dry Wood Creek is influenced by the hydrologic regime both as a direct stressor and through its ability to impact the habitat, dissolved oxygen, and turbidity.

Stressor Pathway: Riparian condition

The riparian buffers along Dry Wood Creek are minimal in some areas. In portions of the creek, the stream banks have gone through increased trampling and decreased riparian and bank vegetation, leading to changes in structural habitat with influence the hydrologic regime by influencing water depth and velocity.

Stressor Pathway: Channelization

Channelization of reaches within Dry Wood Creek and the channelization of reaches contributing to the creek have led to changes in the hydrological and geomorphological condition. This has led to changes in discharge patterns. Additionally tile drain also contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs.

Stressor Pathway: Impoundments

Active impoundments change the discharge of a system creating changes in water slope leading to changes in scouring and deposition as well as changes to water velocity and depth. They can hold back water which increases discontinuity and potential stranding.

Weight of Evidence

The evidence for each potential stressor, the quantity and quality of each type of evidence is evaluated. The consistency and credibility of the evidence is evaluated. Each step for Dry Wood Creek was scored and summarized in Table 12. For more information on scoring please see EPA's CADDIS Summary Table of Scores.

Table 12. Weight of evidence table for potential stressors in Dry Wood Creek

Types of Evidence	Low Dissolved Oxygen	High Phosphorus	High Nitrate	Lack of Connectivity	Lack of Habitat	High Turbidity	Altered Hydrology
Evidence using data from Dry Wood Creek Watershed							
	Scores						
Spatial/temporal co-occurrence	+	+	+	R	+	+	+
Temporal sequence	+	0	+	0	+	+	+
Field evidence of stressor-response	++	+	++	0	++	++	++
Causal pathway	++	++	++	++	++	++	++
Evidence of exposure, biological mechanism	++	++	++	0	++	+	++
Field experiments /manipulation of exposure	NE	NA	NE	NE	NE	NE	NE
Laboratory analysis of site media	NE	NA	NE	NE	NE	NE	NE
Verified or tested predictions	+++	+	+++	-	NE	NE	NE
Symptoms	+	+	+	0	+	+	+
Evidence using data from other systems							
Mechanistically plausible cause	+	+	+	+	+	+	+
Stressor-response in other lab studies	++	NE	+	NA	NE	NE	NE
Stressor-response in other field studies	++	+	+	-	+	+	+
Stressor-response in ecological models	NE	NE	NE	NA	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE	NA	NE	NE	NE
Analogous stressors	NE	NA	NE	NA	NA	NE	NE
Multiple lines of evidence							
Consistency of evidence	+++	+	+++	-	+++	+++	+++
Explanatory power of evidence	++	++	++	-	++	++	++

Conclusions

In Dry Wood Creek there exists a suite of stressors that additively prevents the biological community from attaining a desirable, healthy biological community.

The dissolved oxygen is clearly below the standard at all sites and the biology responded at all four sites with high numbers of fathead minnows and minimal EPT. In 2008, one site was observed to have more than seven hours below 1 mg/L of dissolved oxygen.

Phosphorus levels are excessive in this watershed. Although the fish community was not comprised of planktivorous species, this is likely due to other stressors interacting. Sensitive invertebrate response metrics of percent EPT, percent Tanytarsini, and percent intolerant are reduced due to increased nutrients. Phosphorus is likely directly contributing to the dissolved oxygen and turbidity stressors present. Habitat and alteration of food resources is also influenced by excess phosphorus.

Nitrate is elevated during snowmelt and was measured at 15 mg/L in a ditch to Dry Wood Creek. Nitrate sensitive fish species were reduced, particularly in the three upstream biological stations. Invertebrate populations were comprised of almost all tolerant individuals.

Connectivity was not found to be a direct stressor with the evidence available; however structures present have a profound effect on other stressors.

Habitat is a limiting factor for the biological community in Dry Wood Creek. The cover and riparian corridor could be greatly improved. Erosion is common and accelerated in many of the reaches. The erosion has led to increased embeddedness and lack of habitat availability. Fish species present in the creek are known to be tolerant of silt substrates. Invertebrates known to cling were also reduced with the lack of habitat.

Turbidity and associated TSS measurements were considerably high throughout Dry Wood Creek. Both fathead minnows and common carp are tolerant to high levels of turbidity and were prevalent throughout the creek.

Altered hydrology greatly influences the list of stressors present in the Dry Wood Creek. The fish community and invertebrate community have been affected by changes to the hydrologic regime including the lack of baseflow. The invertebrate population is comprised of short lived species able to respond to changes in hydrologic regime rather than those that depend on the dynamics of the flow pattern to be predicable and seasonal.

The pathways present for these stressors to persist in the watershed are the riparian condition, channelization, source-water pollution and impoundments.

In some riparian areas of Dry Wood Creek, the corridor is trampled, heavily grazed, de-vegetated banks, or replaced with row crop. These actions have led to increases in erosion potential and measured erosion, changes in structural habitat, influences on the hydrologic regime by influencing water depth and velocity, changes in cover availability, alterations to stream stability and the allowance of high amounts of nutrients, sediment and pesticides from adjacent fields to enter adjacent streams and rivers.

Channelization is apparent in the channel of Dry Wood Creek as well as intermittent ditches to the creek, along with tiling in the watershed. These landscape alterations have led to changes in the hydrological and geomorphological condition; including changes in erosion rates, changes in discharge patterns (e.g. contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs), changes in substrate, and changes in sinuosity.

Sources of water to Dry Wood Creek are contributing to the impairments. North Dry Wood Lake, the headwater source of Dry Wood Creek, is rich in nutrients. The sources of nutrients to the lake are thus also contributing a high load of phosphorus to Dry Wood Creek that manifested in an abundance of blue green algae at times which limits water transparency and alters the dissolved oxygen regime. Water inputs from channelized intermittent tributaries to Dry Wood Creek are high in nitrates during snowmelt and rain events.

Impoundments in Dry Wood Creek have led to instability creating increased erosion around impoundments as well as channel alteration to regain stability. Dissolved oxygen levels can be affected by impoundments by collecting nutrients and organic materials. In the Dry Wood Creek watershed, there are two constructed impoundments and a beaver dam downstream of 504PDT649 altering flow and thus decreasing dissolved oxygen concentrations upstream of the dam.

Low dissolved oxygen, high phosphorus, high nitrate, lack of habitat, high turbidity, and altered hydrology are stressors to the biological community in Dry Wood Creek. To improve the biological community in Dry Wood Creek, the direct stressors need to be removed through: improvements and protection in the riparian corridor; improvements to how water is supplied to the creek such as increasing infiltration to improve baseflow conditions; improvements to the quality of water in North Dry Wood Lake and sources, such as intermittent tributaries; and improvements to the current impoundments.

Unnamed Creek

Biology in Unnamed Creek

The fish community in the unnamed creek is impaired. The fish community at site 07MN021 was sampled in 2007. The three species collected were fathead minnow (196 specimens), white sucker (30), and brook stickleback (3). The metrics used to assess this reach all scored low, and gave an IBI score of 2. This stream is lacking a diverse biological community. The site within this reach was not sampled for invertebrates due to lack of adequate water to produce a representative sample during the sampling time window.

Candidate Cause: Nitrate

In this watershed, there were only 4 nitrate-N samples collected, and all four samples were greater than the annual 75th percentile nitrate-N level for the ecoregion (Figure 67). A baseflow sample was attempted in 2009, but there was no water at 601PDT677 and no flow at 601PDT698. At the time of fish surveying, on June 20, 2007, the nitrate sample measured at 4.3 mg/L.

Fathead minnows and white suckers have high tolerance indicator values for nitrate-nitrite of those studied by Meador and Carlisle (2007, Table 5 Brook stickleback were not included in the study, however they are known to be generally tolerant. Invertebrates were not available for comparison given that samples were not collected due to lack of flow.

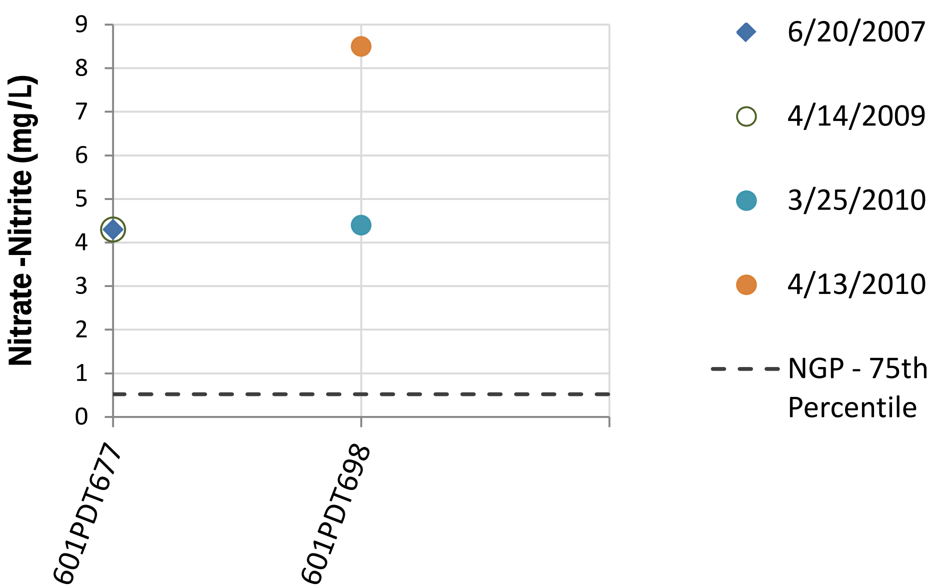

Figure 67. Nitrate-N measurements collected in Unnamed Tributary watershed

Stressor Pathway: Source-water pollution

Drainage systems and agricultural fields are source of the surface water component to the unnamed tributary. It is assumed that nitrogen and forms of nitrogen, such as ammonia, are being applied to the cropland throughout the watershed as it is 82 percent cropland. It is unknown how much groundwater contributes nitrate.

Candidate Cause: Habitat

The unnamed creek scored 55 (fair) for the MSHA. Riparian width was originally evaluated as being none, and received a score of zero. The riparian width is defined as the width of undisturbed vegetative zone adjacent to the stream with beneficial vegetation such as stable grasses, trees and shrubs with low runoff potential (MSHA Protocol).

Upon further evaluation of this component of the MSHA it was found that the riparian width on the left bank ranged from 70 to 440 feet and on the right bank 215 to 600 feet based on the 2006 and 2008 aerial photographs available for this site (MnGeo's Geospatial Image Server). Conservatively, focusing on the minimum widths, the left bank had a moderate width (30 – 150 feet) with a score of 3 and the right bank had a wide width (150 – 300 feet) with a score of 4. These scores are then averaged to combine both sides leading to 3.5 point addition to the riparian subcategory and total score (9 and 58.5 respectively).

Additionally the site pictures taken at the time of fish sampling support the stable vegetation with willows on the left bank and grasses that have not been disturbed throughout (Figure 68). At the time of sampling in June of 2007, shade was limited and was measured as none and light shading, which is typical for that time of year (June 26, 2007). It would not be expected that this small prairie stream would have heavy shade until the grasses have grown to their mature height of the season in August or September when cover is needed due to typically warmer air temperatures in those months. Figure 69 shows the site from the upstream road crossing on August 6, 2009 and Figure 70 shows the dry stream bed and thick vegetation surrounding the creek. Based on this analysis, MPCA staff concluded that the condition of the riparian zone is not a limiting factor adversely affecting the fish community at this site.

Figure 68. Biological site 07MN021, view downstream of biological reach (left) and view downstream of the upstream start of reach (right)

Figure 69. Biological site 07MN021, view downstream of road crossing

Figure 70. Biological site 07MN021, view of vegetation and dry stream bed

Channel morphology scored the proportionally the highest of the five subcategories, and the high score was also verified by a geomorphic survey of the biological site. Land use and cover scored below fifty percent of the available score and substrate was received 50 percent of the possible score (Figure 71).

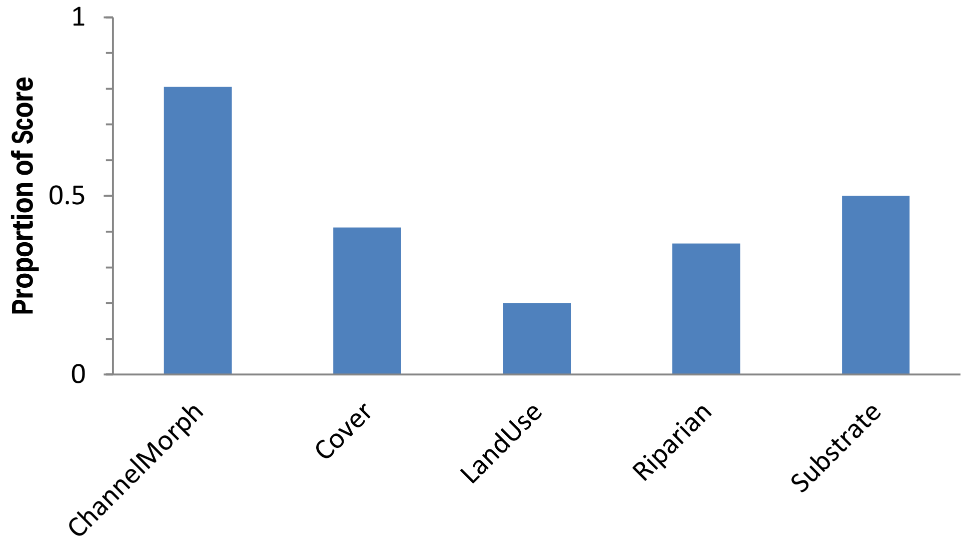

Figure 71. Proportion of possible subcategory scores in unnamed tributary at site 07MN021

The substrate in this reach was observed as having gravel throughout the reach and in all habitat types – riffle, run, pool, along with some sand in the riffles and silt in the pool and run at the time of fish surveying. During the geomorphic survey, in 2009, the substrate throughout the reach was approximately 30 percent each of silt/clay, sand, and gravel, and 9 percent cobble. Sand comprised of about 49 percent of the riffle along with 29 percent gravel, 12 percent cobble and 9 percent silt/clay. It is unlikely that the substrate in this biological reach is a contributer to the biotic impairment as it is only lightly embedded and comprised of gravel and cobble in this prairie stream.

While the habitat could be better in this reach, habitat is likely not a contributer to the biotic impairment. It appears as though other stressors play a larger role in degrading the fish population.

Candidate Cause: Altered Hydrology

Over half of the daily mean flows for this reach are less than 1 cfs, as estimated by the HSPF model. The model output estimates flows in the range from 0.02 to 201.7 cfs (Figure 72). Field observed bankfull was estimated to occur approximately at 8.27 cfs (6^{th} percentile flow) and has an RI (recurrence interval) of 1.52 years. Bankfull flows often began at the end of March and would last until June (Figure 73). A few flows rose above the 20^{th} percentile in October and November with velocities ranging from 0.42 to 3.67 ft/s.

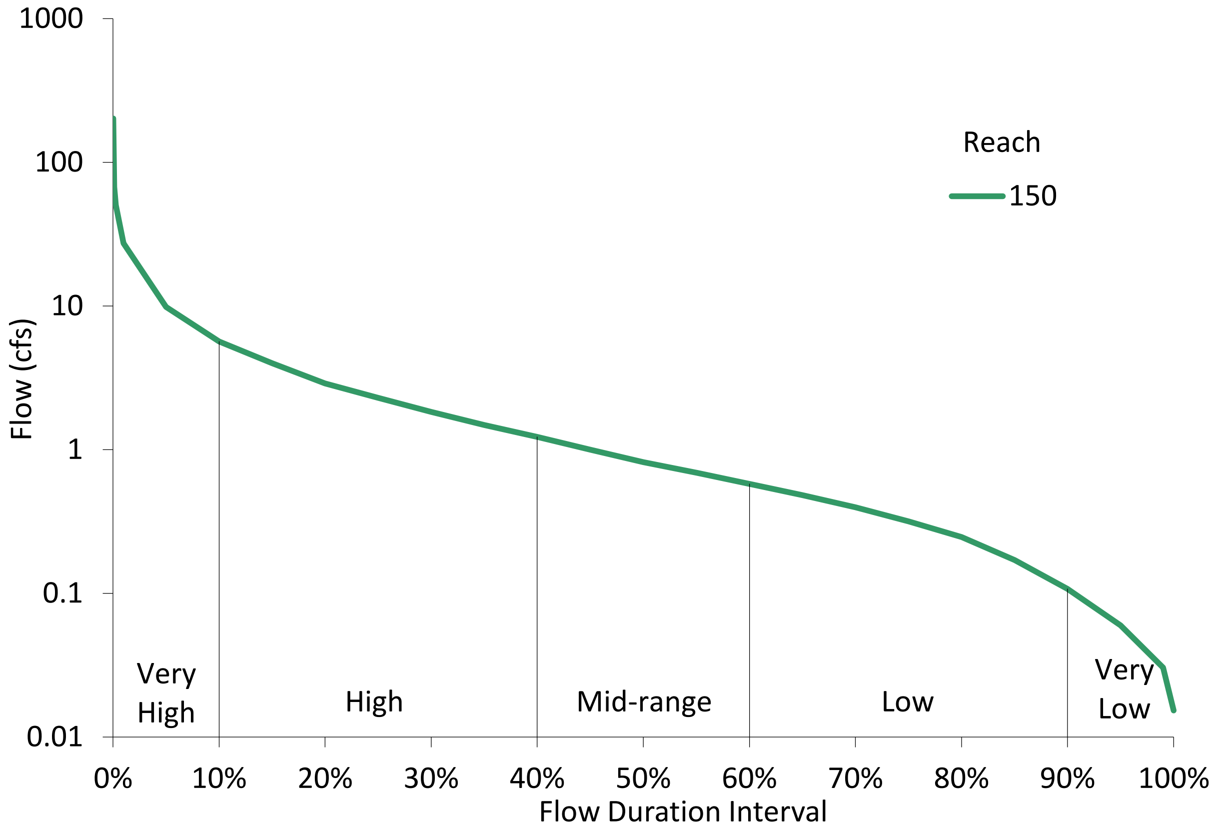

Figure 72. Flow duration curves for HSPF reach 150, unnamed creek

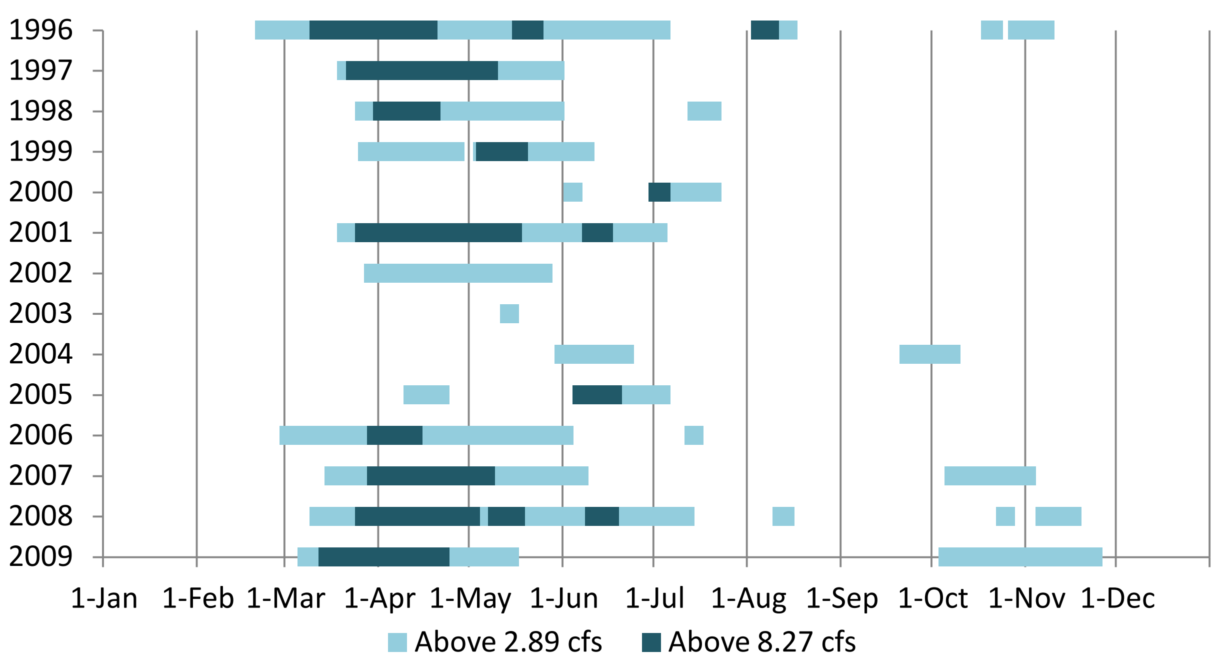

Figure 73. Bankfull flow events (above 8.27 cfs) and flows greater than 2.89 cfs (highest 20 percent flows) at the outlet of the unnamed creek, reach 150, from 1996 to 2009

A lack of flow was observed in the unnamed tributary to the Pomme de Terre River on June 24, August 6, and September 9, 2009. In general, from July to March, the unnamed tributary is below 1 cfs (Figure 74). Areas including the biological site were completely void of puddles at the time of geomorphic survey (August 6, 2009), except at the downstream scour pool at the road crossing. The lack of water for the durations observed will definitely result in the lack of biological community desired by other small streams.

On June 20, 2007, there was sufficient water and flow for fish surveying. In this reach, fish individuals that are considered generalists comprised of 98.69 percent of the survey and the non-lithophilic nest guarders made up 86.90 percent of the survey. The tolerant individuals comprised of 100 percent and those very tolerant made up 85.59 percent of the survey.

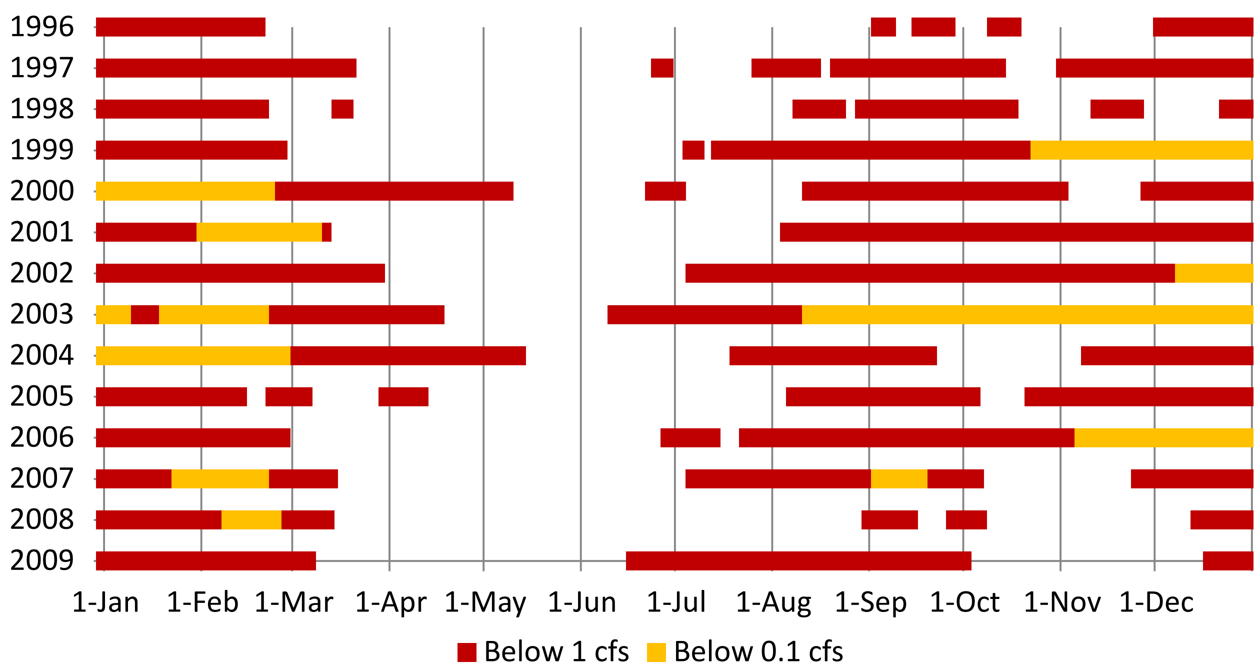

Figure 74. Low flow events, below 1 cfs and below 0.1 cfs at the outlet of Unnamed Tributary, reach 150, from 1996 to 2009

Stressor Pathway: Groundwater Withdrawal

It is unknown the effects of groundwater withdrawal on the unnamed creek. The surrounding landscape has a number of groundwater withdrawals for irrigation and livestock watering. In particular a group of seven wells north of the small watershed that began pumping in 2004 (Figure 75). In 2009, according to the DNR SWUDS, the wells pumped 139.9 million gallons of water. It is unknown the effects of this groundwater withdrawal on the water levels in the creek. There are no obvious differences after the instillation of the wells in the HSPF modeling to conclude that the groundwater withdrawal may be a factor in the low baseflow present in the unnamed creek. Groundwater withdrawal can have dramatic effects on flows in streams and rivers. Further study, such as a groundwater model, would need to be completed to better understand this relationship in the unnamed creek.

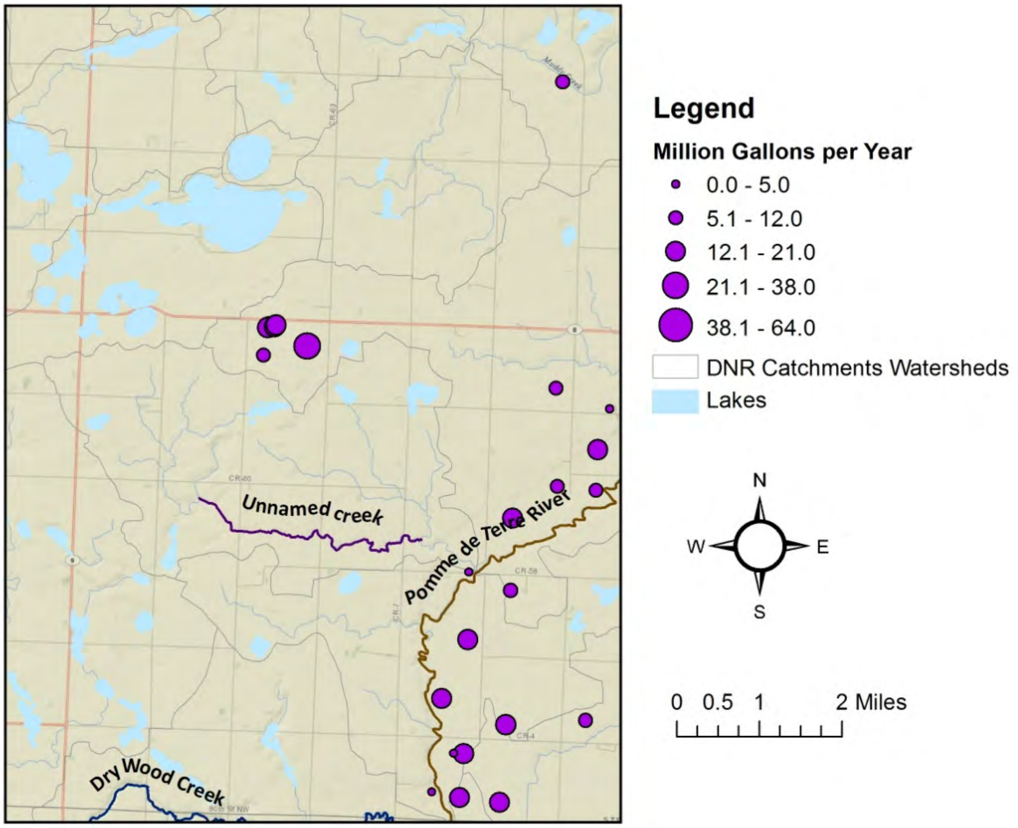

Figure 75. Groundwater withdrawals near the unnamed creek (DNR, 2012)

Stressor Pathway: Channelization

Channelization of the headwater reaches within the unnamed creek watershed and the drainage systems have led to changes in the hydrological and geomorphological condition. This has led to changes in discharge patterns. Additionally tile drain also contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs.

Stressor Pathway: Natural regime

There is a potential that the flow regime present in the unnamed creek is natural. The watershed is small, at only 6.77 square miles to the biological station. The flow could be seasonally intermittent without anthropogenic influence.

Weight of Evidence

The evidence for each potential stressor, the quantity and quality of each type of evidence is evaluated. The consistency and credibility of the evidence is evaluated. Each step for Unnamed Creek was scored and summarized in Table 13. For more information on scoring please see EPA's CADDIS Summary Table of Scores.

Table 13. Weight of evidence table for potential stressors in Unnamed Creek

Evidence using data from Unnamed Creek Watershed			
Types of Evidence	**Scores**		
	High Nitrate	**Lack of Habitat**	**Altered Hydrology**
Spatial/temporal co-occurrence	+	---	+
Temporal sequence	+	0	+
Field evidence of stressor-response	0	-	++
Causal pathway	++	0	++
Evidence of exposure, biological mechanism	++	--	++
Field experiments /manipulation of exposure	NE	NE	NE
Laboratory analysis of site media	NE	NE	NE
Verified or tested predictions	+	NE	NE
Symptoms	+	0	+
Evidence using data from other systems			
Mechanistically plausible cause	+	+	+
Stressor-response in other lab studies	+	NE	NE
Stressor-response in other field studies	+	-	+
Stressor-response in ecological models	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE
Analogous stressors	NE	NA	NE
Multiple lines of evidence			
Consistency of evidence	+	-	+++
Explanatory power of evidence	++	0	++

Conclusions

In the unnamed creek, a lack of flow is clearly a stressor to the biological community and with the limited dataset available, nitrate is also a stressor. Habitat was not to be found a limiting factor at the biological station.

Baseflow conditions are less than optimal for a healthy fish and invertebrate community to exist. In general, from July to March, the unnamed creek is less than 1 cfs as modeled by HSPF.

Changes to the landscape may have allowed for these stressors to persist. The pathways present for flow alteration are source groundwater withdrawal and channelization. The hydrological regime may potentially be natural conditions, but certainly anthropogenic changes exist in the watershed that may also have a role in the flow dynamics of the creek. Groundwater withdrawal is occurring near the watershed both North and East of the unnamed creek. Additionally, channelization and tiling of intermittent tributaries and flow paths may have decrease infiltration reducing baseflow. Natural baseflow conditions should be evaluated further with monitoring and/or a groundwater model to understand further the hydrological connectivity between the altered landscape and the stream.

Nitrate measurements were all above the ecoregion expectations including at the time of fish sampling. Tolerant fish were all that was observed in the unnamed creek. Drainage systems and agricultural fields are source of the surface water component to the unnamed tributary. It is assumed that nitrogen and forms of nitrogen, such as ammonia, are being applied to the cropland throughout the watershed as it is 82 percent cropland. It is unknown how much groundwater contributes nitrate. Further monitoring should be completed to understand the sources of nitrate.

Pomme de Terre River, Barrett Lake to North Pomme de Terre Lake (Upper PdT)

Biology in Upper PdT

In the Upper PdT reach the fish are impaired and metrics that comprise the IBI were analyzed to look for indicators of stressors. Of the eleven fish metrics in the Southern Rivers IBI for Fish (class 1), eight of the scores were below 5. The metric, SSpnTxPct, which is the percent of taxa that are serial spawners (multiple times per year), had the lowest mean score of zero (Figure 76). Serial spawners have ecological advantage over other spawners because they spawn numerous times during the summer months. For example, bluntnose minnows spawn continually from May to August (Ohio DNR). Single spawners, as suggested by the name, spawn only once per season. Thus, if environmental conditions for the single spawners are not optimal, the season's new generation may be lost. A few common serial spawners present in this reach are fathead minnows, orangespotted sunfish, bluntnose minnows, and spotfin shiners.

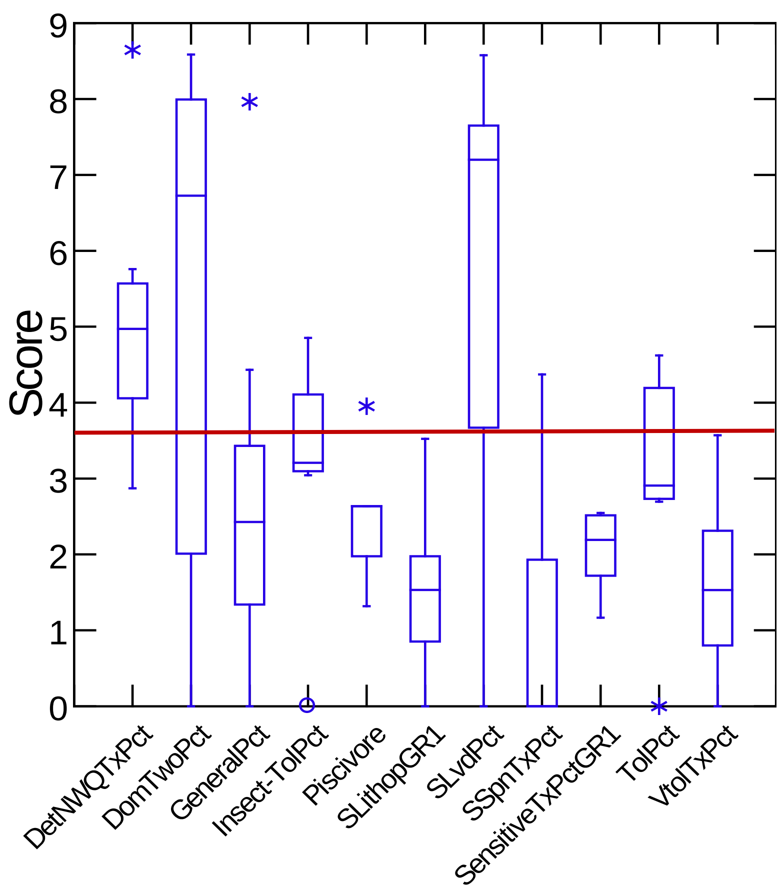

Figure 76. Fish metrics belonging to the Southern Rivers IBI for the Upper PdT; Red line indicates the average metric score (3.6) needed for IBI score to be at the threshold

Another low metric score was SLithopGR1, the taxa richness of simple lithophilic spawning species (adjusted for gradient). This is indicative of a possible loss of habitat, primarily a lack of gravel for these species to reproduce. Additionally, the percent of taxa that are very tolerant, VtolTxPct, is higher than would be desired, thus reducing that metric's scores for this reach.

Candidate Cause: Dissolved Oxygen

Biological site 03MN003, on August 19, 2003, at 12:30pm, had one measurement of dissolved oxygen at 4.88 mg/L, just below the standard of 5 mg/L. At each of the four biotic sampling sites in both 2007 and 2009, the synoptic and diurnal water quality field measurements did not indicate dissolved oxygen issues (i.e. extremely high dissolved oxygen levels or levels below the standard).

Twice in 2009, YSI sondes were deployed to measure dissolved oxygen concentrations in 15-minute intervals (Figure 77 and Figure 78). Neither record indicated a low dissolved oxygen concentration excursion below the standard. From August 6 - 14, 2010, a YSI sonde was deployed at site 303PDT615 to measure dissolved oxygen in 15-minute intervals (Figure 79). The dissolved oxygen levels fell below the standard numerous times.

During the summer of 2009, the Pomme de Terre River water levels remained fairly high even though the watershed received little precipitation during this time (Figure 80). The higher flow (sixth highest annual mean flow on record, 308.1 cfs) was likely due to the large amount of snow in the headwaters during the previous winter. In 2010, the Pomme de Terre River had the third highest annual flow on record (352.9 cfs) but the rainfall was much greater than in 2009, which likely flushed out adjacent wetlands. This may be the reason for the lower dissolved oxygen readings in 2010.

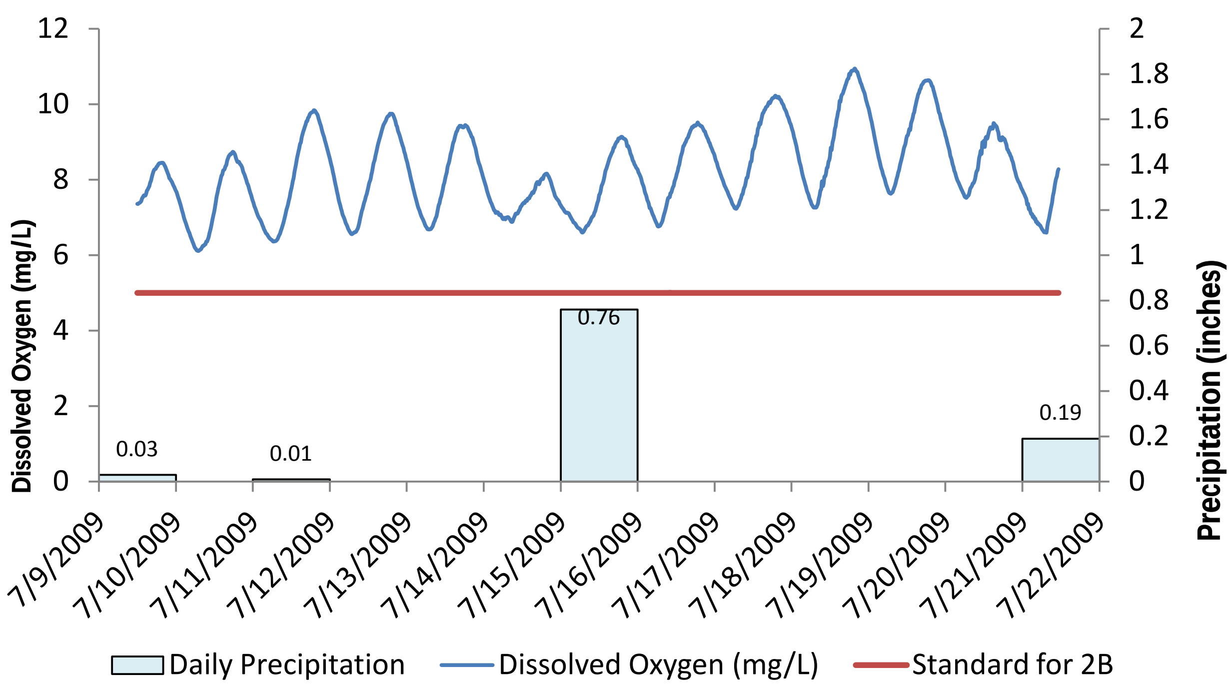

Figure 77. Dissolved oxygen measurements per 15 minute intervals for site 303PDT615, during July 2009, with daily precipitation for 45.86196° N, 95.86067° W (National Weather Service via Minnesota State Climatology Office)

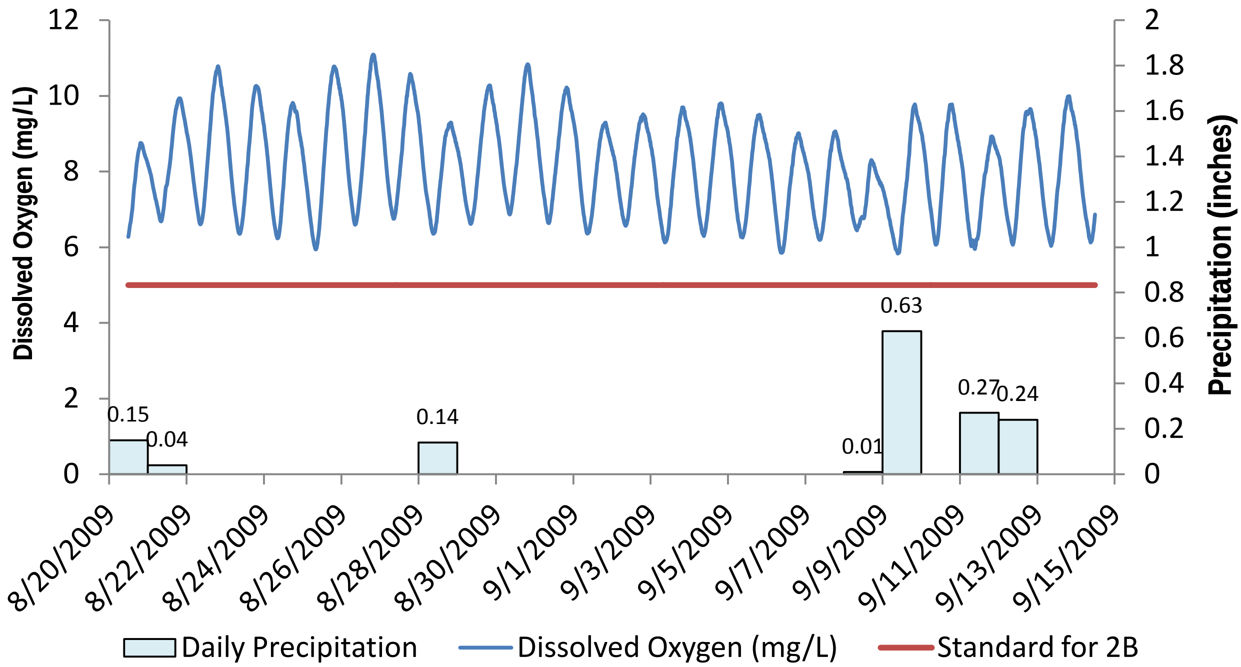

Figure 78. Dissolved oxygen measurements per 15 minute intervals for site 303PDT615, during August and September 2009, with daily precipitation for 45.86196° N, 95.86067° W (National Weather Service via Minnesota State Climatology Office)

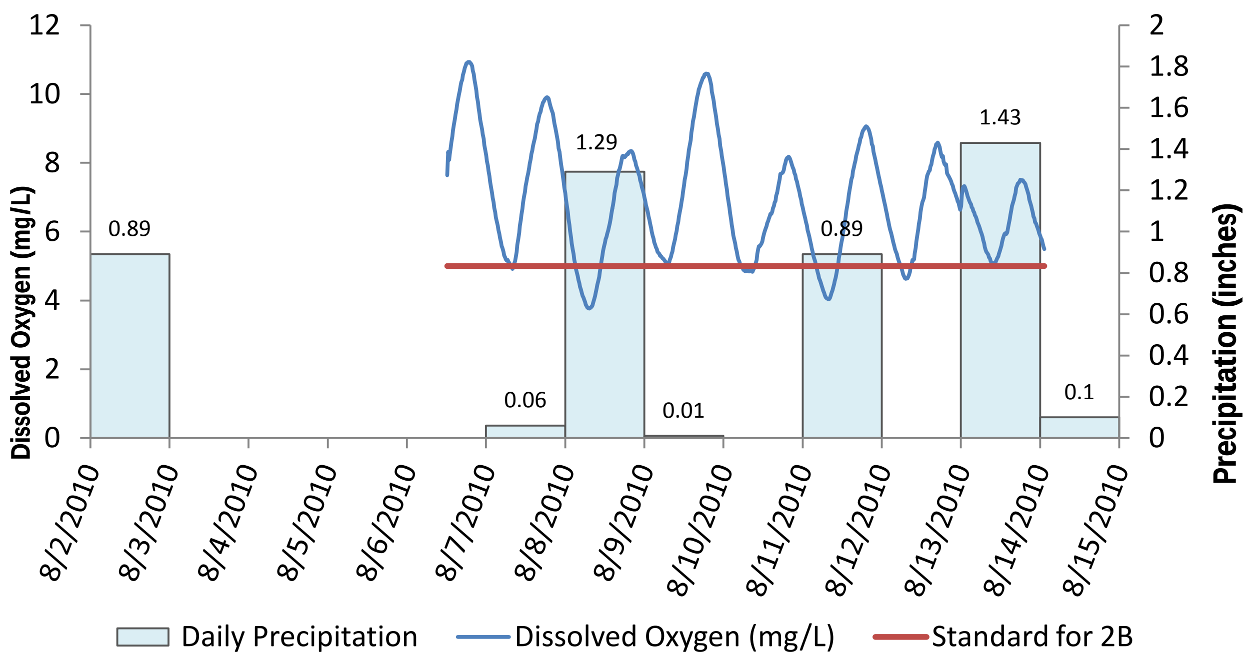

Figure 79. Dissolved oxygen measurements per 15 minute intervals for site 303PDT615, during August 2010, with daily precipitation for 45.86196° N, 95.86067° W, National Weather Service via Minnesota State Climatology Office

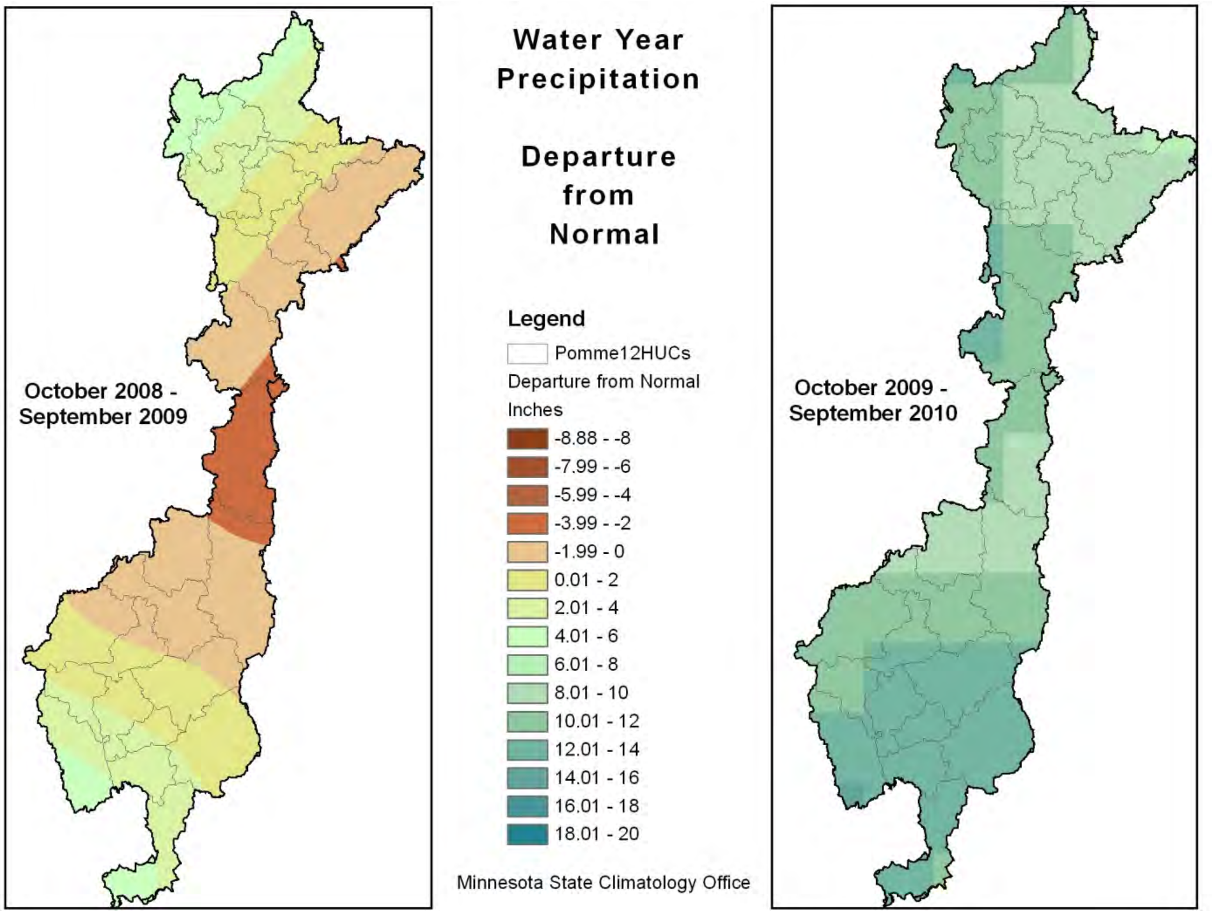

Figure 80. Precipitation departure from normal for water years 2009 and 2010

Fathead minnows are among those species which are tolerant to very low dissolved oxygen concentrations, whereas many other species need to seek higher dissolved oxygen levels, moving to other reaches if suitable DO can be found elsewhere. In 2003, at site 03MN003, 67 percent of the fish surveyed were fathead minnows. In 2007 and 2009, the fathead minnow percentage was drastically less with 2.2 and 1.5 percent, respectively.

Mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), and caddisflies (*Trichoptera*) are commonly referenced as EPT and are sensitive to low dissolved oxygen levels. Although this reach is not impaired for macroinvertebrates, the percent of EPT has increased at site 03MN003 each year sampled (Table 14). Sites located downstream have a greater percentage of EPT than that of 03MN003, potentially indicating a localized issue. There was no biological data collected in 2010 to be used for comparison with the measured low dissolved oxygen.

Table 14 . Percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in invertebrate samples at selected sites in the Pomme de Terre River

	2003	2007		2009
03MN003	7.9%	23.3%	19%	29.1%
09MN084				38.6%
09MN085				40.1%
07MN014		46.7%		

The fish impairment in this reach is not solely caused by low dissolved oxygen but may be a contributing factor at 03MN003. In 2010, low dissolved oxygen was present suggesting that it is not necessarily improving as potentially suggested by the 2007 and 2009 data.

Stressor Pathway: Riparian condition

The riparian buffers along the Pomme de Terre River are minimal in some areas (Figure 81). This can allow high amounts of nutrients, sediment and pesticides from adjacent fields to enter adjacent streams and rivers. This nutrient enrichment can lead to an increased oxygen demand.

Stressor Pathway: Riparian wetlands

A potential pathway exists with the flushing of adjacent wetlands during rain events. The rain events may flush out low dissolved oxygen water into the Upper PdT reach. More information about these wetlands would need to be collected to confirm.

Figure 81. Pomme de Terre River, Barrett Lake to Perkins Lake, between 150th Avenue and State Highway 27, May 27, 2009

Candidate Cause: Phosphorus

Phosphorus is not a direct stressor to the fish community in this reach but analyzed on its influence with other stressors (dissolved oxygen and turbidity). Site 302PDT198 at the outlet of Barrett Lake, had little total phosphorus data. The data available was all below the proposed standard within the past 10 years. At site 303PDT615, it was a similar story as the upstream site with limited data and below the proposed standard.

It is only at site 303PDT630, before Perkins Lake, where phosphorus concentrations were elevated (Figure 82). Variable levels of effort were used over the duration; from 1994 to 2009 a range of 0 to 6 samples per year were analyzed; in 2010, 33 samples were analyzed; and in 2011, 19 samples were analyzed.

It is uncertain whether the phosphorus in the channel is producing low dissolved oxygen or there is a source of low oxygenated water.

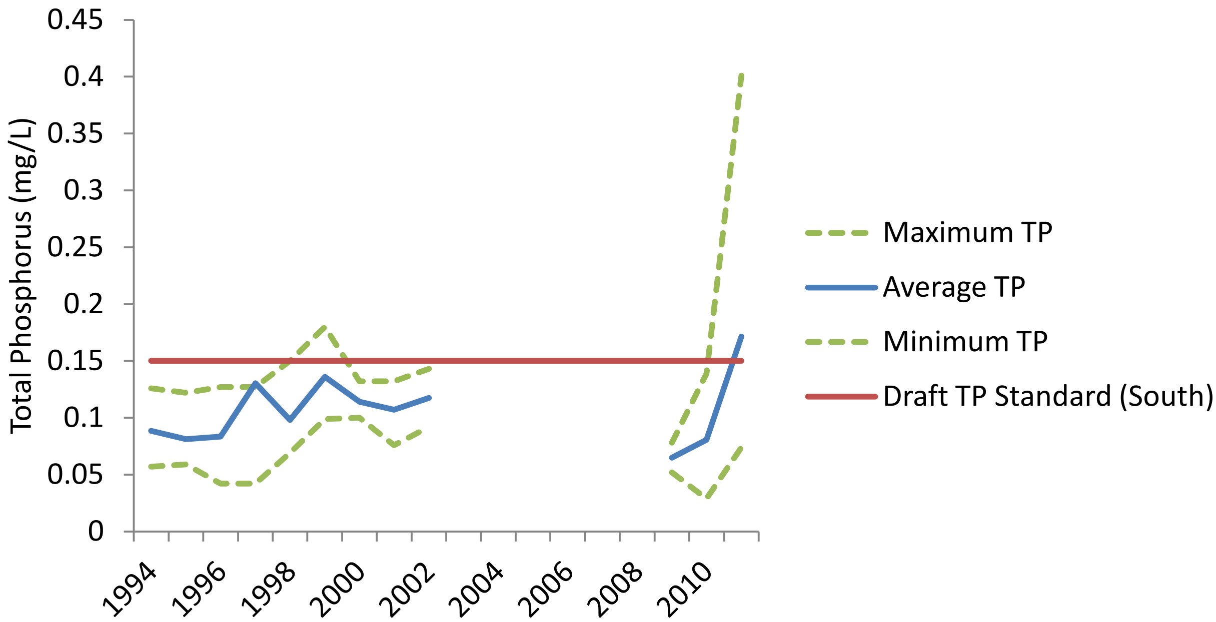

Figure 82. Total phosphorus concentrations for site 303PDT630

Candidate Cause: Nitrate

In 2009, nitrate in this reach was minimally over the ecoregion expectation in this reach of the river (Figure 10). Small tributaries to the Upper PdT reach were higher in nitrate than the mainstem during 2009 snowmelt and 2010 rain event. The fish in the Upper PdT do not have a signature that suggests that nitrate is a stressor. The nitrate sensitive fish species are present in this reach.

There is little evidence that nitrate is a stressor to the biota in the reach of the Pomme de Terre River from Barrett Lake to North Pomme de Terre Lake. This reach should be protected from activities that may increase nitrate levels and impair the biological community.

Candidate Cause: Habitat

In this reach of Pomme de Terre River, the average score of three biological sites was in the fair range for the MSHA (Figure 83). Site 09MN085 was the highest scoring in the Pomme de Terre River watershed (81.8) and 03MN003 was the lowest scoring site, scoring 40.75 in 2009. Among components of the total MSHA score, land use scored poorly (Figure 84); however land use is not a large component of the overall score. Channel morphology median score for the four sites was 14.5, only 40 percent of the score available.

This section of the Pomme de Terre River is generally low gradient. Site 03MN003 has an accumulation of fine sediment with poorly defined riffles. Generally, the lack of stream features does not provide much habitat for aquatic organisms. Site 09MN084 also had few riffles and generally featureless bottom. Site 09MN085 has an in slope and some riffles are present; and then 07MN014 flattens out again. The distribution of riffle-dwelling taxa mimic this pattern of channel slope (Table 14). The bankfull materials for the entire reach length appear to correlate with the stream slope profile (Figure 85).

In the Southern Rivers IBI, the Upper PdT received a low metric score for SLithopGR1, the taxa richness of simple lithophilic spawning species (adjusted for gradient). This is indicative a lack of gravel for these species to reproduce. Additionally, the percent of taxa that are very tolerant, VtolTxPct, is higher than would be desired, thus reducing that metric's scores for this reach. These both correspond to the available habitat in the Upper PdT.

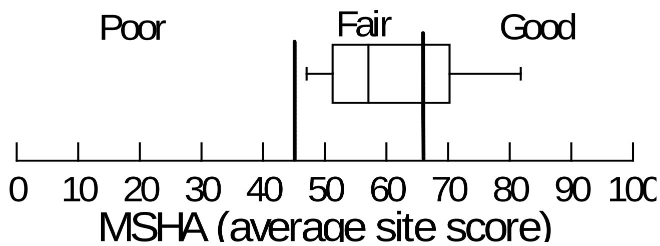

Figure 83. MSHA scores in the Pomme de Terre River, from Barrett Lake to North Pomme de Terre Lake

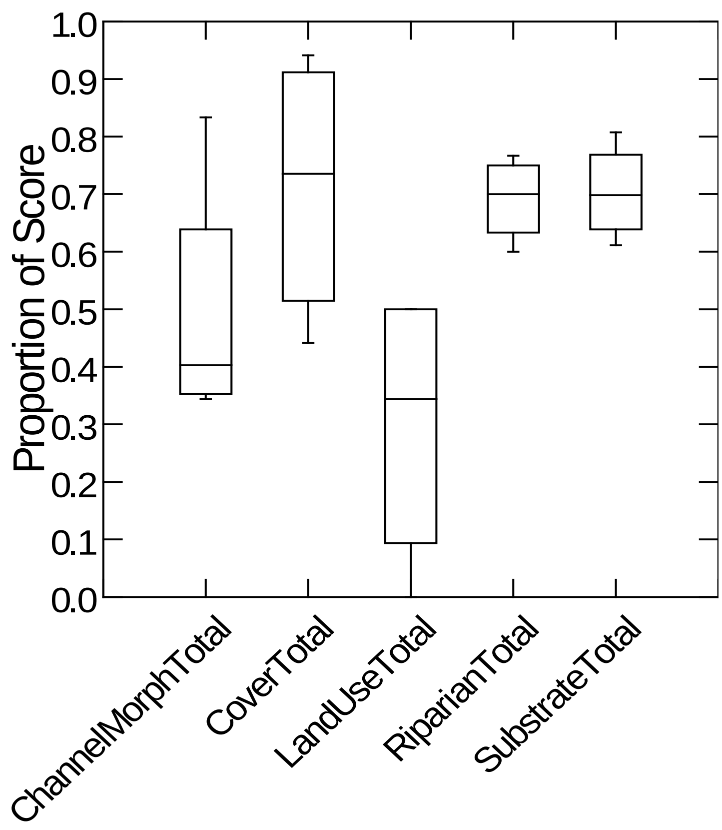

Figure 84. Proportion of possible subcategory scores in the Pomme de Terre River, from Barrett Lake to North Pomme de Terre Lake

Table 15. Percent riffle dwellers present at survey

	03MN003	09MN084	09MN085	07MN014
2003	3.29			
2007	2.96 3.38			9.97
2009	6.32	12.39	22.21	

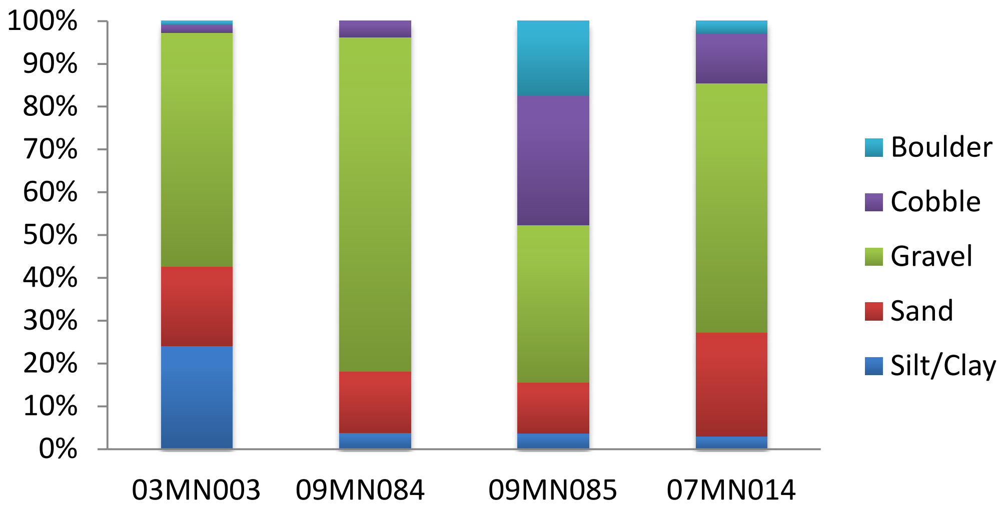

Figure 85. Reach bankfull channel materials

The cross-sectional channel profile in many sections of this 20 mile reach is wide and shallow, with higher width to depth ratios than would be expected of similar stream types (Table 16). The increase in width to depth ratio may be indicative of widening throughout the reach, as the average width-to-depth ratio for a C4 stream type is 29.28 and the modal value for C stream types in the Eastern U.S. is 24 (Rosgen, 1996). The biological site 07MN014 closest to North Pomme de Terre Lake and furthest downstream is approximately one mile upstream of the lake and thus may be influenced by lake levels and associated backwater. If widening has occurred in this reach, one potential cause would be increases in both magnitude and frequency of high flows.

Table 16. Width to depth ratio (dimensionless) at biological sites

Biological site	Width to Depth Ratio
03MN003	36.6
09MN084	38.0
09MN085	32.7
07MN014	23.5

The fish community in this reach is made up of less desirable serial spawners. More desirable simple lithophilic spawning species were lacking in this reach. Habitat can directly affect both of these metrics and cause a decrease in top carnivores and piscivores. The metric for piscivores was depressed here, thus lowering the IBI score. The fish community is generally impaired throughout the reach, with the lowest fish IBI scores occurring at the furthest upstream site.

Station 03MN003

Site 03MN003 was classified as a C4c- stream type with a stream bed composed of 55 percent small gravel, 19 percent sand, and 24 percent silt/clay. The reach had a high width to depth ratio for its classification, moderate sinuosity, and low slope. The wide and shallow dimension of the channel and low slope in this reach are reasons to suspect low stream power and shear stress values. Sediment competence calculations to assess bed stability revealed that a greater depth of water than we would typically expect to see, and a greater slope than exists, are needed to entrain the largest particles in the bar sample. This provides evidence that conditions favorable to aggradation exist and is why there is an accumulation of fine sediment within this reach. This station's location in the watershed below Barrett Lake should theoretically make the sediment supply to the station low. However, the sediment supply between Barrett Lake and this station, and the tendency toward aggradation at this station, have resulted in a station with a high percentage of fines. The low gradient (0.00029), generally small substrate with high percentage of fines, generally featureless bottom with poorly defined riffles and few pools do not provide optimal habitat for fish and other aquatic organisms.

Stream banks were generally well vegetated with reed canary grass and marshy cattail floodplain benches were common. Sinuosity is moderate through the reach which is characterized by wide sweeping bends, but increases downstream, where shorter radius meanders are present. Most stream banks through the reach were stable but some higher outside banks showed moderate to high erosion rates. Water and habitat quality would benefit from wider and more robust buffers along this reach and an improved vegetative buffer would provide resistance to channel widening.

Station 09MN084

The Pomme de Terre River at station 08MN084 is classified as a C4c- stream type that sustains a gravel bed, low entrenchment with good connectivity to the flood plain, a high width depth ratio for its classification (38), moderate low sinuosity (1.2), and low slope (0.00056 water surface slope). The 963 foot long longitudinal profile had few and unsubstantial riffles and two pools. No incision was evident along this reach and the low bank elevation was generally equal to bankfull elevation, which means that floodplain connectivity is excellent. The reach bed composition was 78 percent gravel, 14 percent sand, and equal parts of silt and cobble made up the rest.

Stream banks were well vegetated with reed canary grass and marshy cattail floodplain benches were common. Sinuosity is moderate to low through the reach which is characterized by large radius meanders. Stream banks through the reach were stable and erosion rates were visually estimated to be very low. No channel migration was evident when 1991 and 2010 aerial photos were compared.

Station 09MN085

The 09MN085 reach on the Pomme de Terre River was assessed and classified in August of 2010 as a C4 stream channel. The reach has a well developed active floodplain with a moderately steep water slope of 0.0027ft/ft. The steeper energy slope and increased stream power is well represented in the stream bed materials which consists of 12 percent sand, 36 percent gravel and 30 percent cobble with frequent large random boulders. Field bankfull elevations and low bank height elevations were essentially the same elevation and both seemed to have a parallel relationship to that of the water slope suggesting the stream channel is not incising.

The steeper water slope in this reach helped to accent the frequent prominent riffle features by creating steep riffle slopes. The quality riffles in this study reach are providing grade control, aquatic habitat and supporting healthy air/water exchange. The general composition of riffles is 59 percent gravels, 22 percent cobble and 2 percent boulders.

Since the stream channel does not appear to be incising in this study reach we can assume the stream banks might be the weakest boundary control point. Therefore, there is a greater need for protecting the currently stable riparian vegetated corridor and floodplain throughout the mid and upper reaches of the Pomme de Terre River watershed. Activities like over grazing, aggressive farming practices, mining or other disruptive activities in the immediate floodplain could induce severe stream channel instability in what is currently a stable reach.

This 09MN085 station is near the midpoint of the Pomme de Terre River watershed. Several small tributaries enter both above and below the assessed reach which seem to have little influence on the main stream channel. Stream bank erosion rates were not collected in this reach but based on bank erosion assessment work at stations lower in the watershed we would expect the average erosion rate for the reach to be less than 0.01 tons/ft/year. Strong floodplain connectivity, steep well developed riffles as natural grade control, a wide stable well vegetated riparian corridor and other channel stability features in this reach make this a stable C4 reference reach. Stream stability or habitat improvement practices that are generally effective in this stream classification include bank placed root wads, rock vanes, j-hooks and bank placed boulders.

Station 07MN014

The 07MN014 station on the Pomme de Terre River was assessed and classified in August 2010 as a C4c- stream channel. This 1335 foot reach has a stream bed generally comprised of 24 percent sand, 54 percent gravel and 12 percent cobble. The stream reach has a relatively flat water slope at 0.0003 ft/ft which is in the lower 25 percent range for this stream classification. This limited energy slope is somewhat surprising since station 09MN085 immediately up stream of this reach has a much steeper water slope. The reduced energy slope is apparent in the higher composition of fine sand found in the stream bed.

Generally the riffles found in this reach contain some larger bed material with a composition of 78 percent gravel and 12 percent cobble. The reduced energy slope in this reach may weaken the function of the riffles as habitat for fish and invertebrates, and could be caused by a static surface water barrier where the river meets the Pomme de Terre Lakes.

The reach can be characterized as moderately sinuous with high meander length. Both the width depth ratio and entrenchment ratio are at the near mid-point range for a C4 stream classification. Deep pools, steep riffles and a well vegetated riparian stable riparian corridor are also characteristics for this reach. The composition of bed material across the reach was generally 24 percent sand, 58 percent gravel and 11 percent cobble with scattered boulders.

This 07MN014 station lies near the midpoint of the Pomme de Terre River watershed. Several small tributaries enter both above and below the assessed reach but seem to have little influence on the main stream channel. Stream bank erosion rates were not collected in this reach but based on stream bank erosion assessment work at stations below this site in the watershed we would expect the average erosion rate for the reach to be less than 0.01 tons/ft/year. The low stream bank erosion found in this reach is supported by the excellent stream stability in this reach.

In summary, stream reach 07MN014 appears by all measures to be a stable reach. The strong relationship between the channel and its floodplain, well established vegetative riparian corridor, strong grade controlling riffles, well define pools, lack of channel instability features and stable stream reach upstream of this site all contribute to designating this reach as a stable stream channel and considerate of being C4c- reference reach. Stream stability or habitat improvement practices conducive to a the C4c- stream classification include bank placed root wads, rock vanes, j-hooks and bank placed boulders.

Stressor Pathway: Riparian condition

The riparian buffers along Upper PdT are minimal in some areas. In portions of the reach, the stream banks are immediately adjacent to agricultural fields, decreasing riparian and bank vegetation. The riparian condition has led to changes in cover availability, stream stability and led to other alterations.

Stressor Pathway: Altered Hydrology

The habitat in this reach is controlled by the hydrology. The impoundments and channelization of intermittent flow pathways have led to changes in flow dynamics and changes in substrate.

The lack of riffle availability, driven by aggradation, in the upper reaches of this section of river, may be in part the cause of biotic impairment. The habitat is better in the lower two reaches than in the upper two reaches and is reflected in the IBI scores as well. Habitat is likely contributing to the impairment but is not the single stressor in the Upper PdT.

Candidate Cause: Connectivity

Fourteen species of migratory fish are present in the Pomme de Terre River watershed with the majority of the species only present downstream of the dam in Morris (Table 17). Only four of the 14 species were found throughout the watershed. Iowa darters were only found above the dam in Morris and the least darters were only found above Barrett Lake. The Golden redhorse were present below Morris and above Barrett Lake, but were absent between Barrett Lake and North Pomme de Terre Lake.

Table 17. **Migratory fish species present in the mainstem Pomme de Terre River, separated by dams**

CommonName	Below Morris Dam	Between Barrett Lake and N. Pomme de Terre Lake	Upstream of Barrett Lake
blackside darter	x	x	
central stoneroller	x		
golden redhorse	x		x
greater redhorse	x		
Iowa darter		x	x
largescale stoneroller	x		
least darter			x
shorthead redhorse	x	x	x
silver redhorse	x		
slenderhead darter	x		
spottail shiner	x	x	x
walleye	x	x	x
white bass	x		
white sucker	x	x	x
TOTAL	**12**	**6**	**7**

Stressor Pathway: Impoundments

The removal of the Appleton dam on the Pomme de Terre River improved fish communities to a more desired state with increased movement of migratory species and repopulation. The remaining dams located on the Pomme de Terre River, particularly the dam in Morris and Perkins Lake dam are influencing the fish population upstream of the barriers. It is likely that with the absence of these barriers, migratory fish species would be able to inhabit reaches further upstream in the watershed.

Candidate Cause: Altered Hydrology

HSPF predicted mean daily flows in this reach ranged from 1.6 to 2170 cfs in reach 450 and 4.6 to 5171.5 cfs in reach 440 (Figure 86). Bankfull discharge was estimated by geomorphic surveys at the biological stations and ranged from 208 to 253 cfs. Bankfull flows have a recurrence interval of 1.3677 (450) and 1.3768 (440) with the annual series method (based on peak annual discharge, Log-Pearson Type III Distribution). Bankfull flow is the 3.82 and 4.25 percentile flow at reaches 450 and 440 respectively. Bankfull flows and the highest 20 percent flows were calculated by HSPF and are shown in Figure 87, from 1996 to 2009. Most bankfull events occurred at the end of March and into April as spring runoff. In 2004, a bankfull event did not occur until September. The estimated longitudinal velocities in this reach range from 0.28 to 2.94 ft/s. The ranges of velocities endured are most important to biota rather than an average.

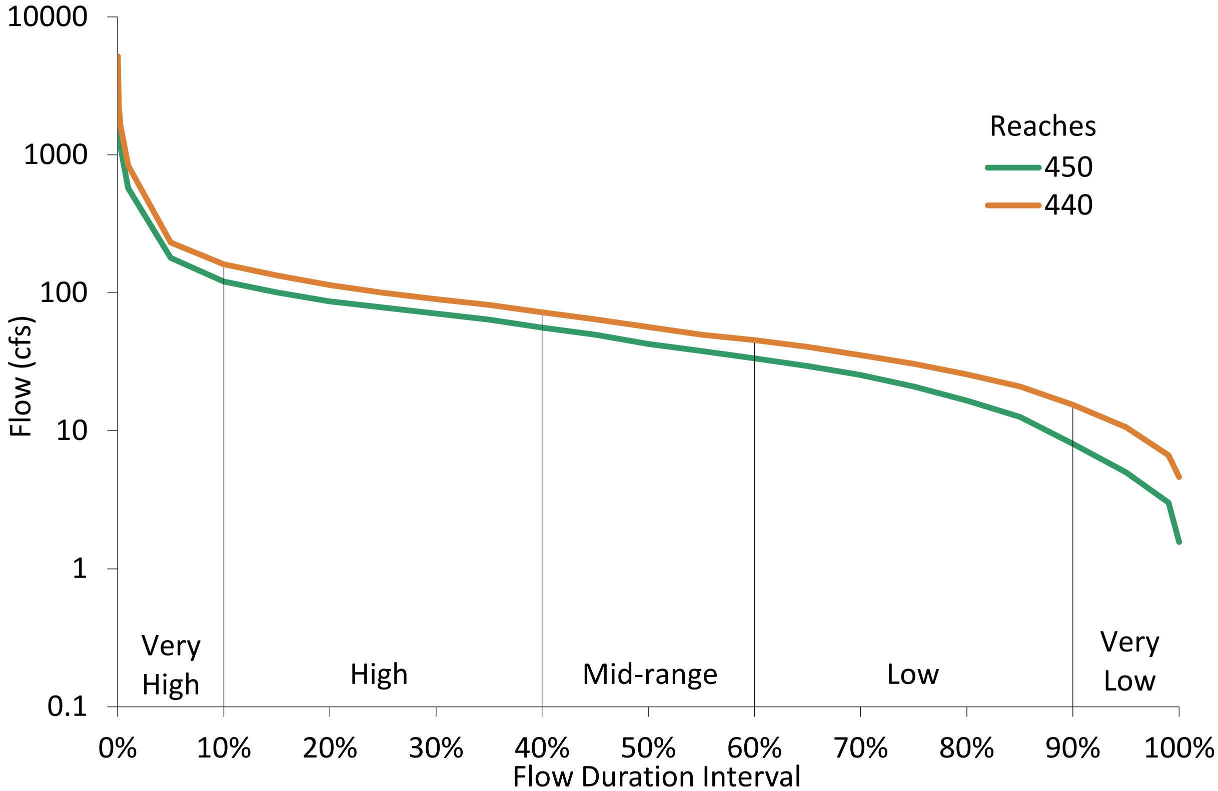

Figure 86. Flow duration curves for HSPF reach 450 and 440

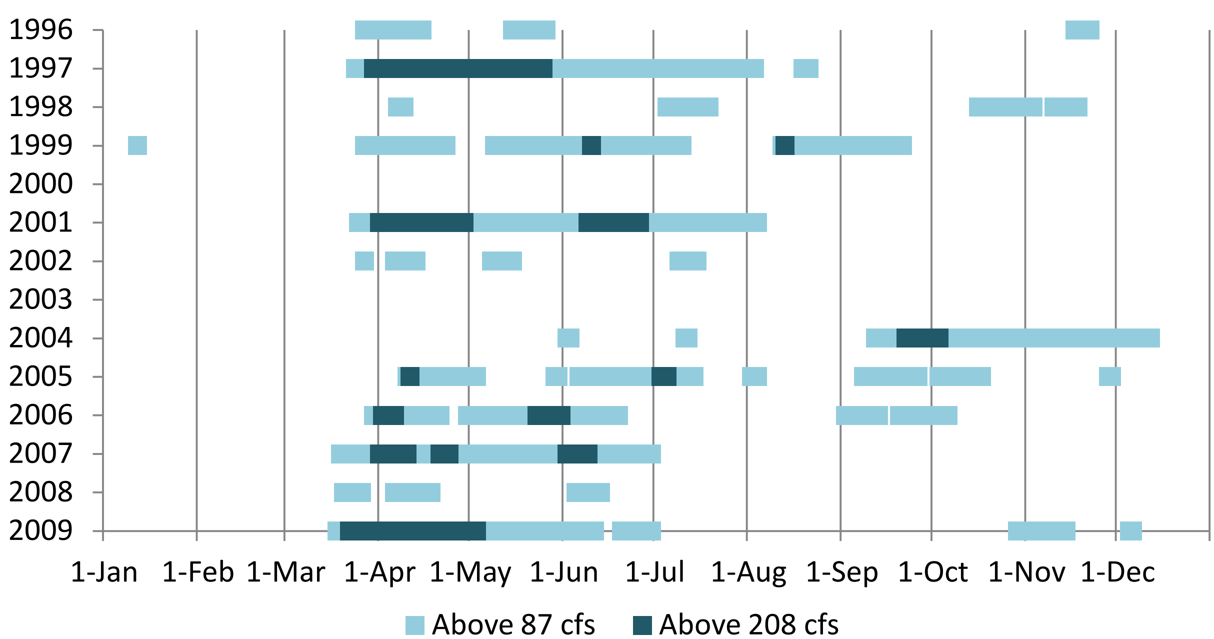

Figure 87. Bankfull flow events (above 208 cfs) and flows greater than 87 cfs (highest 20 percent flows) at the outlet of Pomme de Terre River reach 450 from 1996 to 2009

Low flow events are a natural part of a river's cycle, but flows that are too low or low too often could result in a negative biological impact. Extended low flow events occurred in 1996, 2000 and 2003 to 2004 which were below the estimated 90th percentile flows of 8.1 cfs (Figure 88). It is also notable that this reach is below the 80th percentile flows in the early part of the year (January through early March, prior to snowmelt) in 2000 to 2004, 2007 and 2008 (approximately half of the years).

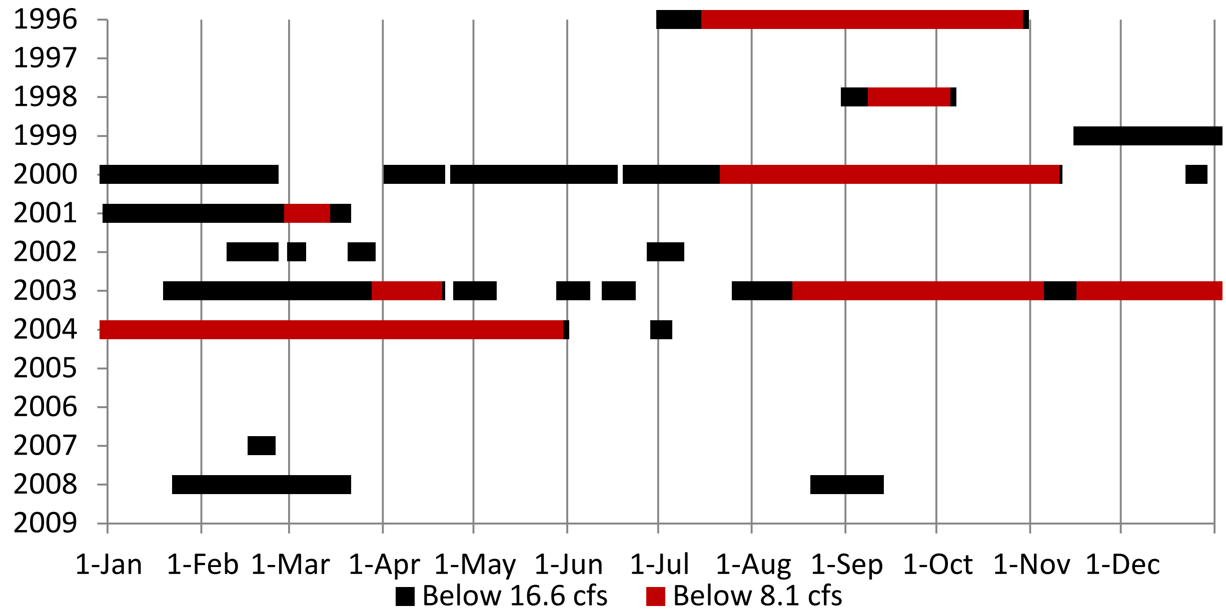

Figure 88. Low flow events, below 16.6 cfs (80th percentile flow) and 8.1 cfs (90th percentile flow) at the outlet of Pomme de Terre River reach 450 from 1996 to 2009

The percent of the fish surveyed that are considered generalists ranged from approximately 13 to 90 percent with the median at 48 percent. The highest amount was surveyed in 2003 at site 03MN003 and the lowest in 2007 at site 07MN014. There appears to be a gradient with the amount of generalists decreasing from high to low starting at the upstream to downstream (Figure 89). Nest guarding individuals excluding lithophilic spawners are variable in the reach (Table 18). The percent tolerant fish varied amongst the years and biological stations, ranging from 43.19 at site 07MN014 in 2007 to 89.95 at site 03MN003 in 2003.

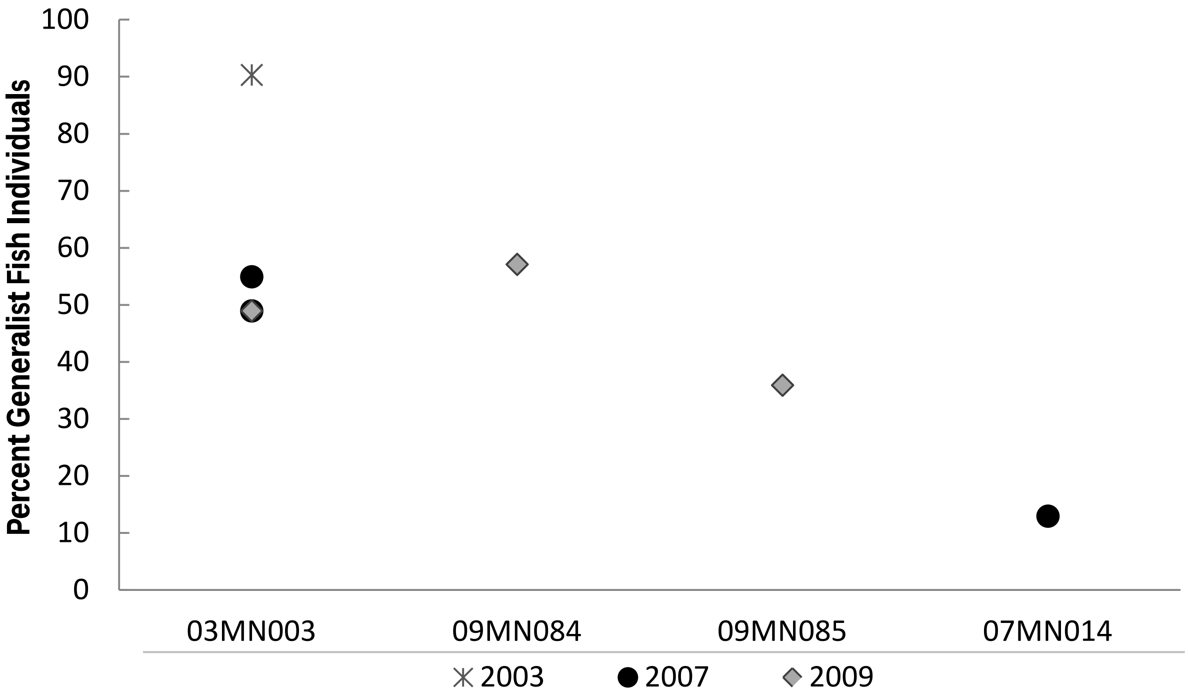

Figure 89. Percent generalist fish individuals at biological stations in the Pomme de Terre River, from Barrett Lake to North Pomme de Terre Lake

Table 18. Percent nest guarding individuals excluding lithophilic spawners

	03MN003	09MN084	09MN085	07MN014
2003	73.67			
2007	3.94 12.66			12.96
2009	48.95	43.50	24.24	

Station 03MN003 had a width to depth ratio of 37; well above the modal value of 24 for C stream types in the Eastern U.S., and high compared with other Pomme de Terre stations, which could be an indication that some channel widening has occurred in this reach. If widening has occurred here, the suspected cause would be an increase in the frequency and magnitude of high flows. Channel widths through the reach are not dissimilar to those found through the state wildlife management areas immediately upstream of this reach.

Similar to the station 03MN003, three miles downstream station 09MN084, had a width to depth ratio of 38; well above the modal value of 24 for C stream types and high compared to most other stations on the river. Like the upstream station, this could be an indication that some channel widening has occurred with the suspected cause being an increase in the frequency and magnitude of high flows.

Station 09MN085 contains a very sinuous channel, with a moderate to large belt width and wide flood prone area. The width to depth ratio for the reach of 32 is at the upper end of the C stream classification. This high width to depth ratio is indicative of a wide shallow stream channel which is likely to continue stressing area boundary controls especially in areas of riparian vegetation instability or disturbance. This continued channel evolution is the result of the river attempting to increase the stream channel capacity. This is done by changing the weakest boundary controlling variable in the system to allow the channel capacity to increase for carrying the increasing annual flow discharge from the Pomme de Terre River watershed

The width to depth ratio at site 07MN014 is 23.5 in closer proximity to the modal value. The downstream lake has a large influence on this station.

Stressor Pathway: Riparian condition

As mentioned previously, the riparian buffers along the Upper PdT reach are minimal in some areas. The riparian areas provide resistance to overland flows and minimize contributions of sediment, nutrients and pesticides to the reach.

Stressor Pathway: Channelization

The channelization of intermittent flow pathways and tile drainage has led to changes in flow dynamics and changes in substrate. The changes in the hydrological and geomorphological condition have direct impact to the biology of the reach. Additionally tile drain also contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs. The changes incurred inhibit species that need cues for spawning and only spawn a single time during a season.

Stressor Pathway: Impoundments

Active impoundments change the discharge of a system creating changes in water slope leading to changes in scouring and deposition as well as changes to water velocity and depth. They can hold back water which increases discontinuity and potential stranding.

Stressor Pathway: Groundwater Withdrawal

Significant irrigation occurs in the watershed, especially in the surficial aquifer adjacent to the Pomme de Terre River (Figure 21; see Pomme de Terre River Watershed Monitoring and Assessment Report for more information on irrigation).

The reach of the Pomme de Terre River, from Barrett Lake to N. Pomme de Terre Lake, has a large width to depth ratio and a lack of habitat, both of which are indicative of an altered flow regime. It is buffered by lakes both upstream and downstream which may affect the extent in which the alterations have influenced the biotic community. However, there is a clear connection between the hydrological alteration and the other stressors found in this reach (dissolved oxygen, lack of connectivity and lack of habitat).

Weight of Evidence

The evidence for each potential stressor, the quantity and quality of each type of evidence is evaluated. The consistency and credibility of the evidence is evaluated. Each step for Upper PdT was scored and summarized in Table 19. For more information on scoring please see EPA's CADDIS Summary Table of Scores.

Table 19. Weight of evidence table for potential stressors in Upper PdT

Types of Evidence	Low Dissolved Oxygen	High Nitrate	Lack of Connectivity	Lack of Habitat	Altered Hydrology
Evidence using data from Pomme de Terre River Watershed					
Spatial/temporal co-occurrence	+	---	+	+	+
Temporal sequence	+	0	0	+	+
Field evidence of stressor-response	++	-	+	+	+
Causal pathway	++	++	++	++	++
Evidence of exposure, biological mechanism	++	0	++	+	++
Field experiments /manipulation of exposure	NE	NE	NE	NE	NE
Laboratory analysis of site media	NE	NE	NE	NE	NE
Verified or tested predictions	+	-	+	NE	NE
Symptoms	+	0	+	+	+
Evidence using data from other systems					
Mechanistically plausible cause	+	+	+	+	+
Stressor-response in other lab studies	++	+	NA	NE	NE
Stressor-response in other field studies	++	+	+	+	+
Stressor-response in ecological models	NE	NE	NA	NE	NE
Manipulation experiments at other sites	NE	NE	NA	NE	NE
Analogous stressors	NE	NE	NA	NA	NE
Multiple lines of evidence					
Consistency of evidence	+++	-	+	+	+++
Explanatory power of evidence	++	0	++	++	++

Conclusions

In the Upper PdT, low dissolved oxygen, lack of connectivity, lack of habitat and altered hydrology are the stressors identified as contributing to the impairment of the fish community. These stressors are not uniform throughout this reach.

Dissolved oxygen was measured as below the standard only one in 2003 and again in 2010 at site 03MN003. The low dissolved oxygen led to an increased number of fathead minnows; which dramatically decreased when the dissolved oxygen was above the standards.

The lack of connectivity has influenced migratory fish species in the Upper PdT. The dam located in Morris and the dam on Perkins Lake are influencing up river migration.

Habitat, including over-widening of the channel due to aggradation and changes to substrate, are likely a reflection of the altered hydrologic condition. It is buffered by lakes both upstream and downstream which may affect the extent in which the hydrologic alterations have influenced the biotic community.

The pathways for the stressors to persist in the Upper PdT include the riparian corridor, the riparian wetlands, channelization, impoundments and groundwater withdrawals. Altered hydrology also leads to changes in physical habitat.

The riparian areas provide resistance to overland flows and minimize contributions of sediment, nutrients and pesticides to the reach. In some areas of the Upper PdT, the stream banks are immediately adjacent to agricultural fields, decreasing riparian and bank vegetation. The riparian condition has led to changes in cover availability, and stream stability.

A potential pathway exists with the flushing of adjacent wetlands during rain events. The rain events may flush out low dissolved oxygen water into the Upper PdT reach. More information about these wetlands would need to be collected to confirm.

The channelization of intermittent flow pathways and tile drainage has led to changes in flow dynamics and changes in substrate. The changes in the hydrological and geomorphological condition have direct impact to the biology of the reach. Additionally tile drain also contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs.

The remaining dams located on the Pomme de Terre River, particularly the dam in Morris and Perkins Lake dam are influencing the fish population upstream of the barriers. It is likely that with the absence of these barriers, migratory fish species would be able to inhabit reaches further upstream in the watershed. The impoundments upstream of this reach are also influencing the hydrologic regime influencing the stressors to the biotic community.

Significant irrigation occurs in the watershed, especially in the surficial aquifer adjacent to the Pomme de Terre River. This also led to changes in the hydrologic pattern.

There is a clear connection between the hydrological alteration and the other stressors found in this reach (dissolved oxygen, lack of connectivity and lack of habitat). Both restoration and protection of the biological community should focus on the pathways present that may contribute to the stressors.

Pomme de Terre River, Perkins Lake to Muddy Creek (Middle PdT)

Biology in Middle PdT

The Middle PdT only has one biological site that is assessable, site 07MN009. The site exhibits a low metric score for the percent of fish taxa that are very tolerant, VtolTxPct (Table 20). The range of metric scores from this reach is similar to the adjacent upstream reach. The percentage of individuals that are tolerant, TolPct, is higher here than that of the upstream reach. Tolerant fishes can be tolerant of a variety of stressors which will often require additional information to determine why there is an over-abundance of tolerant fishes. In this reach, there are a low number of insectivores that are not tolerant, Insect-TolPct. This metric can indicate when there is a depletion of insects, which would alter the fish community favoring a greater proportion of omnivores that are adaptable to a variety of food sources. Insectivores are an important link between lower and higher trophic levels (Simon, 1998). This reach also has a high proportion of detritivores, DetNWQTxPct, which feed on small pieces of non-living organic matter, also known as detritus. The macroinvertebrates are not impaired in this section of the river, but are within the confidence interval near the threshold. Thus, the lack of insectivores may be more indicative of other stressors, than a lack of their insect food-source. This is possibly substantiated by the observed presence of a large number of tolerant species and an abundance of generalists, individuals known to be adaptable to a broader range of environmental conditions.

Table 20. Fish metrics belonging to the Southern Rivers IBI for Middle PdT. Bold indicates score is below the average metric score (3.6) needed for IBI score to be at the threshold

Site	DetNWQTxPct	DomTwoPct	GeneralPct	Insect-TolPct	Piscivore	SensitiveTxPctGR1	SLithopGR1	SLvdPct	SSpnTxPct	TolPct	VtolTxPct
07MN009	**2.9**	5.8	**3.5**	**0.9**	4.0	**3.1**	**3.5**	6.8	3.6	**1.7**	**1.5**

Candidate Cause: Phosphorus

At site 304PDT640, total phosphorus (TP) was collected in 2006, 2007 and 2010. Total phosphorus was elevated above the draft standard (0.150 mg/L) in 2006 (5 out of 8 samples) and 2010 (1 out of 2 samples). It was not elevated in 2007, during the course of the summer where 12 samples were taken.

Phosphorus should be reduced in the Middle PdT, but with the limited dataset available, it does not appear to be limiting the dissolved oxygen concentrations at this time, as synoptic dissolved oxygen surveys reveal. It is uncertain how or if the phosphorus is contributing to the impaired fish community present in the Middle PdT.

Candidate Cause: Nitrate

There is not convincing evidence that the Pomme de Terre River from Perkins Lake to Muddy Creek has a biotic impairment due to nitrate; however some symptoms are evident, such as elevated nitrate levels when compared to the NCHF ecoregion 75th percentile. It is recommended that continued monitoring be conducted to further evaluate nitrate concentrations in the reach and impacts on the biological community.

Figure 90. Photographs showing streambanks below Morris dam

Figure 91. Aerial photographs of station 07MN009 from April 18, 1991, left; and September 14, 2008, right (Google, 2011)

Candidate Cause: Habitat

The land use around this site (2 square miles of both sides of the river) is predominantly row crop. This prevalence of row cropping resulted in a zero score in the land use subcategory of the MSHA score. (Figure 92). Overall the site scored fair with 52.5. The channel morphology subcategory was below expectations at this site with a score of 14 out of 36. There was little depth variability, but fast and moderate velocities; the entire reach was classified as a run.

Embeddedness was measured at 43 percent with 67 percent fines throughout the reach. Simple lithophilic spawners' numbers may be depressed due to the lack of adequate substrate. Similarly, the lack of riffles may have directly reduced the riffle dwelling individuals at this site (8.31 percent). It is likely that the dam located in Morris is preventing upstream sediment from being delivered to this reach, however there is a great deal of bank erosion occurring on the downstream side of the dam, less than 2 miles upstream of this site (Figure 90). This site also exhibits channel widening and the presence of cut off channels that have enlarged since 1991 (Figure 91).

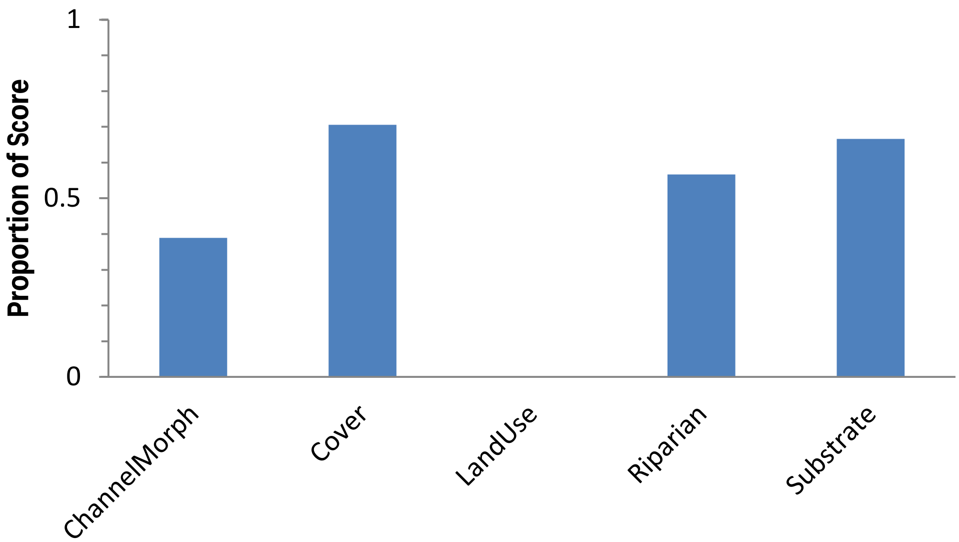

Figure 92. Proportion of possible subcategory scores in the Pomme de Terre River at site 07MN009

With only one biological site in the reach and only one sampling year, no trends are unable to be discerned. The fish at this site are tolerant individuals, with many detritivores (33 percent). Orange-spotted sunfish and common carp dominated the survey comprising of 46 percent of the fish. Orange-spotted sunfish have been found in Wisconsin predominately in channels with mud substrates; and they have been found to be increasing in range coinciding near areas with the tilling and clearing of land (Becker, 1983). Carp are tolerant of all bottom types and in both clear and turbid waters; they prefer shallow waters with aquatic vegetation (Becker).

Stressor Pathway: Riparian condition

The riparian condition in this reach has led to changes in cover availability, stream stability and led to other alterations. Particularly downstream of the dam in Morris, riparian condition is in need of great improvement (Figure 90). Reaches between Perkins Lake and the dam in Morris also have narrow buffers between agricultural land and the river.

Stressor Pathway: Impoundments
Both impoundments at Perkins Lake and in Morris have caused instability channel alterations and channel dynamic changes to regain stability.

There is convincing data to support the lack of habitat as a stressor to the biological community in the Middle PdT reach.

Candidate Cause: Connectivity

Due to a lack of biological data between Perkins Lake dam and the dam in Morris, it is uncertain whether or not connectivity would be a stressor to the biological community in this reach above Morris. More data should be collected to evaluate that potential stressor further as well as considerations for connectivity should be made for this reach and the Upper PdT reach in future plans associated with those impoundments.

Candidate Cause: Altered Hydrology

This part of the river corresponds to HSPF model reaches 420 and 410 (Figure 5. Mean daily flows ranged 1.7 to 4700 cfs in reach 420 and 3.4 to 4882 cfs in reach 410 (Figure 93). Velocities in this reach ranged from 0.33 to 2.15 ft/s.

The fish that are generalists consisted of 41.84 percent of the survey in 2007 suggesting that they are adaptable to a variety of conditions and feeding strategies. However, the non-lithophilic nest guarders comprised of only 11.57 percent, suggesting that nest guarding to ensure reproductive success may not be needed. Tolerant fish comprised of 68.25 percent and scored a meager 1.7 out of 10 as a metric score for the IBI (Table 20). With the dam located just upstream, it has undergone anthropogenic hydrological alteration, leading to changes in habitat and it evident in the fish community.

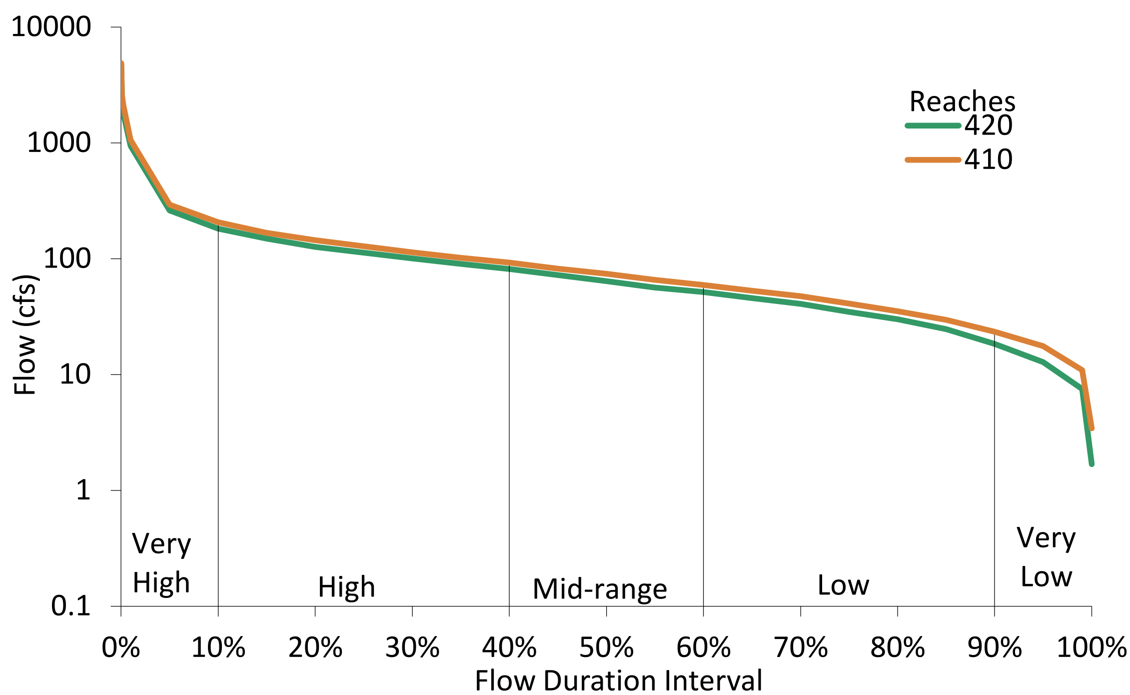

Figure 93. Flow duration curves for HSPF reach 420 and 410

Stressor Pathway: Riparian condition

As mentioned previously, the riparian buffers along the Middle PdT reach are minimal in some areas. The riparian areas provide resistance to overland flows and minimize contributions of sediment, nutrients and pesticides to the reach.

Stressor Pathway: Channelization

The channelization of intermittent flow pathways and tile drainage has led to changes in flow dynamics and changes in substrate. The changes in the hydrological and geomorphological condition have direct impact to the biology of the reach. Additionally tile drain also contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs. The changes incurred inhibit species that need cues for spawning and only spawn a single time during a season.

Stressor Pathway: Impoundments

Active impoundments change the discharge of a system creating changes in water slope leading to changes in scouring and deposition as well as changes to water velocity and depth. They can hold back water which increases discontinuity and potential stranding.

Stressor Pathway: Groundwater Withdrawal

Significant irrigation occurs in the watershed, especially in the surficial aquifer adjacent to the Pomme de Terre River (Figure 21; see Pomme de Terre River Watershed Monitoring and Assessment Report for more information on irrigation).

The Middle PdT has a similar history with impacts of an upstream dam that is altering the hydrologic regime along with broad upstream landscape changes. The fish community shows a population adapted to changing conditions, one that is consistent with a river reach impacted by altered hydrology.

Weight of Evidence

The evidence for each potential stressor, the quantity and quality of each type of evidence is evaluated. The consistency and credibility of the evidence is evaluated. Each step for Middle PdT was scored and summarized in Table 21. For more information on scoring, please see EPA's CADDIS Summary Table of Scores.

Table 21. Weight of evidence table for potential stressors in Middle PdT

Evidence using data from Pomme de Terre River Watershed			
Types of Evidence	Scores		
	High Nitrate	Lack of Habitat	Altered Hydrology
Spatial/temporal co-occurrence	0	+	+
Temporal sequence	0	+	+
Field evidence of stressor-response	0	0	+
Causal pathway	++	++	++
Evidence of exposure, biological mechanism	+	+	++
Field experiments /manipulation of exposure	NE	NE	NE
Laboratory analysis of site media	NE	NE	NE
Verified or tested predictions	0	NE	NE
Symptoms	+	+	+
Evidence using data from other systems			
Mechanistically plausible cause	+	+	+
Stressor-response in other lab studies	+	NE	NE
Stressor-response in other field studies	+	+	+
Stressor-response in ecological models	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE
Analogous stressors	NE	NA	NE
Multiple lines of evidence			
Consistency of evidence	+	+	+++
Explanatory power of evidence	0	++	++

Conclusions

The stressors in the Middle PdT are altered hydrology and lack of habitat. Connections to elevated nitrate concentrations and lack of connectivity could not be made at this time.

The habitat in this reach could greatly be improved as there is little depth variability which translated into reduced numbers of lithophilic spawners and reduced percent of riffle dwelling species. The hydrologic alteration is reflected in the fish preferring moderate and fast velocities would also be expected to be higher at site 07MN009; as well as a high percentage of generalists.

The pathways present in the Middle PdT for the lack of habitat and altered hydrology include the riparian condition, channelization, impoundments, and groundwater withdrawal. Altered hydrology also leads to changes in physical habitat.

The riparian condition in this reach has led to changes in cover availability, stream stability and led to other alterations. Particularly downstream of the dam in Morris, riparian condition is in need of great improvement. Reaches between Perkins Lake and the dam in Morris also have narrow buffers between agricultural land and the river. The riparian areas provide resistance to overland flows and minimize contributions of sediment, nutrients and pesticides to the reach.

The channelization of intermittent flow pathways and tile drainage has led to changes in flow dynamics. The changes in the hydrological and geomorphological condition have direct impact to the biology of the reach. Additionally tile drain also contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs.

Both impoundments at Perkins Lake and in Morris have caused instability in the channel as well as changes to the hydrologic regime. Active impoundments change the discharge of a system creating changes in water slope leading to changes in scouring and deposition as well as changes to water velocity and depth. They can hold back water which increases discontinuity and potential stranding.

Significant groundwater withdrawals occur in the watershed, especially near the channel of the Pomme de Terre River.

For restoration of the biotic community, habitat and the hydrologic regime will need to be improved upon. There are pathways that need restoration and protection to enable a healthy biotic population.

Pomme de Terre River, Muddy Creek to Minnesota River (Lower PdT)

Biology in Lower PdT

The sampling results from the Lower PdT showed that associated fish metrics scored similarly to those from the reaches upstream. These include the percent of serial spawning taxa and the percent sensitive taxa. However, unlike upstream reaches, this lower reach scores better in the percent generalists, the percent tolerant individuals, and the percent taxa that are very tolerant (Figure 94). The metric defining the dominance of the two most abundant taxa, DomTwoPct, has a wide range of scores with a mean metric score of less than 3, an undesirably low score. The two dominant species throughout this reach are sand shiners and spotfin shiners, averaging approximately 60 percent of the individuals in each sample. These species are serial spawners and detritivores. Additionally, sand shiners are short-lived, with age-to-maturity of less than a year, while spotfin shiners mature in less than two years. Neither species is sensitive; with the sand shiner considered tolerant. The spotfin shiner is intermediate between sensitive and tolerant. These two species dominate the community throughout this reach and contribute to a decrease in other metric scores due to their high abundance. This is in spite of the presence of more desirable fish species. The more desirable species include golden and silver redhorse, which are insectivores, lithophilic spawners, mature at ages greater than three years, and are not tolerant Other desirable and sensitive species present in this reach are stonecat, spottail shiner, slenderhead darter, rock bass, logperch, greater redhorse, and banded darters.

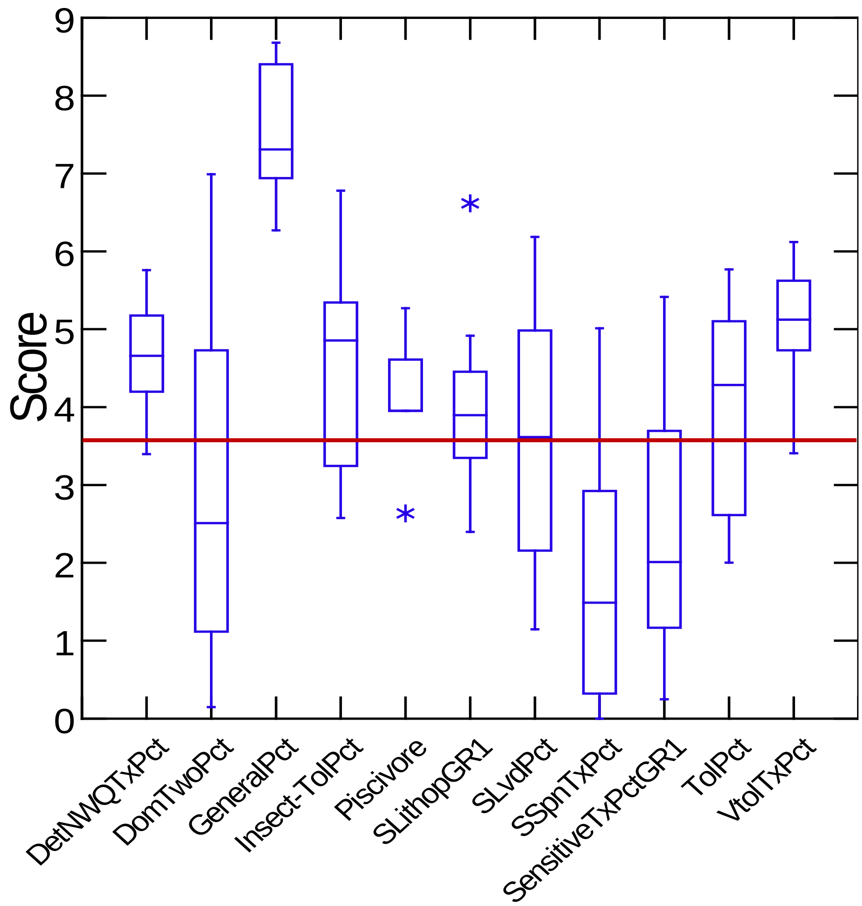

Figure 94. Fish metrics belonging to the Southern Rivers IBI for Lower PdT; Red line indicates the average metric score (3.6) needed for IBI score to be at the threshold

The invertebrate community in the Lower PdT lacked Odonata taxa (dragonflies and damselflies), which are sensitive to habitat availability and diversity (Figure 95). As predators, they are also dependent on the availability of a healthy food supply. This reach also lacked invertebrates that are classified as intolerant. This lack of intolerant species, and preponderance and abundance of tolerant species, was also reflected in the HBI_MN metric, which is a measure of pollution based on tolerance values assigned to each species. A low metric score of HBI_MN indicates that there are numerous species that are tolerant to pollution. As shown in Figure 95, this metric received a very poor score.

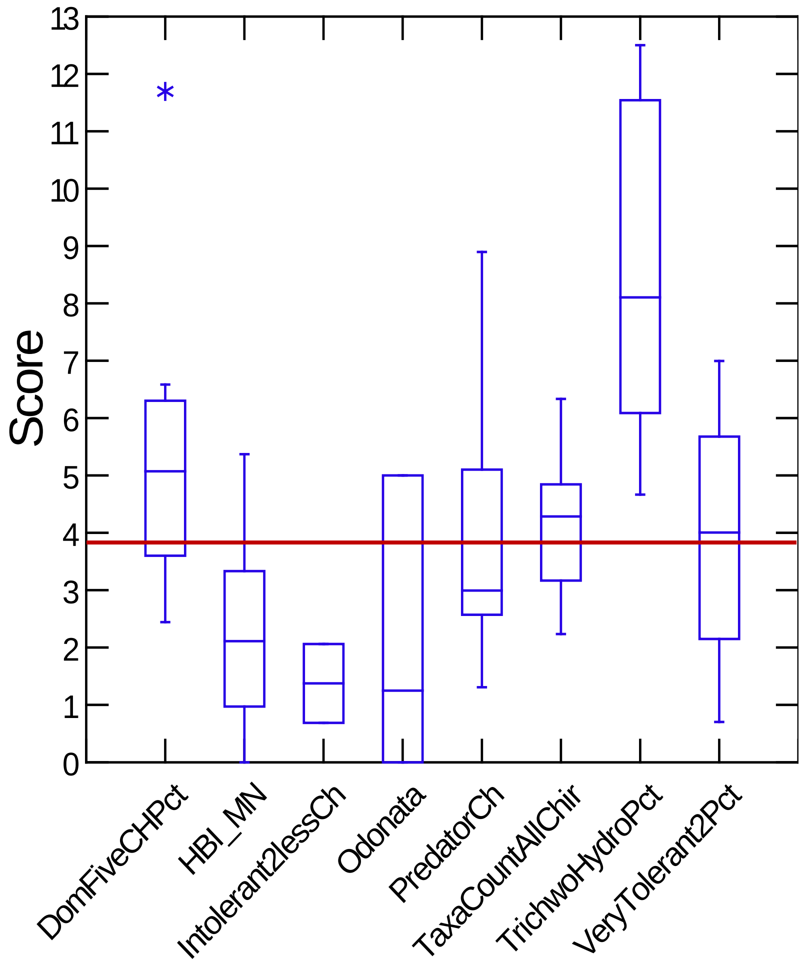

Figure 95. Invertebrate metrics belonging to the IBI Lower PdT; Red line indicates the average metric score (3.84) needed for IBI score to be at the threshold

Candidate Cause: Phosphorus

In the Lower Pomme de Terre River, total phosphorus concentrations were observed for numerous years and trending down. Planktivorous fish did not make up a large part of the community present in the Lower Pomme de Terre River, as would be expected of a high nutrient system. This reach also has increased suspended sediment which would lower the planktivore population.

Of the invertebrate metrics that are expected to decrease with increasing nutrients, lower percent Tanytarsini responded accordingly, but percent EPT and percent intolerant did not have lower values than that of the unimpaired areas of the Pomme de Terre River watershed (Figure 35). The invertebrate metrics that are expected to increase with increased nutrients also showed mixed results. Percent scrapers increased but the other three metrics were about the same (percent dominant) or lower (percent mollusca and crustacea, and percent tolerant) than that of the unimpaired sites (Figure 36).

It is difficult to distinguish the effects of phosphorus in the Lower Pomme de Terre River from other stressors. Other stressors may be confounding the inconsistent patterns of biological response that were observed here. Reducing the somewhat-elevated levels of phosphorus could help to improve conditions for the biotic community.

Candidate Cause: Nitrate

Numerous sites on the mainstem Pomme de Terre River had nitrate values greater than the ecoregion 75^{th} percentile, particularly in the Lower PdT (Figure 96). Meador and Carlisle (2007) derived tolerance indicator values (TIVs) for common fish species of the U.S. The species in the Pomme de Terre River watershed were compared with the TIVs, and quartiled for comparison. The first quartile species are more sensitive to nitrate while the fourth quartile species are less sensitive to nitrate (some fish did not have tolerance data available, Table 5.

In a comparison of TIVs on the mainstream Lower PdT had a greater percentage of fish individuals that are considered less sensitive to nitrate than upstream reaches with lower nitrate levels (Figure 97). The Middle PdT also had a depressed number of sensitive fish species from the first quartile, but had a larger proportion of the sample in the third quartile than both upstream and downstream reaches. The Upper PdT had the least percentage in the fourth quartile and the most in the first quartile indicating that it may not be affected by nitrates like the reaches downstream.

In a comparison of percent tolerant invertebrate individuals for the Pomme de Terre mainstem, no discernible pattern with nitrate was found. The percent tolerant invertebrate individuals may be influenced by factors other than nitrate.

Stressor Pathway: Riparian condition

The riparian buffers along the Pomme de Terre River are minimal in some areas. This can allow high amounts of nutrients, sediment and pesticides from adjacent fields to enter adjacent streams and rivers.

Stressor Pathway: Source-water pollution

Intermittent and often channelized tributaries, as well as larger contributors, such as Dry Wood Creek, to Lower PdT are high in nitrates during snowmelt and rain events. It is assumed that nitrogen and forms of nitrogen, such as ammonia, are being applied to the cropland throughout the watershed as it is 53 percent cropland. It is unknown how much groundwater contributes nitrate.

There is convincing evidence that nitrate is a biotic stressor in the Lower PdT.

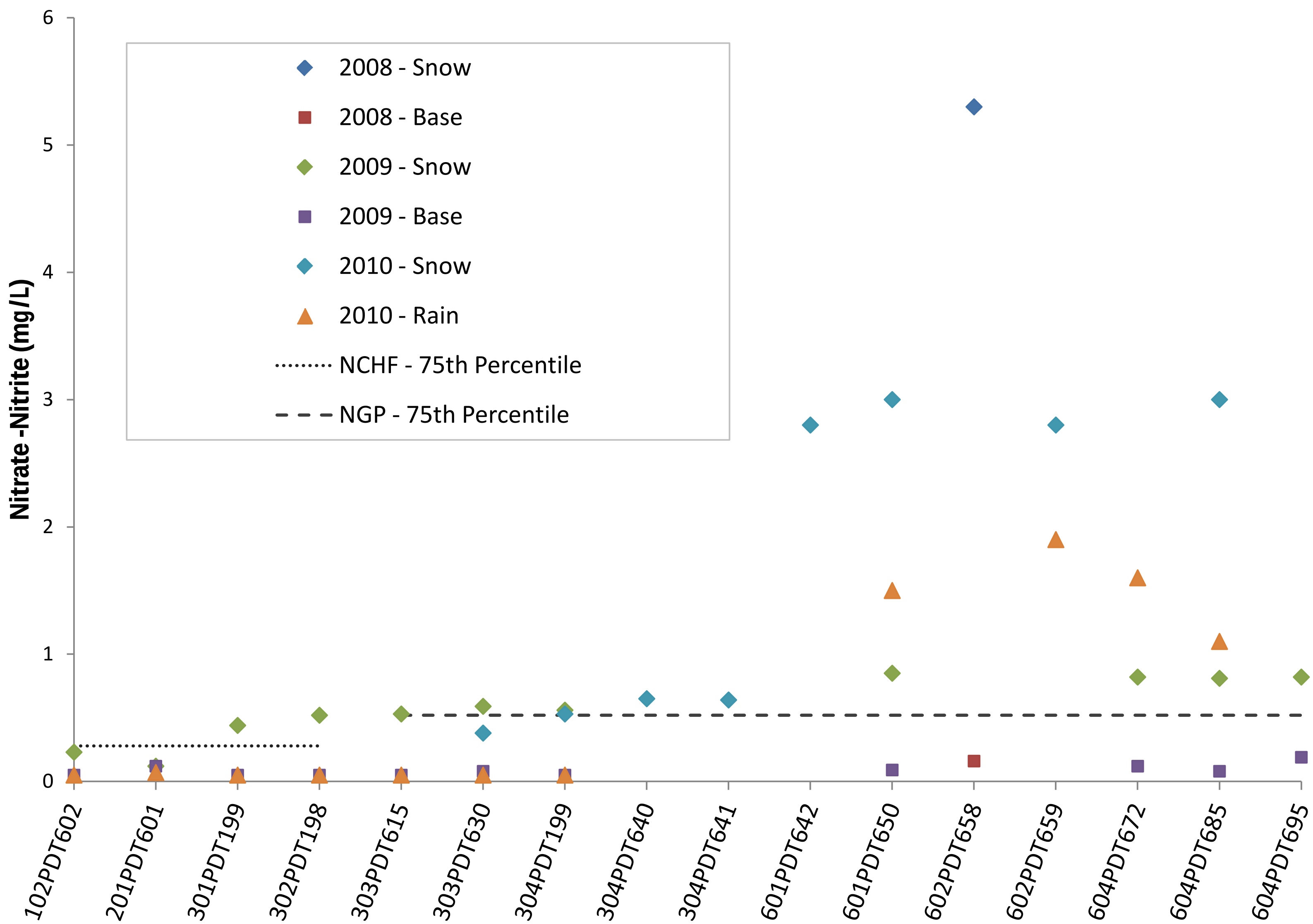

Figure 96. Nitrate-N measurements collected in the Pomme de Terre River, a longitudinal view from headwaters to downstream

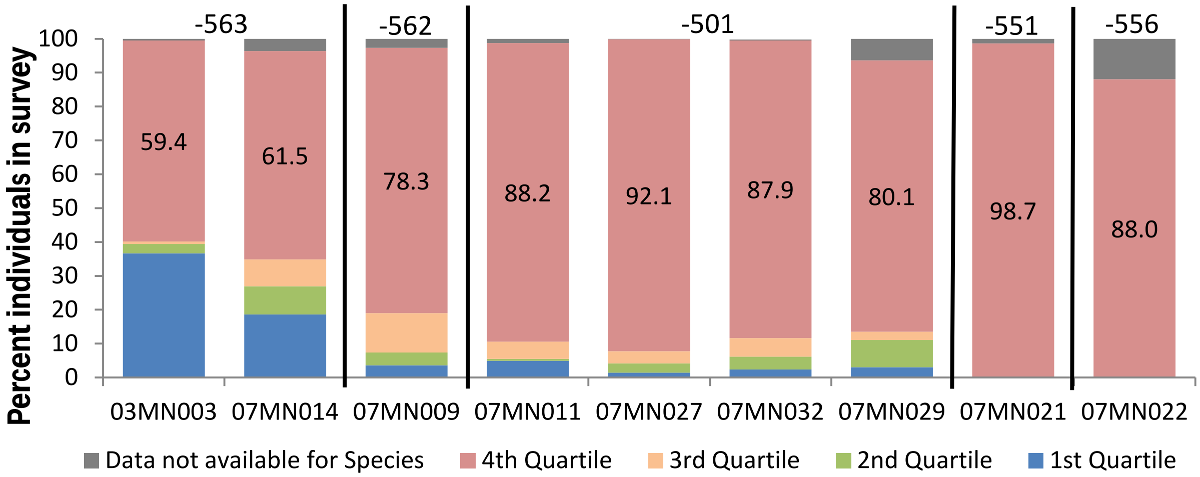

Figure 97. Percent individuals by biological site sampled in 2007 in impaired reaches, for each quartile based nitrate tolerance indicator values, separated by AUID, last three digits shown (Meador and Carlisle, 2007)

Candidate Cause: Habitat

This reach covers the uplands, the transition (high gradient area) into the Minnesota River Valley, and then the MN River Valley section of the Pomme de Terre River. The reach has MSHA scores in the fair range (Figure 98). At some sites, the land use and cover subcategories scored relatively low (Figure 99). Land use is highly variable from the upstream portions of this AUID to the downstream reaches, which is observed in the variable scores present in the land use subcategory scores.

Sparse cover was observed at all sites in the Lower PdT during fish surveying, except site 07MN029, which was noted as having moderate cover. Cover is an important factor for biological communities as it provides refuge from high flows and predators (CADDIS, M.B. Griffith, B. Rashleigh, K. Schofield; Wesche, 1985). The amount of cover affects the amount of niche environments in which fish and invertebrates can reside. Thus a higher amount of cover will support a higher abundance and diversity of fish and invertebrates (Wesche, 1985; Barbour et al. 1999).

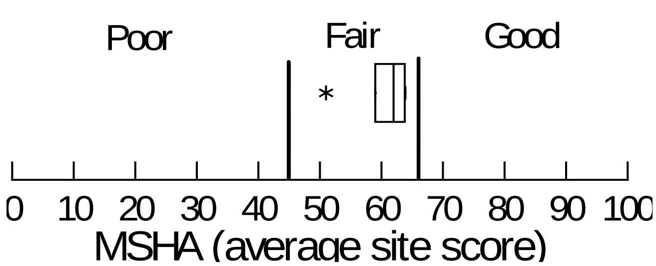

Figure 98. MSHA scores in the Lower PdT

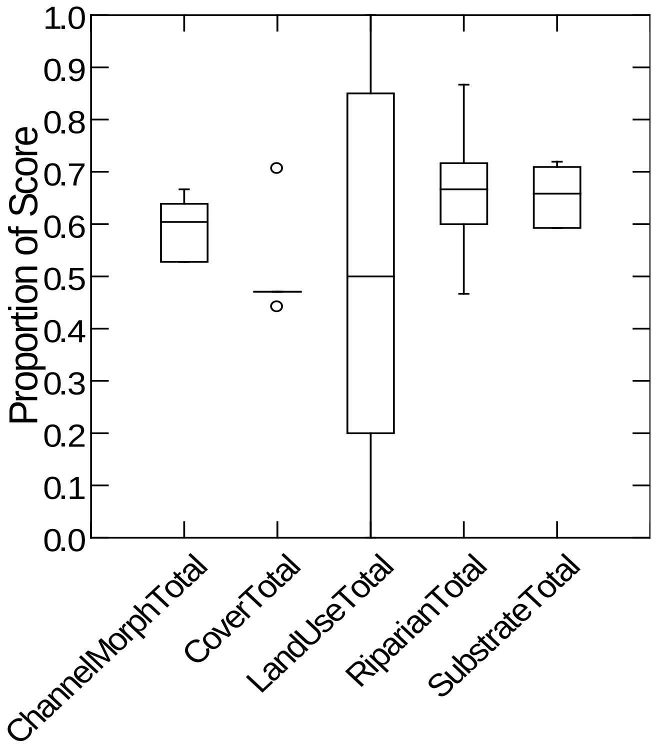

Figure 99. Proportion of possible subcategory scores in the Lower PdT

The group of invertebrates that cling appears to respond fairly well with the average MSHA scores (Figure 100). Only one site, 07MN032, does not follow the same pattern as the other four sites, as it had less relative to the others. This may be due to other factors effecting clingers at this site. It is not likely to be caused by increased sedimentation, since the MSHA indicated that this site has the least amount of fines and the embeddedness of the biological sites in the Lower PdT. Riffle and run, rocky substrates; undercut bank or overhanging vegetation; and snag, woody debris or root wad were habitat types sampled in each of the sites except at sites 07MN032 and at 07MN011. Riffle and run, rocky substrates were not observed or were unable to be sampled and may be one reason these sites have a reduced percentage of clingers.

The fish community is greatly dominated by two species throughout the Lower PdT, sand shiner and spotfin shiner (Figure 101). The spotfin shiner is 'tolerant of a wide variety of habitats and usually the most numerous shiner where waters are turbid' (Becker, 1983). Spotfin shiners are strongly territorial, seeking to spawn in rock fractures, log crevices, and "on top of a minnow pail" (Becker, 1983).

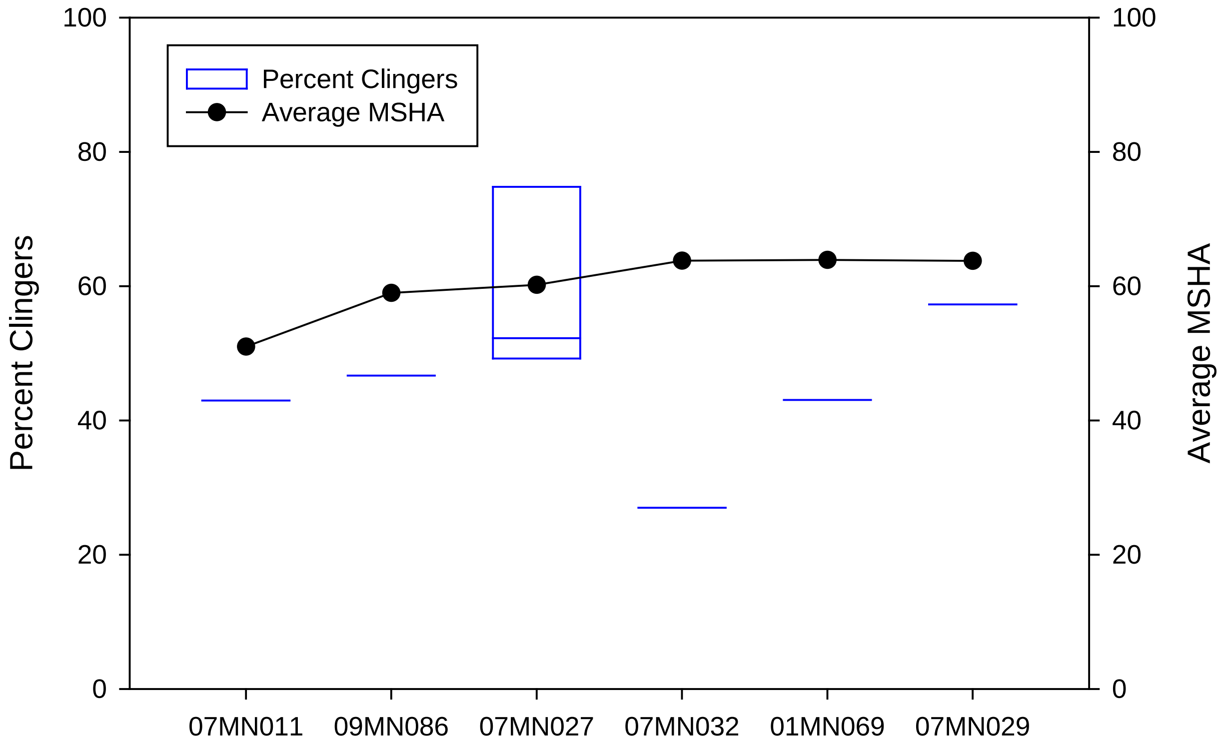

Figure 100. Percent clingers and average MSHA scores in the Lower PdT

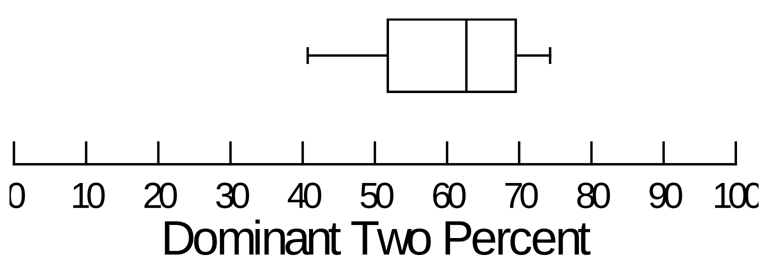

Figure 101. Percentage of dominant two fish species in the Lower PdT

Station 09MN086

The 09MN086 reach on the Pomme de Terre River was assessed and classified in August 2010 as a C4c- stream type. A very flat water slope exists throughout the study reach at 0.00017ft/ft putting this into the lower 25 percent for stream classification. The1450 foot longitudinal profile in this reach has a general stream bed composition of 31 percent sand and 55 percent gravel with the remainder in silts, clays, cobbles and random boulders.

This reach has poorly defined riffle features composed of 17 percent sands and 80 percent gravels. The lack of larger particles in the riffle reflects the reduced stream power and lack of critical sheer needed to entrain and move larger bed particles.

The lack of stream power throughout this reach is allowing the smaller bed particles to inundate the riffle and pool features. These same actions are also reducing critical habitat quality and quantity for fish and invertebrate species. The impacts to the various stream facets in this reach could also be residual cumulative impacts of a previous channel cutoff that occurred immediately upstream of this study reach. Aerial photo analysis suggest the river channel near County Road 56 was extensively modified by the removal and over widening of nearly 1000 feet of a preexisting stream meanders (Figure 102). The modification in this reach occurred sometime 1938-1991 with a more specific time frame likely occurred 1950-1970. The realignment of the stream channel was likely to encourage the river to run cleanly through a newly constructed County Road 56 bridge. This stream channel modification can be at least partially attributed to the reduced stream power, inundated or insignificant riffles and pools, lower quantity and quality aquatic habitat and also correlated to low IBI scores for both fish and invertebrates in this reach. Over widening of the stream channel would certainly contribute to some of the stream characteristics observed in this reach.

Figure 102. Aerial photo analysis near County Road 56 showing meander cut

The stream channel in this reach is moderately sinuosity, with a large belt width and wide flood prone area. The width to depth ratio of 25 is in the mid range for the stream classification. The entrenchment ratio at 3.3 is at the lowest range for this stream class and possibly indicating the channel is becoming more entrenched. The reach has floodplain connectivity but seems to lack notable geological or morphological features to resist stream bed down cutting and further entrenchment is likely.

The 1450 foot longitudinal profile in this stream reach clearly show the low energy (water) slope, poorly defined riffles and moderate sized pools filling with fine material. The slope between bankfull elevations indicators or low bank heights which were the same in this reach and the water slope do not correlate as well as what was measured in other reaches. This descending or narrowing relationship between these variables would support a possible incising channel that could be a cumulative impact of the historical channel work immediately upstream of this site.

The 09MN086 reach has a moderately wide riparian corridor consisting of reed canary grass with sections of dense woody vegetation. Numerous indicators of channel degradation and channel instability exist throughout this reach. These indicators are symptomatic of possible stream channel evolution. The current assessed stream reach is a C channel stream by classification but is evolving towards an F or G channel classification. This fluvial evolution in the stream channel is promoting changes in dimension, pattern and profile that may include a wider shallower channel, increasing entrenchment, reduced water slope, reduced sinuosity and increased stream bank sheer stress and stream bank erosion.

In areas where there is stream instability this addition bed load can overwhelm the ability of the river to move this sediment. As a result we would expect to see stream facet features inundated, pools filled, mid channel bars forming, stream habitat is lost and low IBI scores are likely.

Station 07MN027

This reach is classified as a C4c- stream type with a stream bed composed of 55 percent gravel, 25 percent sand, 18 percent silt/clay, and a small percentage of cobble. Sinuosity is atypically low through the reach (1.37) and higher both above and below. Other reach characteristics include a low degree of channel incision with good connectivity to the flood plain, moderate width depth ratio for its classification (22), and low slope (0.00039 water surface slope, 0.00051 bankfull slope).

The 1987 foot long longitudinal profile had three fairly substantial riffles located at the upper, middle, and lower end of the reach, and several deeper pools. This is in contrast to station 09MN086 upstream, which had poorly defined pools and riffles, a higher degree of channel incision, and a higher width depth ratio. The riparian corridor and stream banks along this reach are heavily wooded, supporting a stable stream dimension and somewhat better habitat quality by maintaining a lower width depth ratio which increases stream power and shear stress and helps to maintain adequately scoured pools. However, this reach, like most other reaches on the Pomme de Terre, would benefit from a lower sediment supply from upstream reaches.

Particle size analysis at the riffle revealed a composition of 89 percent gravel with a D50 of 21 mm and D84 of 32 mm, which is somewhat larger material than we found at station 09MN086 upstream.

Bank erosion rates appeared to be higher in areas without trees and lower where trees populated the stream banks, showing their importance to bank stability on rivers of this size. Considering the low degree of channel incision through this reach, it would appear that the prescription for lower erodibility, better water quality, and higher quality habitat is the promotion of a wooded corridor where it is sparse or does not exist, and protection where it does. This recommendation holds true for much of the river.

In summary, this station is showing dimensional resilience to higher flows but would benefit from a lower sediment supply based on the fairly high percentage of sand and clay/silt found throughout the station. Channel migration and bank erosion rates are high just upstream and into the upper end of this station and this entire reach would benefit from lower erodibility, better water quality, and higher quality habitat through the promotion of a wooded corridor where it is sparse or does not exist, and protection where it does.

Station 01MN069

This reach is classified as a C4c- stream type with a stream bed composed of 40 percent gravel, 36 percent sand, 11 percent silt/clay, 9 percent cobble, and 4 percent boulder. Sinuosity is about 1.2 through the reach and about 1.7 both upstream and downstream. Other reach characteristics include a low degree of channel incision for most of the reach with adequate flood plain connectivity, moderate width depth ratio for its classification (20), and low slope (0.00058 water surface slope, 0.0006 bankfull slope).

The 1280 foot long longitudinal profile had three fairly short riffles located at the upper and lower ends of the reach, and several deeper pools connected by long runs, which was somewhat similar to station 07MN027 above Highway 12. The riparian corridor and stream banks along most of the reach are moderately to heavily wooded, supporting a stable stream width dimension and somewhat better habitat quality than found just upstream and at the next station downstream by maintaining a width depth ratio of 20 (the lowest of the four lower geomorphic stations in the Lower PdT) which increases stream power and shear stress and helps to maintain adequately scoured pools. A more intermittent wooded corridor with a larger percentage of grass and sedge floodplain flats has allowed more channel movement upstream of this reach.

The monumented riffle at station 0+09 of the longitudinal profile had a bankfull cross sectional area of 207 ft^2, a mean bankfull depth of 3.2 feet, and a bankfull width of 65 feet. The bankfull discharge at the riffle was estimated at 514 cfs using Manning's equation and a known "n" back calculated from known USGS gage discharge at Appleton. Particle size analysis at the riffle revealed a composition of 73 percent gravel, 26 percent sand, and 1 percent cobble. The riffle had a D50 and D84 of 20 mm and 45 mm. This riffle was not completely perpendicular to the channel and had some transverse bar characteristics, directing water to the right bank downstream causing extreme near bank stress and higher erosion rates along the 120-260 right bank BEHI segment.

The surveyed pool cross section at station 1+77 on the longitudinal profile was located on a close to 90° bend in the river. The pool cross section thalweg, a 7.5 foot deep scour hole located closer to the inside bend (right bank) side of the channel, was the result of the location of the cross section on the pool, and the thalweg crossing over from the high right bank flows described above.

Station 01MN069

The 07MN029 reach on the Pomme de Terre River was assessed and classified in August 2009 as a C4c- stream type. The reach has flat water slope at 0.00053ft/ft which put it in the lower 25 percent range for this stream classification. The 1500 foot longitudinal profile assessed in this reach had a bed composition of 32 percent sand and 59 percent gravel with the remainder in silts, clays, cobbles and random boulders.

Well defined riffle features found in this reach were also represented in the 5+44 cross section which was composed of 9 percent sands and 86 percent gravels. The lack of larger particles in the riffle reflects the reduced stream power and lack of critical sheer needed to entrain and move larger bed particles.

The stream channel through this reach is highly sinuous supporting a large belt width and wide flood prone area. Considerable channel meandering is apparent from aerial photograph analysis of this reach. This addition channel meandering is the result of good grade control features in this reach and the instability of the stream banks which are composed of loose unconsolidated heterogeneous material consisting of silt, sand, gravel and cobble.

The width/depth ration of 26 for this reach is in the mid modal range for the stream classification. The entrenchment ratio of 5.7 is at the lower end of the rage for this stream class which might be indicating the channel is slightly entrenched. However, the high erosion potential for stream banks in this reach will likely to continue allowing the stream to make horizontal adjustments easily as a means of dissipating energy rather than vertical adjustment which could eventually cause the channel to become entrenched.

The 1500 foot longitudinal profile assessed in this reach clearly show the low energy (water) slope, well defined riffles and deep pool features. The slope between bankfull indicators and low bank heights were the same in this reach and seemed to correlate well with the water slope. There is a slight ascending trend to bankfull slope which suggest the stream could be becoming incised. However, the trend is so slight it could simply represent error in the bankfull estimates.

The moderately wide riparian corridor in this reach consists of reed canary grass with sections of dense flood plain forest. Numerous indicators of channel degradation and channel instability that exist this reach such as mid channel bars, traverse riffles and numerous eroded stream banks. These indicators are symptomatic of possible stream channel evolution. The assessed stream classification for this reach is a C channel but the system is likely evolving towards an F channel classification. This fluvial evolution is promoting changes in dimension, pattern and profile.

In summary, stream reach 07MN029 does is not appear to be a stable stream reach. The reach has some good geomorphic features assisting with grade control, well developed riffle and pool features, strong flood plain connectivity but the reach does lack sufficient lateral stability. This channel instability is likely a cumulative effect of excessive hydrology, the heterogeneous soil composition of the flood plain, and lack of sufficient riparian vegetation to limit bank failures. Stream stability or habitat improvement practices conducive to a the C4c- stream classification include bank placed root wads, rock vanes, j-hooks and bank placed boulders.

Stressor Pathway: Riparian condition

In some areas the riparian corridor is the preventer from the river unraveling further from stability. As previously mentioned, the riparian buffers along the Lower PdT are minimal in some areas. In portions of the river, the stream banks have gone through increased trampling and decreased riparian and bank vegetation. The riparian condition has led to changes in cover availability, stream stability and led to other alterations.

Stressor Pathway: Channelization

Channelization of reaches within the Lower PdT and the channelization of reaches contributing to the river have led to changes in the hydrological and geomorphological condition. This has led to changes in discharge patterns, changes in substrate, changes in sinuosity, and increases in erosion.

Stressor Pathway: Altered Hydrology

The habitat in this reach is controlled by the hydrology and vegetation. The channelization of intermittent and perennial flow pathways by way of ditching and tiling have led to changes in flow dynamics strongly linked to the stream stability and habitat.

The Lower PdT has convincing data to support the lack of habitat as a stressor to the biological community.

Candidate Cause: Turbidity

In the Lower PdT, invertebrate metric values that would be expected to increase with increased turbidity did not follow an increasing longitudinal pattern such as in the longitudinally increasing TSS values (CADDIS, Figure 103). The number of tolerant taxa was not greatly different in the lower parts of the Pomme de Terre River than other reaches not shown to have increased TSS values. The percent tolerant individuals and both the number of Chironomidae taxa and percent Chironomidae individuals appear to decrease longitudinally rather than the expected increase. This may be due to the sampling methodology rather than a conflict with the stressor -response. Similarly, an expected decrease in score due to an increase in turbidity was not observed in a collective group of eight metrics (Figure 104 and Figure 105). For instance the collector-filterers in this reach did not show a decline, as expected, with sites 07MN027 and 07MN029 comprising of 50 and 45 percent of the surveys in 2007.

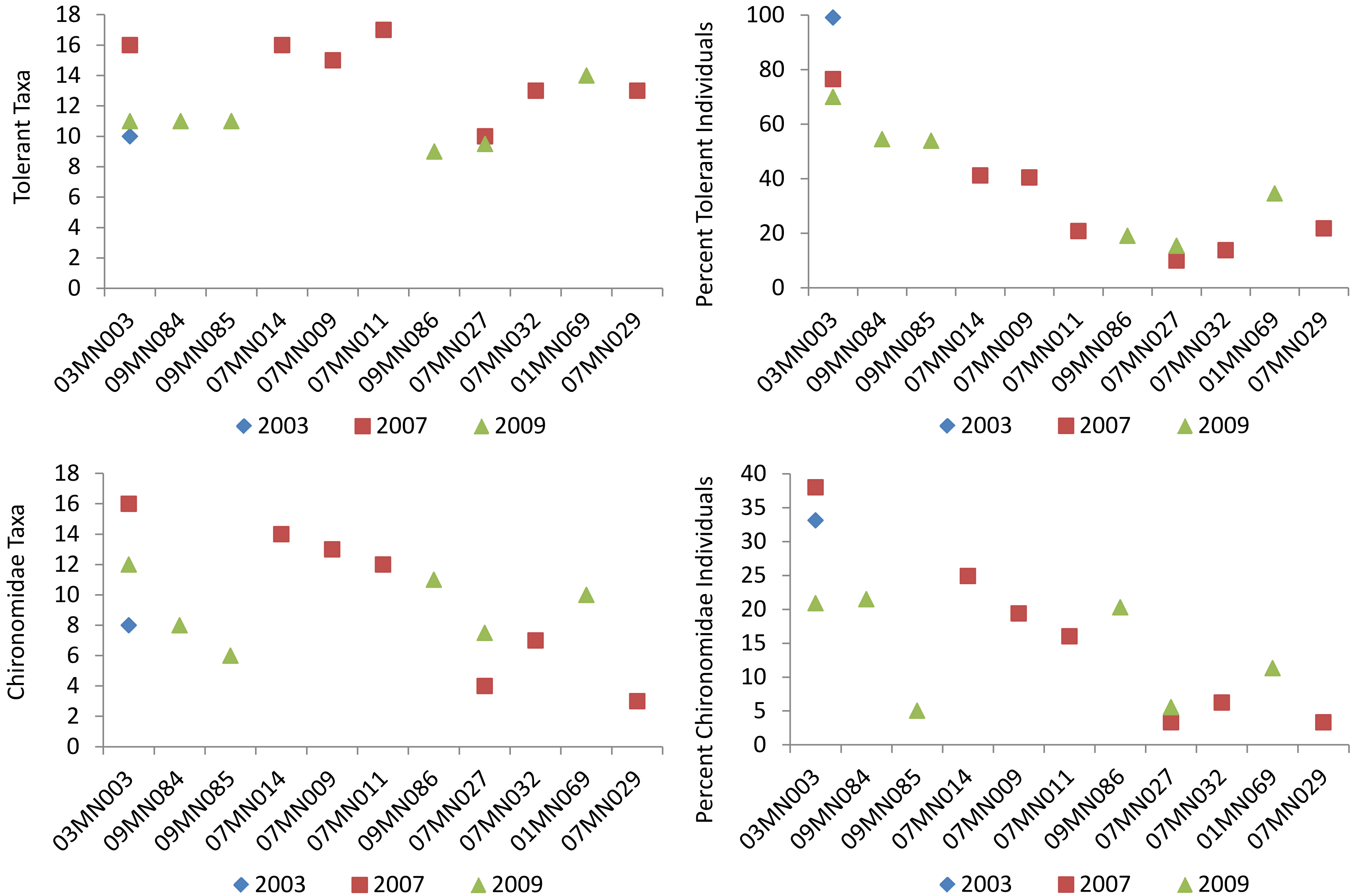

Figure 103. Invertebrate metrics that are expected to increase with increases in turbidity

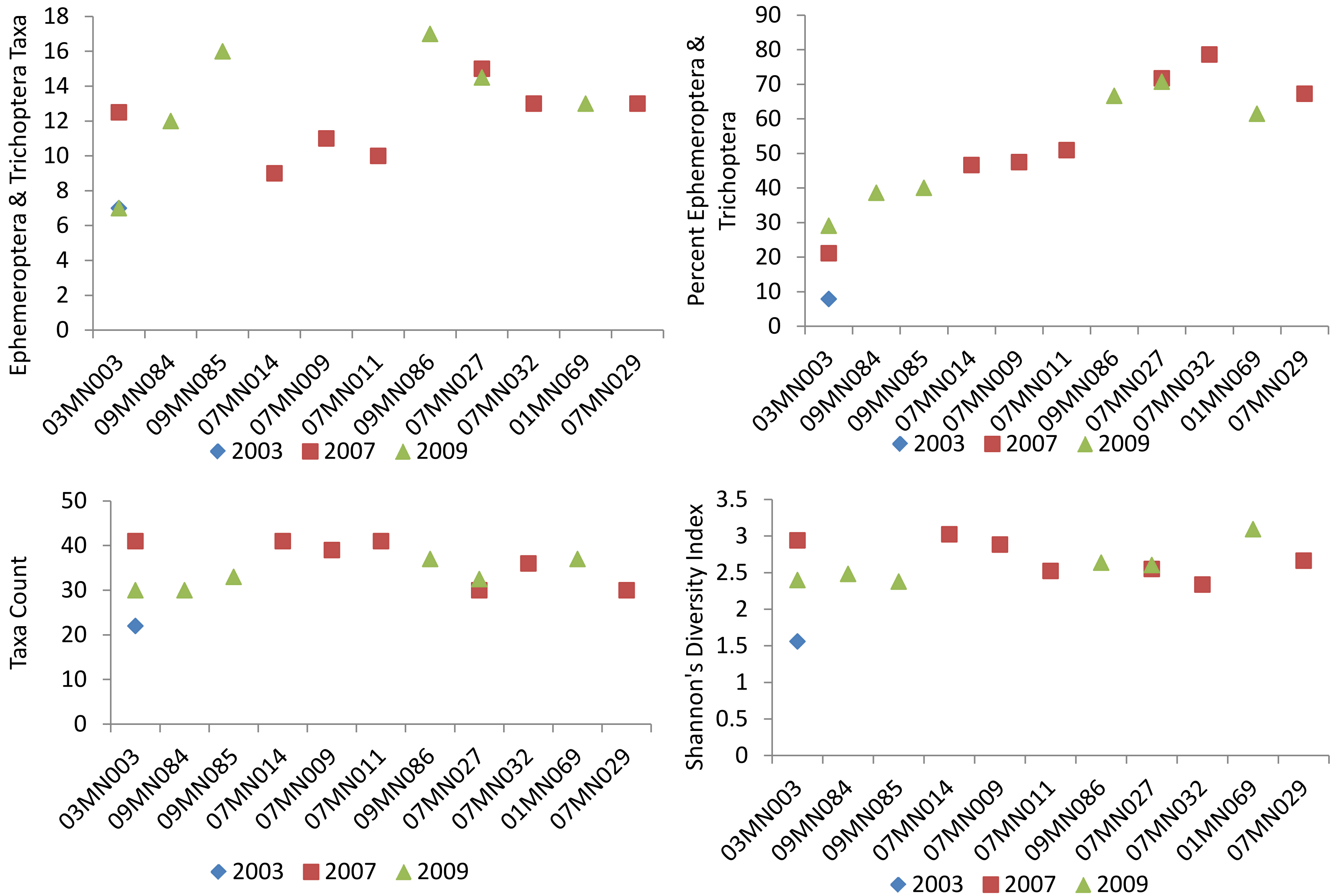

Figure 104. Invertebrate metrics that should decrease with increases in turbidity

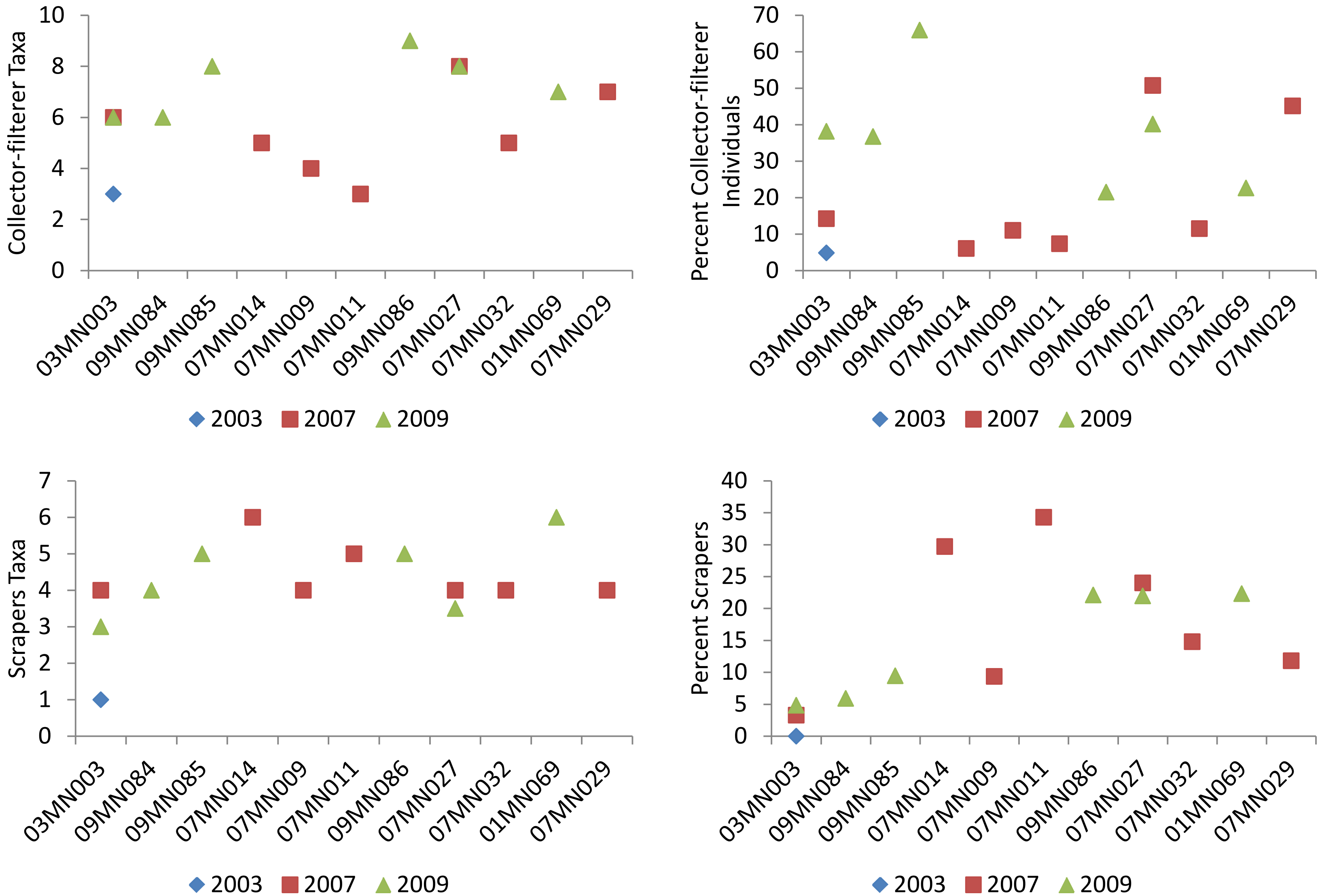

Figure 105. Invertebrate metrics that should decrease with increases in turbidity

Fish in this reach were also compared to the other impaired reaches in the Pomme de Terre using Meador and Carlisle's values for suspended sediment tolerance (Figure 106). The Lower PdT reach has a greater proportion of fish species in higher two quartiles that is most tolerant to suspended sediment when compared to upstream reaches on the river. However, fish species that are most sensitive to suspended sediment in all of the stations surveyed in 2007 were still present.

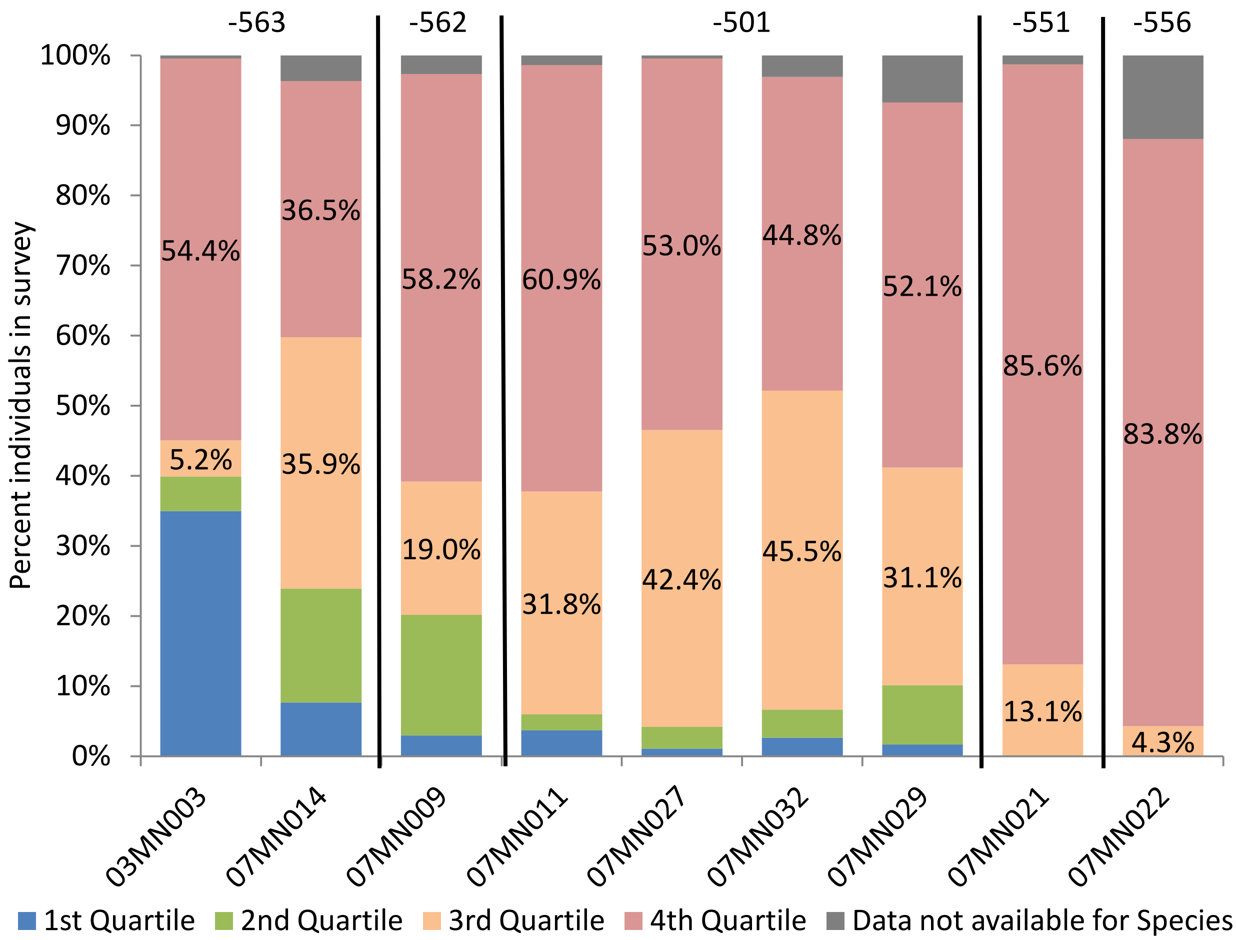

Figure 106. Percent individuals by biological site sampled in 2007 in impaired reaches, for each quartile based on suspended sediment weighted averages, separated by AUID, last three digits shown (Meador and Carlisle, 2007)

Although not present in great numbers, two of the more sensitive fish species to suspended sediment (of those found in the Pomme de Terre River watershed and according to Meador & Carlisle, 2007), were found in this reach of the Pomme de Terre River. One largescale stoneroller and one silver redhorse were surveyed at site 07MN032 in 2007 and six silver redhorse were surveyed at site 07MN029 in 2007. Becker stated that largescale stonerollers are "essentially a fish of clear water" and silver redhorse are known to "avoid streams with high gradients and with excessive turbidity" (1983). Their presence is noted, but the proportion of these fish species that are less tolerant to suspended sediment could be greater, similar to the upstream reaches. The lack of connection to a riverine section of the Minnesota River, as the Pomme de Terre confluence is currently situated, may hinder any repopulation from other source waters.

The herbivore fish population can be reduced as a response to increased suspended sediment. In this the Lower PdT, the percentage of herbivorous fish was quite low, averaging 3.5 percent. The average percent herbivorous fish in the Minnesota River Basin Southern Rivers IBI of similar drainage area is 10.48. Longitudinally in the Pomme de Terre River, the proportion of herbivores does not vary greatly, with an average of 3.5 percent (Figure 107). Thus herbivores are reduced all along this section of the Pomme de Terre River, when compared to the Minnesota River basin, regardless of observed variations in suspended sediment concentrations.

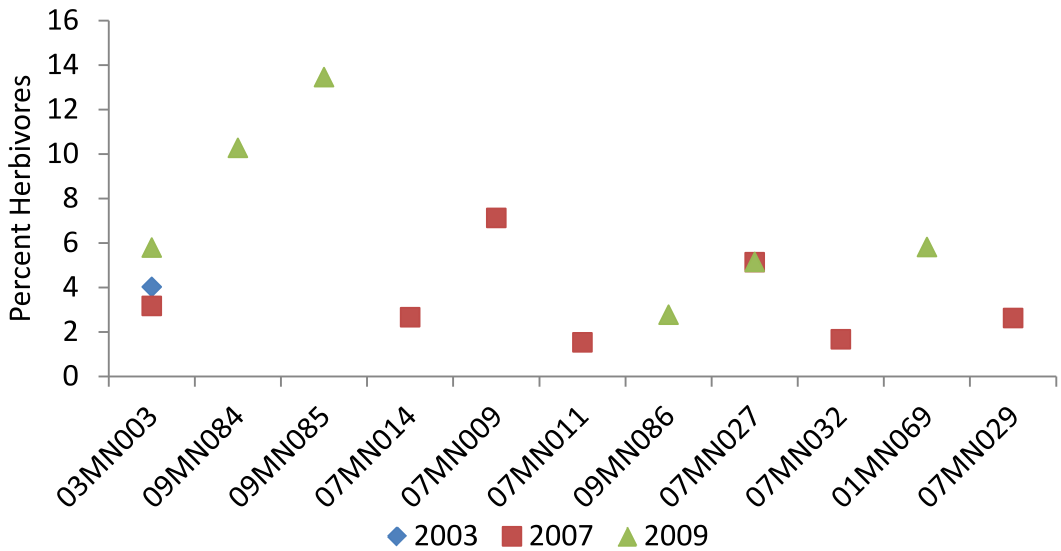

Figure 107. Percent herbivores (fish) longitudinally along the Pomme de Terre River in 2003, 2007 and 2009

One of the lowest average metric scores in this reach was dominant two percent. In all of the biological sites in this reach, sand shiners and spotfin shiners dominated the sample, averaging approximately 60 percent of the surveys. Both of these fish are known to be adaptable to wide ranges in turbidity.

In the lower reach of the Pomme de Terre River, IBI scores for both fish and invertebrates vary from site to site. In contrast turbidity gradually increases in the downstream direction, indicating that other stressors may be influencing this reach as well.

At station 09MN086, the stream bank erosion estimates from the BANCS assessment work reflect significantly higher sediment loading contributed from the stream banks. The erosion rate estimates for this river reach fall between 0.21-0.48 tons/foot/year. The high stream bank erosion in this reach reflect the entrenchment of the stream channel, increased cumulative watershed hydrology, increased stream bank sheer stress and overall higher stream bank erosion potential related both the geology and stream bank soil composition.

The high stream bank erosion rates estimated for this reach are disproportionately weighted by a few significant terrace sites (Figure 108). The terraces become an erosion issue where the stream channel is abutting the terrace in the floodplain. The terraces generally consist of heterogeneous silt, sand and small gravels that are highly erodible. These historical floodplain features represent an abandon floodplain from an era when the river channel was at a much higher elevation. Eroding terraces are common throughout the lower watershed and represent significant sources of stream bank erosion contributing a significant suspended load and total bedload to the Pomme de Terre River.

In areas where there is stream instability this addition bed load can overwhelm the ability of the river to move this sediment. As a result we would expect to see stream facet features inundated, pools filled, mid channel bars forming, stream habitat is lost and low IBI scores are likely.

Figure 108. Terrace sites within station 09MN086

The BANCS model was used to estimate bank erosion through station 07MN027 during the June 2009 reconnaissance. These estimates also included station 09MN086 upstream which showed higher erosional processes than station 07MN027. Two independent estimates were completed for this reconnaissance reach and one of those is presented in Table 19. The range of estimates for one observer was 604 to 2167 total tons for the reach (0.0298 – 0.1069 tons/year/foot). The second observers' estimates ranged from 858 to 1740 total tons for the reach (0.0413 – 0.0837 tons/year/foot). Estimated erosion rates in feet per year ranged from 0 to 2.5 for various bank segments.

Analysis of 2010 and 1991 aerial photos for the area immediately upstream of the study reach shows clearly that downstream meander migration has occurred over this 19 year period, demonstrating the dynamic nature of the river (Figure 109 and Figure 110). Measurement of channel migration for several average meanders shows 20 to 51 feet (1 – 2.68 foot annual rate) of total migration over that time period for this reach. Total meander migration ranged from 0 to 35 feet (0 to 1.9 foot annual rate) within the station over the same time period (Figure 111 Figure 112). Channel width and depositional rates appeared to remain fairly stable over that same period. These observed annual erosion rates of 0 to 2.68 feet were almost identical to the range of estimated erosion rates (0 to 2.5) using the BANCS model during the reconnaissance (Table 22).

Table 22. BANCS Model stream erosion predictions from 10th St to Hwy 12

07MN027 - Pomme de Terre River - 10th St to Hwy 12 - BANCS Empirical Model Stream Bank Erosion Predictions										
					Predicted Loss Using North Carolina, Colorado, and Yellowstone Erosion Rates					
Study Bank	Dimensions (ft)				Loss Using NC Rates		Loss Using CO Rates		Loss Using YS Rates	
WPT, Station, #	Length	Height	BEHI Rating	NBS Rating	Loss (ft/yr)	Loss (tons/yr)	Loss (ft/yr)	Loss (tons/yr)	Loss (ft/yr)	Loss (tons/yr)
256	300	4	Moderate	Very High	0.280	16.17	0.790	45.64	1.200	69.33
257	200	12	Very High	Extreme	1.600	184.89	1.300	150.23	2.500	288.89
258	150	6	High	Very High	0.280	12.13	0.800	34.67	1.700	73.67
260	350	4	Moderate	Very High	0.270	18.20	0.790	53.25	1.200	80.89
261	200	15	Very High	Very High	1.200	173.33	0.800	115.56	1.700	245.56
262	300	4	Moderate	Low	0.027	1.56	0.090	5.20	0.180	10.40
263	300	3	Moderate	Moderate	0.600	26.00	0.190	8.23	0.340	14.73
264	40	20	Extreme	Moderate	2.600	100.15	1.100	42.37	1.200	46.23
265	50	12	Extreme	Very Low	1.000	28.89	0.190	5.49	0.600	17.33
266	200	5	Moderate	Very Low	0.012	0.57	0.042	2.03	0.089	4.29
267	250	6	High	Very Low	0.070	5.06	0.110	7.94	0.300	21.67
268	700	4.5	High	Very Low	0.070	10.62	0.110	16.68	0.300	45.50
269	800	6	Very High	Very Low	0.500	115.56	0.110	25.43	0.300	69.33
270	200	5	Moderate	High	0.130	6.25	0.380	18.29	0.650	31.29
271	800	5	High	Very Low	0.070	13.48	0.110	21.19	0.300	57.77
272.5	363	6	Very High	Very High	1.200	125.84	0.800	83.89	1.700	178.27
273	500	6	Very High	Very High	1.200	173.33	0.800	115.56	1.700	245.56
274	200	8	Moderate	Very Low	0.012	0.92	0.042	3.24	0.089	6.85
275	860	4	Very High	Very Low	0.500	82.81	0.110	18.21	0.300	49.69
277	369	7	Moderate	Low	0.027	3.35	0.090	11.19	0.180	22.39
278	594	6	High	Low	0.100	17.16	0.180	30.89	0.450	77.22
279	300	7	Extreme	Low	1.800	182.00	0.420	42.47	0.820	82.91
Totals:	**8026**					**1298.27**		**857.64**		**1739.75**
				Loss in Tons/Year/Foot of Reach:	**0.0625 tons/ft/yr**		**0.0413 tons/ft/yr**		**0.0837 tons/ft/yr**	

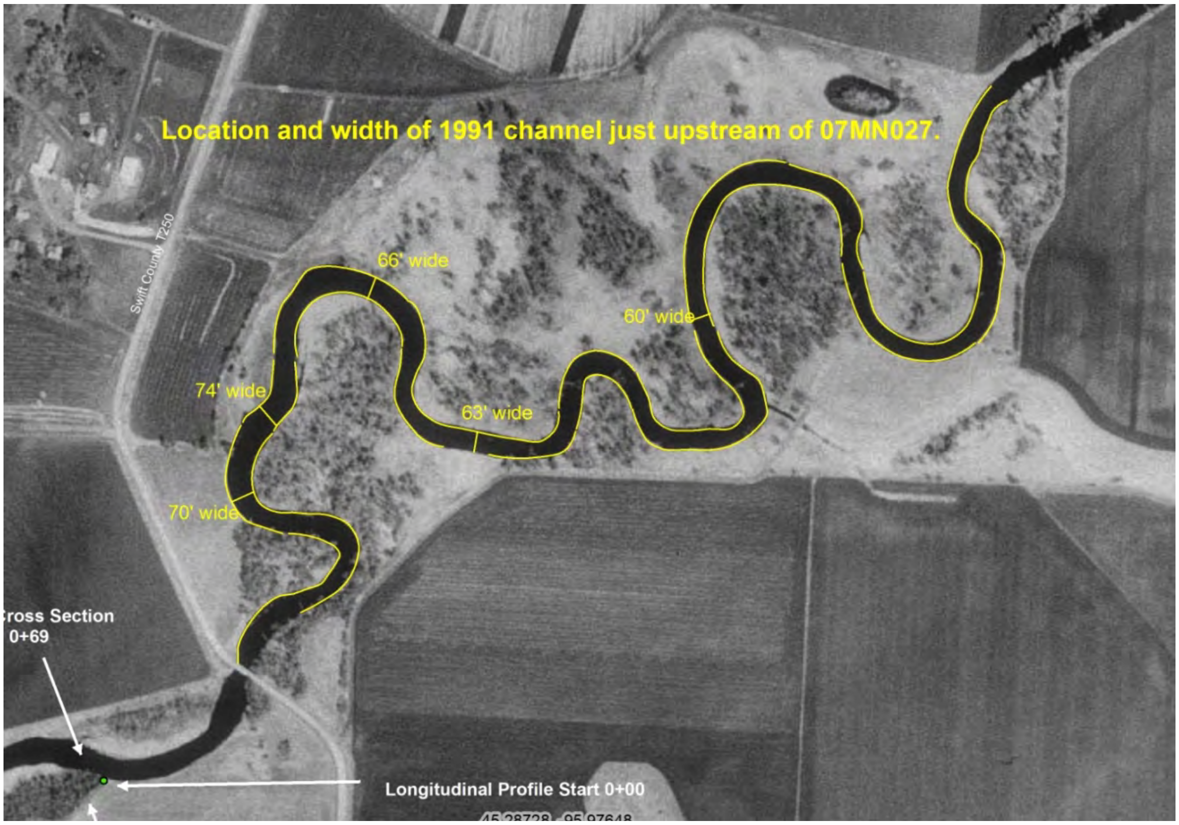

Figure 109. 1991 location and width upstream of station 07MN027

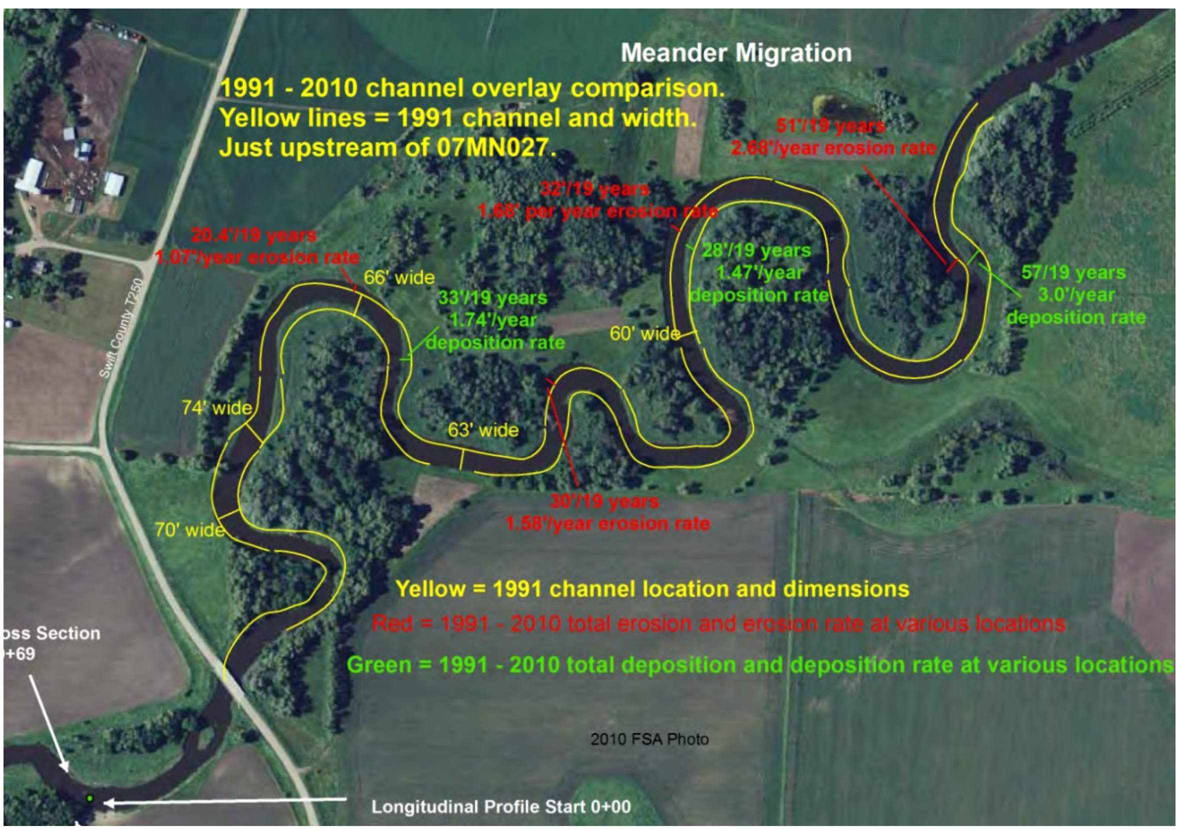

Figure 110. 2010 aerial photograph with 1991 overlay upstream of station 07MN027

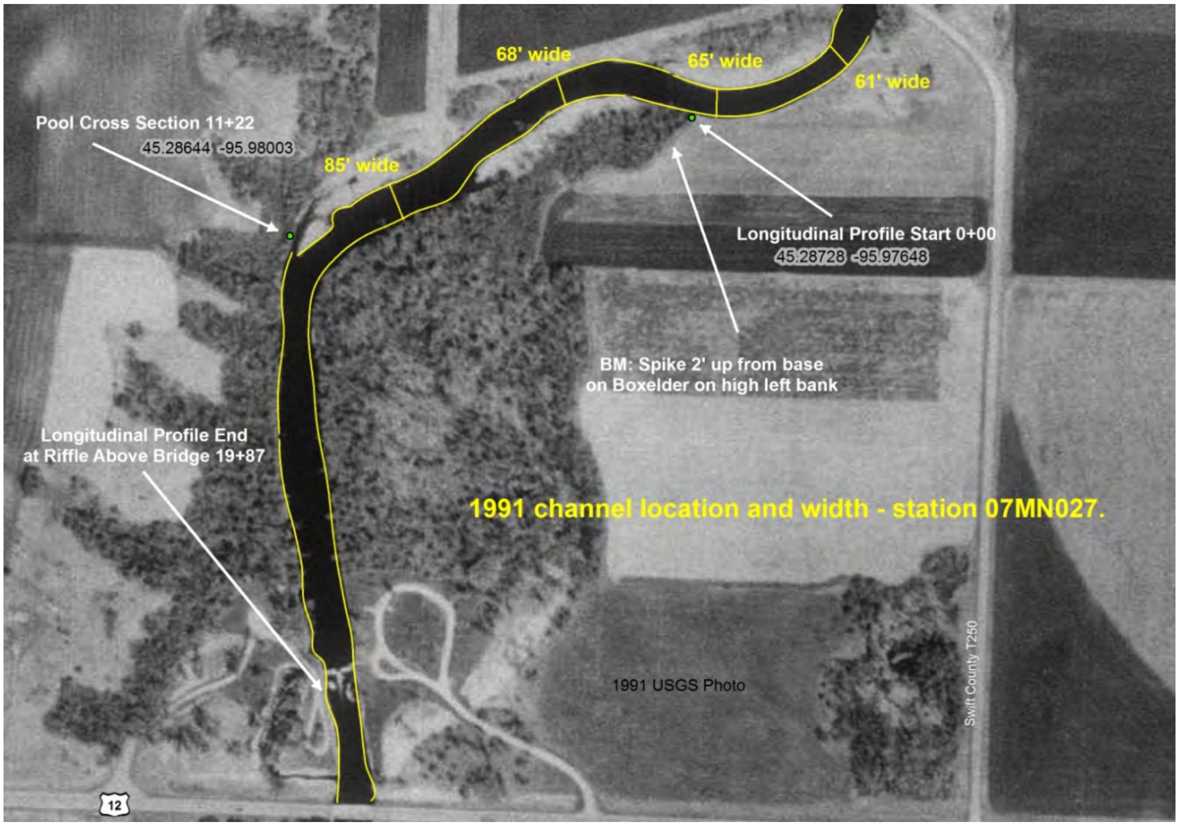

Figure 111. 1991 location and width at station 07MN027

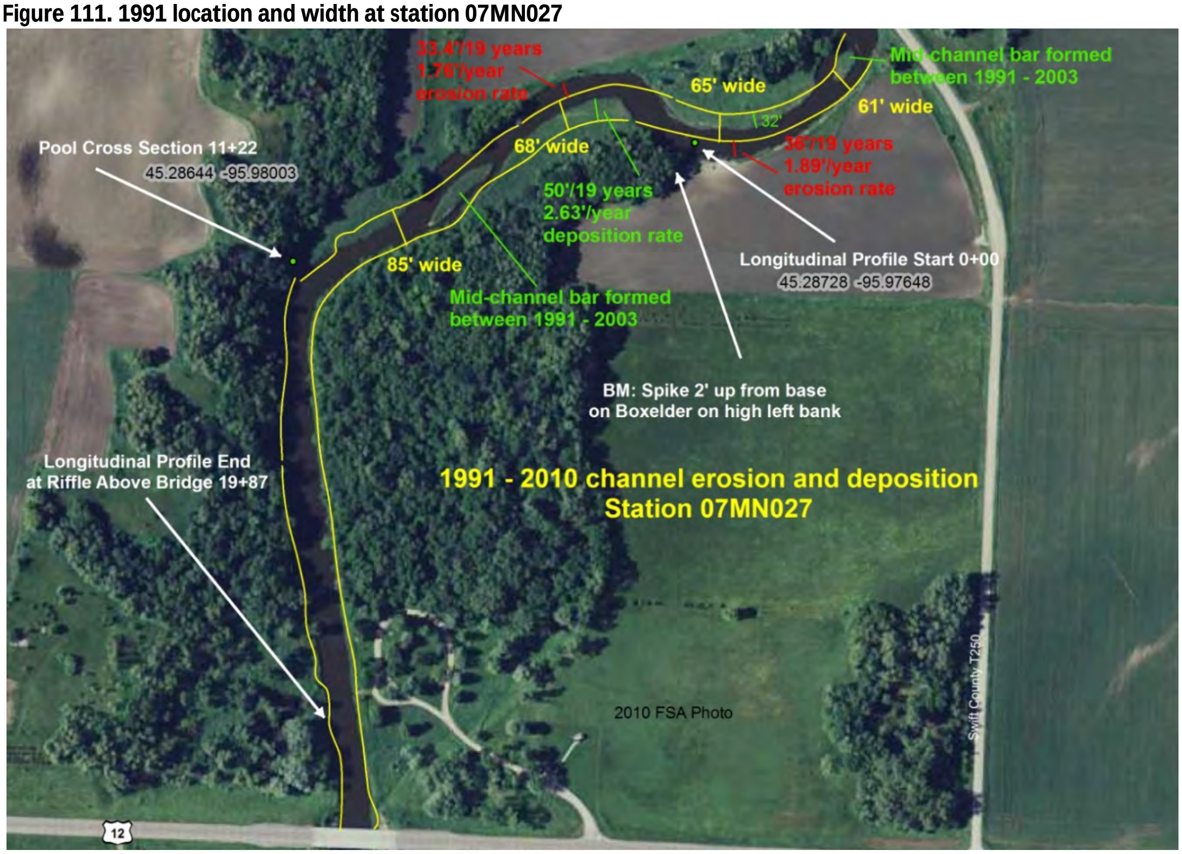

Figure 112. 2010 aerial photograph with 1991 overlay at station 07MN027

It appears that depositional and erosional processes are proceeding at similar rates based on aerial photo measurements of erosion and deposition and channel width. Adding bank material analysis to the BANCS model would allow partitioning of stream bank contributed sediment into bedload and suspended sediment components. This bank material analysis could be accomplished by taking a composite sample of erosional bank surfaces and performing a sieve analysis of particle sizes.

The BANCS model was used to estimate bank erosion rates and total bank erosion for at station 01MN069 during the August assessment (Table 23). Total bank erosion estimates were 42, 105, and 195 tons based on North Carolina, Colorado, and Yellowstone rates, respectively. Bank erosion rate estimates ranged from 0.0324 to 0.1522 tons/ft/year, again based on available empirical erosion rate data. Bank erosion rate estimates for various bank segments within the station ranged from 0 to 2.4 feet per year.

Analysis of 2010 and 1991 aerial photos provides evidence of a very active channel over the past 19 years. Measurement of channel migration for several typical meanders upstream and downstream of the station shows 30 to 43 feet of total migration (1.6 – 2.3 feet per year) over that time period for this reach. Very little channel movement was evident within the heavily wooded station. Channel width appeared to remain fairly stable over that same period. These actual observed annual erosion rates of 0 to 2.3 feet per year for various bank segments fell within the range of estimated erosion rates (0 to 2.4 feet per year) using the BANCS model. Two observations are probably likely. First, erosion rates within the station are lower than both upstream and downstream and are not representative of the larger reach, and second, the glacial soils present through the larger reach probably erode at the middle or high end of the range of estimates. This is further supported by the fact that Yellowstone erosion data were derived in glacial soils.

Table 23. BANCS Model stream erosion predictions at station 01MN069

01MN069 - Pomme de Terre River - WMA - BANCS Empirical Model Stream Bank Erosion Predictions										
					Predicted Loss Using North Carolina, Colorado, and Yellowstone Erosion Rates					
Study Bank	Dimensions (ft)				Loss Using NC Rates		Loss Using CO Rates		Loss Using YS Rates	
WPT, Station, #	Length	Height	BEHI Rating	NBS Rating	Loss (ft/yr)	Loss (tons/yr)	Loss (ft/yr)	Loss (tons/yr)	Loss (ft/yr)	Loss (tons/yr)
0-120 RB	120	4	Moderate	Low	0.027	0.62	0.090	2.08	0.180	4.16
120-260 RB	140	5	Moderate	High	0.600	20.23	1.400	47.19	2.400	80.89
260-320 LB	60	20	Very High	Moderate	0.150	8.67	0.300	17.33	0.700	40.44
260-680 RB	420	3.5	Moderate	Low	0.027	1.91	0.090	6.37	0.180	12.74
320-740 LB	420	5.5	Moderate	Low	0.027	3.00	0.090	10.01	0.180	20.02
680-1000 RB	320	3	Low	Very Low	0.002	0.08	0.017	0.78	0.020	0.92
740-1000 LB	260	3	Low	Low	0.004	0.16	0.034	1.27	0.033	1.24
1000-1280 RB	280	3	Very Low	Very Low	0.000	0.00	0.000	0.00	0.000	0.00
1000-1100 LB	100	3.5	Low	Low	0.004	0.07	0.034	0.57	0.033	0.56
1100-1280 LB	180	6	Moderate	High	0.130	6.76	0.380	19.76	0.650	33.80
Totals:	**2300**					**41.50**		**105.37**		**194.77**
				Loss in Tons/Year/Foot of Reach:	**0.0324 tons/ft/yr**		**0.0823 tons/ft/yr**		**0.1522 tons/ft/yr**	

Bank erosion rates were substantially higher in areas without heavy tree cover along the stream banks and lower where trees populated the stream banks, showing the importance of trees to bank stability on rivers of this size. Considering the low degree of channel incision through this reach, it would appear that the prescription for lower erodibility, better water quality, and higher quality habitat is the promotion of a wooded corridor where it is sparse or does not exist, and protection where it does. This recommendation holds true for much of the river.

The 07MN029 reach is located in the lowest section of the Pomme de Terre River watershed. This is an area transitioning from a stream reach of significant elevation relief coming down into the low gradient Minnesota River Valley. The floodplain through this reach is considerably narrower than the upper reaches of the watershed. The stream bank erosion estimates from BANCS assessment work in this lower section of the watershed reflect significantly higher sediment loading contributed from the stream banks. The erosion rate estimates for this stream reach fall between 0.21-0.48 tons/foot/year. The high stream bank erosion in this reach reflect the increased cumulative watershed hydrology, natural geomorphic features for stream grade stability, and the overall higher stream bank erosion potential related to the soil composition.

In 2007, the HSPF model predicted a maximum TSS concentration at the outlet of the Pomme de Terre River (reach 10) of 3060 mg/L. The simulated TSS concentration was above 65 mg/L for 36 days, but only a maximum total of 6 consecutive days. In 2008, concentrations were predicted above 65 mg/L for consecutively 21 days and 56 days total. TSS concentrations were elevated above the draft standard for 61 days and consecutively 34 days, in 2009. The duration of these elevated concentrations may play a role in the biotic community composition, if the biology does not have opportunities to move into refuges away from the high sediment loads.

The impairment of the biological community and elevated turbidity are co-occurring but the biological community does not respond as would be expected with high turbidity. There are more TSS tolerant species than that of upstream reaches that are not suspected of high TSS issues, but the more sensitive species (largescale stoneroller and silver redhorse) were also found in this reach which weakens the case for concluding that turbidity is a stressor here. In the Lower PdT, the data is inconclusive for turbidity as a biotic stressor. It may be of additively still a concern, but not the only limiting factor reducing the health of the biotic community.

The sediment load conveyed by the drainage network may still be a cause for concern, even if suspended sediment may not be a primary stressor to the biological community of the Pomme de Terre River. The sediment loading signals a condition that is undesirable and further monitoring, restoration and protection would benefit not only the biological community, but the recreational opportunities that the river offers as well.

Candidate Cause: Altered Hydrology

This segment of the river corresponds to HSPF modeled reaches 50 through 10, which had a range of mean daily flows from 8.4 to 9501 cfs from 1996 to 2009 (Figure 5 and Figure 113). Velocities calculated from the model ranged from 0.57 to 3.41 ft/s in reach 10 to approximately 1.5 to 5.2 ft/s in reaches 40 through 10.

Bankfull discharge was field estimated at occurring at 541 cfs (7th percentile flow) in reach 20 with a recurrence interval of 1.31 years. In reach 10, bankfull discharge was estimated at 523 (8th percentile flow) with a recurrence interval of 1.29 years. Bankfull flows often occurred at the end of March to the beginning of April from 1996 to 2009 (Figure 114).

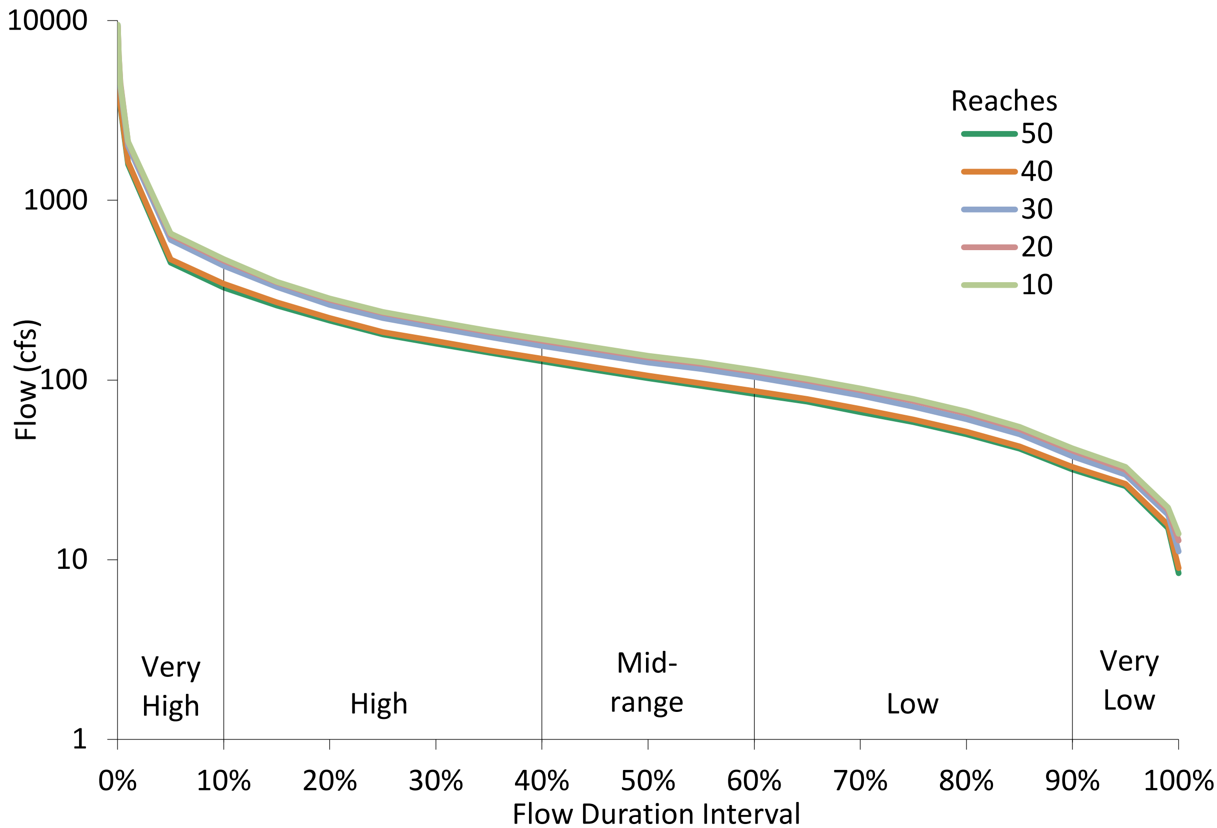

Figure 113. Flow duration curves for HSPF reaches 50, 40, 30, 20 and 10

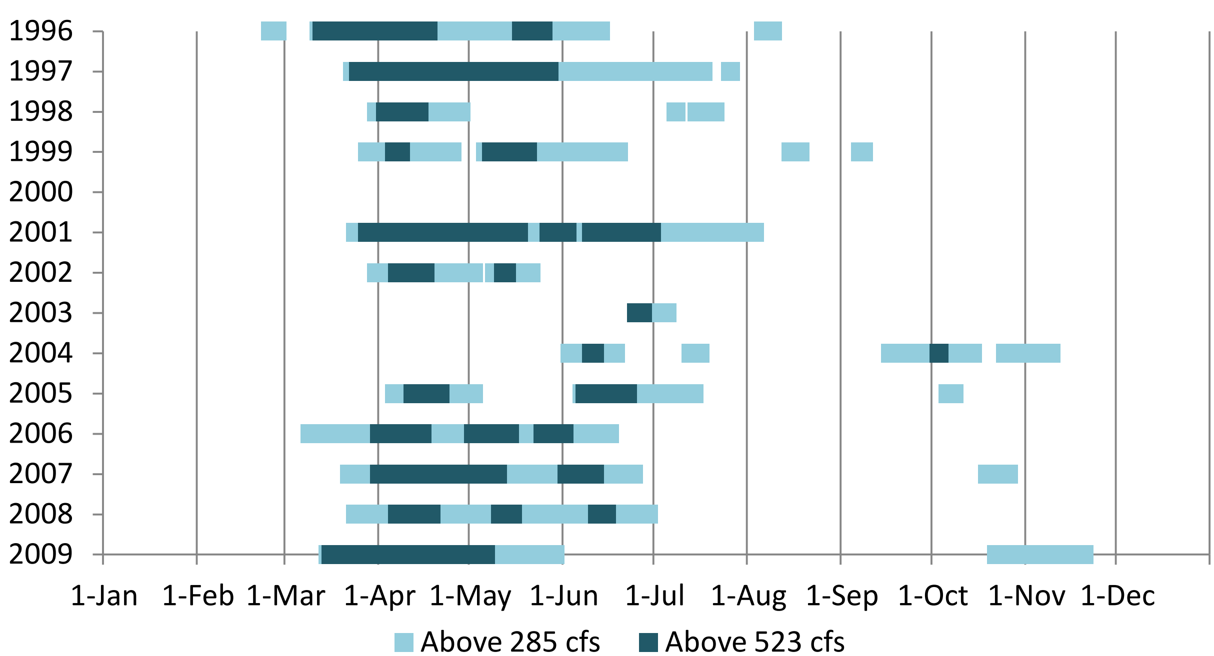

Figure 114. Bankfull flow events (above 523 cfs) and flows greater than 285 cfs (20th percentile flow) at the outlet of Pomme de Terre River reach 10 from 1996 to 2009

Low flows, of less than 66.9 cfs, often occurred during the month of September (7 out of 14 years), and January to March (8 years, Figure 115). In ten of the years, February had some portion of the month with flows below the 80th percentile, from 1996 to 2009.

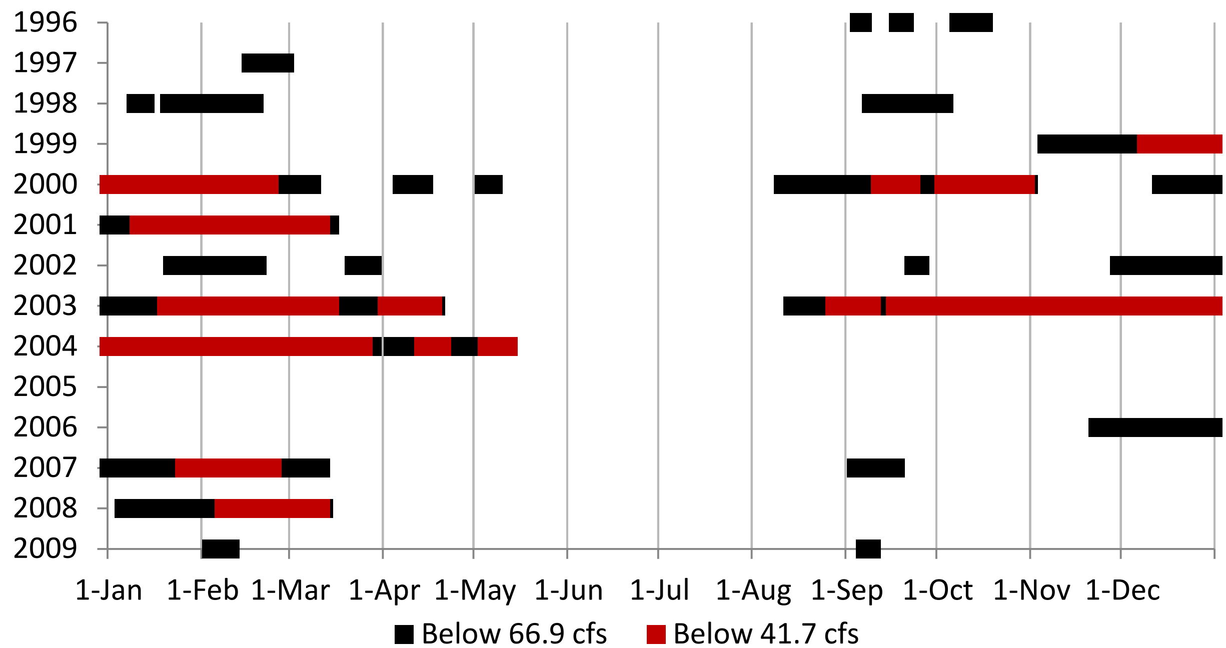

Figure 115. Low flow events, below 66.9 cfs (80th percentile flow) and 41.7 cfs (90th percentile flow) at the outlet of Pomme de Terre River reach 10 from 1996 to 2009

The invertebrate populations in the Lower PdT were comprised of more long lived individuals than the average of stations of the same class in the Minnesota River Basin that scored above the IBI threshold (12.8 percent and 8.6 percent respectively). Similarly, the percent of long lived taxa in the Lower PdT is closer to that of stations, of the same class, in the Minnesota River Basin that scored above the threshold than it is to those in the Minnesota River Basin below the threshold.

At time of analysis, a short life cycle invertebrate metric was not available. The percentage of swimmers is low, ranging from 2 to 8, indicating that low flow is not likely a stressor. Yet, the lack of dragonflies and damselflies signals a potential lack of habitat complexity which is driven by hydrology.

Unlike the other reaches, this reach did not show a decreased proportion of fishes preferring moderate velocities. This may be potentially linked to specific habitat parameters rather than the prevalence of low flow events. The fish considered generalists ranged from 8.31 to 23.97 percent of the population. Similarly to the Middle PdT, non-lithophilic spawners averaged about 11 percent of the surveys in this reach, which had a range of 4.82 to 18.54 percent. Tolerant fish in the lower Pomme de Terre ranged from 33.49 to 65.36 percent, with the metric scores ranging from 2.2 to 6.3. In 2009, sites 01MN069 and 09MN086 scored above 6, and the rest were at or below 5 for the metric score. The fish community is dominated by two species that are quick to mature, signaling the potential for instability in the flow regime. Again, it seems that low flow may not be an issue but that high flows may have some component to the impairment directly and indirectly by causing a lack of adequate habitat.

Several midsized tributaries enter above station 09MN086 and appear to be negatively impacting the stream channel from the added hydrologic contributions through which is reflected through increased stream bank erosion. Station 07MN027 is currently showing dimensional resilience to higher flows currently due to the riparian corridor.

At station 01MN069, two large meander cutoffs have decreased the length of the river over the past 19 years by about 0.7 miles from the original 3.4 mile length (Figure 116). This decrease in length would have increased overall slope, however, riffles at the start and end of the station appear to be providing some grade control through the assessment station. The lengths of the two cutoff channels were approximately 149 and 198 feet respectively.

Although the river within this station is showing dimensional resilience for its C4c- classification and little incision, there are some signs of instability. Those signs include: 1) accelerated erosional processes both above, below, and along one segment of the station, and 2) depositional features that are indicative of increasing instability such as mid-channel and transverse or diagonal bars. These early indicators of channel instability are likely caused by a combination of factors including flows of higher magnitude and longer duration, the heterogeneous soil composition of the flood plain, and areas that lack sufficient woody vegetation to provide bank stability. Sediment competence calculations from the bar sample collected at this station would indicate that aggradation rather than degradation is more probable in the bed of this channel.

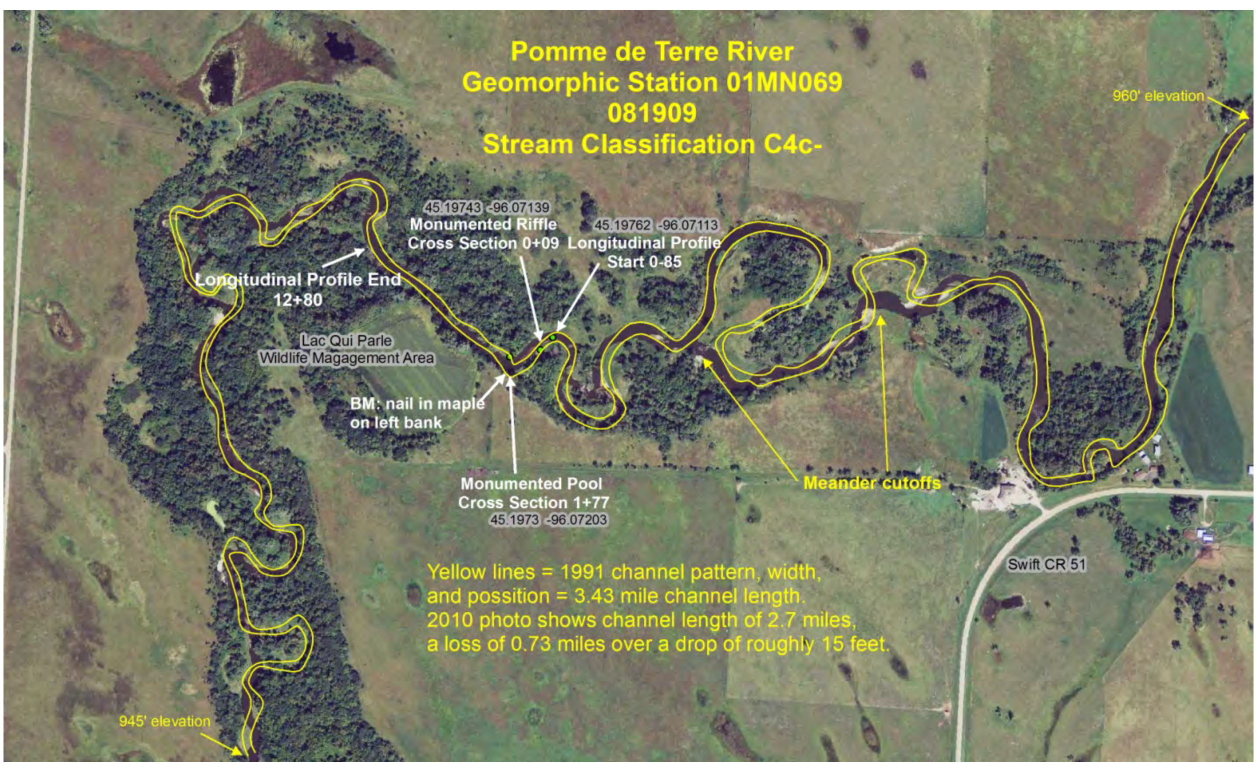

Figure 116. Aerial photograph (2010) overlaid with 1991 river location (yellow lines)

Station 07MN029 does is not appear to be a stable stream reach. The reach has some good geomorphic features assisting with grade control, well developed riffle and pool features, strong flood plain connectivity but the reach does lack sufficient lateral stability. This channel instability is likely a cumulative effect of excessive hydrology, the heterogeneous soil composition of the flood plain, and lack of sufficient riparian vegetation to limit bank failures.

In the lowest reach of the Pomme de Terre River, documented average annual flows have been increasing at a greater rate than that of the increasing precipitation. Low flows are not likely a stressor since they do not occur when the biological community is showing the most stress. The landscape in the watershed has gone through vast alterations. This reach of the Pomme de Terre had the greatest flow of all the reaches during low flow events. The most stress to the biological community is during the uptick in annual average flows with the changes to the habitat and hydrologic timing.

Stressor Pathway: Riparian condition

As mentioned previously, the riparian buffers along the Upper PdT reach are minimal in some areas. The riparian areas provide resistance to overland flows and minimize contributions of sediment, nutrients and pesticides to the reach.

Stressor Pathway: Channelization

The channelization of intermittent flow pathways and tile drainage has led to changes in flow dynamics and changes in substrate. The changes in the hydrological and geomorphological condition have direct impact to the biology of the reach. Additionally tile drain also contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs. The changes incurred inhibit species that need cues for spawning and only spawn a single time during a season.

Stressor Pathway: Groundwater withdrawal

Significant irrigation occurs in the watershed, especially in the surficial aquifer adjacent to the Pomme de Terre River (Figure 21; see Pomme de Terre River Watershed Monitoring and Assessment Report for more information on irrigation).

The evidence indicates altered hydrology is a primary stressor to the biotic communities. Hydrology is foundational to the streams and river's well being and when it is perturbed many other aspects which are influenced or reliant on the hydrology will also be altered.

It would be advantageous for further flow characteristics and attributes to be researched in the Pomme de Terre River watershed. A clearer understanding about how the hydrologic regime has been altered will assist in finding solutions to restoring the hydrology and the resulting stressors impacted by the altered hydrology.

Weight of Evidence

The evidence for each potential stressor, the quantity and quality of each type of evidence is evaluated. The consistency and credibility of the evidence is evaluated. Each step for Lower PdT was scored and summarized in Table 24. For more information on scoring please see [EPA's CADDIS Summary Table of Scores].

Table 24. Weight of evidence table for potential stressors in Lower PdT

Evidence using data from Pomme de Terre River Watershed					
Types of Evidence	Scores				
	High Phosphorus	High Nitrate	Lack of Habitat	High Turbidity	Altered Hydrology
Spatial/temporal co-occurrence	+	+	+	+	+
Temporal sequence	0	+	+	+	+
Field evidence of stressor-response	0	+	+	-	+
Causal pathway	+	++	++	++	++
Evidence of exposure, biological mechanism	+	++	++	0	++
Field experiments /manipulation of exposure	NA	NE	NE	NE	NE
Laboratory analysis of site media	NA	NE	NE	NE	NE
Verified or tested predictions	-	+	NE	NE	NE
Symptoms	0	+	+	0	+
Evidence using data from other systems					
Mechanistically plausible cause	+	+	+	+	+
Stressor-response in other lab studies	NE	+	NE	NE	NE
Stressor-response in other field studies	0	+	+	0	+
Stressor-response in ecological models	NE	NE	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE	NE	NE
Analogous stressors	NA	NE	NA	NE	NE
Multiple lines of evidence					
Consistency of evidence	0	+	+	0	+++
Explanatory power of evidence	0	++	++	0	++

Conclusions

In the Lower PdT, elevated nitrate concentrations, lack of habitat and altered hydrologic regime are the stressors to the biological community.

Elevated levels of nitrate are present in the Lower PdT. The fish that are considered sensitive to nitrate are reduced but not completely absent. This may be due to the pulse nature of nitrate in this system, elevated during snowmelt and rain events.

Sparse cover was observed at all sites in the Lower PdT and the two dominate fish are highly adaptable to varying habitat conditions. Many of the stations that were surveyed for geomorphology were not very stable and exhibited conditions close to changing stream classifications.

Altered hydrologic regime is acknowledged by the changes in habitat and by the changes to the flows since the 1930's which do not parallel changes in precipitation. The fish community is dominated by two species that are quick to mature, signaling the potential for instability in the flow regime. It seems that low flows in this reach may not be an issue but that high flows may have some component to the impairment directly and indirectly by causing a lack of adequate habitat.

The stressor pathways present include the riparian condition, source-water pollution, channelization and groundwater withdrawal. Altered hydrology also leads to changes in physical habitat.

As previously mentioned, the riparian buffers along the Lower PdT are minimal in some areas. This can allow high amounts of nutrients, sediment and pesticides from adjacent fields to enter adjacent streams and rivers. In some areas the riparian corridor is the preventer from the river unraveling further from stability. In portions of the river, the stream banks have gone through increased trampling and decreased riparian and bank vegetation. The riparian condition has led to changes in cover availability, stream stability and led to other alterations. Bank erosion rates appeared to be higher in areas without trees and lower where trees populated the stream banks, showing their importance to bank stability on rivers of this size.

Intermittent and often channelized tributaries, as well as larger contributors, such as Dry Wood Creek, to Lower PdT are high in nitrates during snowmelt and rain events. It is assumed that nitrogen and forms of nitrogen, such as ammonia, are being applied to the cropland throughout the watershed as it is 53 percent cropland. It is unknown how much groundwater contributes nitrate.

Channelization of reaches within the Lower PdT and the channelization of reaches contributing to the river have led to changes in the hydrological and geomorphological condition. This has led to changes in discharge patterns, changes in substrate, changes in sinuosity, and increases in erosion. The changes in the hydrological and geomorphological condition have direct impact to the biology of the reach. Additionally tile drain also contributes an increased discharge into surface waters during snow melt and rain events and decreases groundwater inputs.

Significant irrigation occurs in the watershed, especially in the surficial aquifer adjacent to the Pomme de Terre River potentially contributing to changes in hydrologic regime.

Stressors to the biological community need to be addressed for improvement. Improving the pathways that are present for these stressors to exist would greatly benefit the fish and invertebrates of the Pomme de Terre River.

Conclusions and General Recommendations

The biological community is impaired in the reaches of the Pomme de Terre River beginning at the outlet of Barrett Lake, Unnamed Creek, and Dry Wood Creek. The stressors found to be accumulatively affecting the biology are summarized in Table 25. The following is an overview of conclusions regarding the stressors and general recommendations. Please see the individual reaches for more specific information.

The evidence indicates **altered hydrology** is a primary stressor to the biotic communities throughout the impaired areas of the Pomme de Terre River watershed. Hydrology is foundational to the streams and river's well being and when it is perturbed many other aspects which are influenced or reliant on the hydrology will also be altered. It would be advantageous for further flow characteristics and attributes to be researched in the Pomme de Terre River watershed. A clearer understanding about how the hydrologic regime has been altered will assist in finding solutions to restoring the hydrology and the resulting stressors impacted by the altered hydrology.

The riparian corridor is a pathway for stressors or a preventer of stressors depending on its condition. Healthy vegetated corridors are able to resist changes in channel stability more easily than those areas without vegetation protection. Restoration is needed in areas of limited riparian area and protection is needed in areas with healthy riparian corridors

Dissolved oxygen is influenced by sources of nutrients, source water low in dissolved oxygen, and habitat characteristics. It has clear effects on the biological community. Sources of pollution from lakes, tributaries, ditches, tile drains and groundwater need to be reduced in many areas that have biological impairments. Their contributions of **phosphorus** and **nitrate** to the streams and river have negative effect directly and indirectly. Further information on sources of these nutrients may help ensure actions of restoration and protection are aimed in the correct locations.

Turbidity should be reduced for biological importance. Although turbidity was only found to be of direct biological consequence in Dry Wood Creek, it is present in high levels in the Lower PdT reach as well. Hydrology and riparian health leading to changes in channel stability play a large role in the turbidity. In Dry Wood Creek, turbidity is also a function of the algal community.

Impoundments can limit **connectivity** for fish passage. Dams in the Pomme de Terre River have shown to limit migration of fish species. Further analysis should be conducted on if other dams are limiting connectivity for fish.

Habitat such as cover, substrate, embeddedness and instability of the channel, were commonly lacking in the biologically impaired reaches of the Pomme de Terre River watershed. Habitat is, in part, a response of the hydrology acting upon the channel. Some locations in the watershed had adjacent issues that may be addressed, but overall hydrology is vital to addressing the lack of habitat.

Table 25. Primary stressors to the biological community by impaired reach

Reach	Reach Name	Biotic Impairments	Primary stressors to the biological community						
			Dissolved Oxygen	Nitrate	Phosphorus	Turbidity	Fish Passage (dams)	Altered Hydrology	Habitat
07020002-563	Pomme de Terre River *Barrett Lake to North Pomme de Terre Lake*	Fish	X				X	X	X
07020002-562	Pomme de Terre River *Perkins Lake to Muddy Creek*	Fish						X	X
07020002-501	Pomme de Terre River *Muddy Creek to Minnesota River*	Fish & Invertebrates		X				X	X
07020002-551	Unnamed Creek *Unnamed Creek to Unnamed Creek*	Fish		X				X	
07020002-556	Dry Wood Creek *Dry Wood Lake to Pomme de Terre River*	Fish & Invertebrates	X	X	X	X		X	X

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Appendix A. Water monitoring stations in the Pomme de Terre River Watershed with nearby biological stations.

Field Code	Station ID	Station Name	Latitude	Longitude	Nearby Biological FieldNum
102PDT602	S005-643	POMME DE TERRE R AT DALTON RD, 2 MI NW OF DALTON	46.196770	-95.941890	03MN002
102PDT701	SP021	SEASONAL OVRLND FLW (WOODED INTERFLW) FLW ACCUMLATE IN RD DT	46.195097	-95.939100	
201PDT601	S005-654	UNN STR TO LAKE CHRISTINA ON RABBIT RD, 6 MI NE OF ASHBY	46.136478	-95.709800	
301PDT199	S004-586	POMME DE TERRE R BELOW DAM AT PDT LK, 4 MI E OF ELBOW LAKE	45.998889	-95.891667	
302PDT150	26-0095	BARRETT	45.916700	-95.875270	
302PDT198	S004-584	POMME DE TERRE R AT CSAH-2 (HAWKINS AVE) AT BARRETT	45.911944	-95.882778	
302PDT421	S005-645	UNN STR TO POMME DE TERRE R AT CSAH-21, 3 MI SW OF ERDAHL	45.979181	-95.903940	
302PDT459	S005-646	UNN STR TO POMME DE TERRE R ON US-59, 1.5 MI S OF BARRETT	45.889024	-95.888560	
302PDT610	S005-822	POMME DE TERRE R AT 190TH ST, 1.3 MI SO OF BARRETT	45.890350	-95.886371	
303PDT150	75-0075	PERKINS	45.700800	-95.860580	
303PDT427	S005-647	DRAIN TILE OTLT (FIELD RUNOFF) ON 150TH AVE 5.3 MI S BARRETT	45.835843	-95.862020	
303PDT615	S002-058	POMME DE TERRE R AT BRG ON UNN ROAD, 4 MI S OF BARRETT	45.861400	-95.859300	03MN003
303PDT620	S005-823	POMME DE TERRE R AT MN-27, 5.5 MI SE OF BARRETT	45.832540	-95.860853	09MN084
303PDT623	S002-414	POMME DE TERRE R AT TOWNSHIP RD 179, 4 MI SW OF HOFFMAN, MN	45.803128	-95.863556	09MN085
303PDT625	S005-824	POMME DE TERRE R AT CR-37, 8.4 MI SO OF BARRETT	45.788710	-95.859815	09MN085
303PDT630	S002-886	POMME DE TERRE R AT CR-76, 11 MI NE OF MORRIS	45.744960	-95.857000	07MN014
303PDT635	S002-888	POMME DE TERRE R AT CSAH-20, 9 MI NE OF MORRIS	45.715790	-95.857830	
304PDT199	S002-885	POMME DE TERRE R AT CR-74, 7 MI NE OF MORRIS	45.686900	-95.859769	
304PDT637	S005-827	POMME DE TERRE R AT CR-70/175TH ST, 5.2 MI NE OF MORRIS	45.652230	-95.860839	

Field Code	Station ID	Station Name	Latitude	Longitude	Nearby Biological FieldNum
304PDT638	S005-828	POMME DE TERRE R AT 190TH ST, 3.6 MI NE OF MORRIS	45.628890	-95.872089	
304PDT639	S005-829	POMME DE TERRE R AT MN-329, 1.5 MI E OF MORRIS	45.592530	-95.882071	
304PDT640	S004-411	POMME DE TERRE R AT MN-9, 2 MI SE OF MORRIS	45.552300	-95.875880	07MN009
304PDT641	S004-592	POMME DE TERRE R AT CSAH-5, 2.5 MI S OF MORRIS	45.536944	-95.891944	
404PDT433	S005-649	UNN STR TO MUDDY CK AT 260TH ST, 4.9 MI SW OF MORRIS	45.528116	-95.971930	
404PDT466	S005-648	UNN STR TO MUDDY CK AT 250TH ST, 3.8 MI SW OF MORRIS	45.542663	-95.964900	
404PDT687	S004-412	MUDDY CK AT 490TH AVE, 3 MI SW OF MORRIS	45.540500	-95.932890	
501PDT670	S005-657	UNN STR AT CSAH-8, 7 MI W OF FAIRFIELD	45.398989	-96.121590	
501PDT680	S005-656	UNN STR AT CSAH-8 AND CSAH-27, 7 MI W OF FAIRFIELD	45.398706	-96.117060	
502PDT650	S005-655	ARTICHOKE CK TO DRYWOOD LK (NO) AT CSAH-10, 7 MI W FAIRFIELD	45.384467	-96.120630	
502PDT699	S004-937	ARTICHOKE CK 70TH ST NW & 255TH AVE NW 5 1/2 MI NW FAIRFIELD	45.398447	-96.107492	
503PDT150	76-0169	NORTH DRYWOOD	45.407900	-96.090400	
503PDT860	S004-944	UNN STR TO DRY WOOD LK AT 560TH AVE, 5.52 MI NW OF FAIRFIELD	45.416800	-96.076404	
504PDT104	S004-941	UNN STR (TRIB OF DRY WOOD CK) AT CSAH-4 3.35 MI NW FAIRFIELD	45.426862	-96.004969	
504PDT199	S004-574	DRYWOOD CK AT CR-55, 13 MI NW OF HOLLOWAY	45.400000	-96.075556	
504PDT630	S004-940	DRY WOOD CK AT CSAH-5/230TH AVE, 4.10 MI W/NW OF FAIRFIELD	45.398800	-96.055195	08MN087
504PDT649	S004-942	DRY WOOD CK AT 540TH AVE, 3.75 MI NW OF FAIRFIELD	45.416312	-96.035635	
504PDT665	S004-938	DRY WOOD CK AT 210TH AVE NW, 2.82 MI NW OF FAIRFIELD	45.410506	-96.014910	08MN088
504PDT680	S004-413	DRY WOOD CK AT 200TH AVE NW, 12 MI SE OF ALBERTA	45.408450	-95.994350	07MN022
504PDT699	S004-578	DRYWOOD CK AT 190TH AVE, 11.5 MI NW OF HOLLOWAY	45.411111	-95.973333	08MN089

Field Code	Station ID	Station Name	Latitude	Longitude	Nearby Biological FieldNum
504PDT801	S004-943	DRAIN TILE OTLT (TO DRY WOOD CK) 540TH, 3.75 MI NW FAIRFIELD	45.416604	-96.035185	
504PDT870	S004-945	UNN STR (FIELD RUNOFF) AT 70TH ST NW, 4.68 MI W/NW FAIRFIELD	45.398064	-96.068498	
601PDT427	S005-652	UNN STR TO POMME DE TERRE R AT 530TH AVE 5.7 MI NW FAIRFIELD	45.461736	-96.014600	
601PDT477	S005-651	UNN STR TO POMME DE TERRE R AT CSAH-7, 5 MI NO OF FAIRFIELD	45.462132	-95.973560	07MN021
601PDT498	S005-826	UNN STR TO POMME DE TERRE R AT 500TH AVE, 9 MI SO OF MORRIS	45.457000	-95.955701	
601PDT642	S004-593	POMME DE TERRE R AT US-59, 4.5 MI S OF MORRIS	45.517222	-95.912222	
601PDT643	S002-884	POMME DE TERRE R AT CSAH-8, 5 MI S OF MORRIS	45.498852	-95.913388	
601PDT644	S004-485	POMME DE TERRE R AT CR-78, 7 MI S OF MORRIS	45.484640	-95.913210	
601PDT650	S005-650	POMME DE TERRE R AT CR-58 (310TH ST), 5 MI NO OF FAIRFIELD	45.456020	-95.955170	07MN011
601PDT654	S005-825	POMME DE TERRE R AT CSAH-4, 11 MI SO OF MORRIS	45.426980	-95.962625	
601PDT870	S004-946	ROAD DT (TEMP FLOW) E SIDE OF 510TH AVE, 1.8 MI N FAIRFIELD	45.421783	-95.973455	
602PDT658	S004-579	POMME DE TERRE R, 70TH ST NW, 10 MI N OF HOLLOWAY	45.398611	-95.947778	
602PDT659	S004-572	POMME DE TERRE R AT CSAH-22, 9 MI NW OF HOLLOWAY	45.383889	-95.945556	
602PDT660	S004-571	POMME DE TERRE R AT CSAH-7, 7 MI N OF HOLLOWAY	45.359167	-95.952778	
604PDT411	S005-653	UNN STR TO POMME DE TERRE R AT CSAH-11 4.5 MI NW OF HOLLOWAY	45.275084	-95.994170	
604PDT665	S004-575	POMME DE TERRE R AT CR-56, 6 MI NW OF HOLLOWAY	45.311667	-95.949444	09MN086
604PDT672	S004-576	POMME DE TERRE R AT US-12 BRIDGE, 3 MI NE OF HOLLOWAY	45.282778	-95.978889	07MN027
604PDT675	S004-573	POMME DE TERRE R AT CSAH-36, 3 MI NE OF APPLETON	45.239444	-95.985000	
604PDT683	S005-821	POMME DE TERRE R AT 80TH ST SW, 1.2 MI NE OF APPLETON	45.213000	-95.993900	
604PDT685	S000-195	POMME DE TERRE R UPSTR OF MN-119 / MN-7 / US-59 AT APPLETON	45.203111	-96.020500	07MN032
604PDT695	S004-580	POMME DE TERRE R ON CR-51 (BEFORE MARSH LK) 2 MI S APPLETON	45.188333	-96.071944	07MN029